WORKS IOP FRACTICE SERIES from ... ...ial Interests

27. Spindles

If you do not own a milling machin... ...d even if you do – ... ...an do in your sho... is greatly enhanced if you own a s... ...e or two with your l... ...dles come in man... shapes and sizes, ranging from ... ...n. (19.05 mm) to 2... ...7.15 mm) in diam... eter, depending on the uses envis... ...d for them. This boo... ...s the design, co... struction and use of a variety of ...dles that will be of i... ...he amateur eng... neer. Milling, grinding and drillin... ...ndles are covered al... wi... unique light gea... cutting frame for clockmakers.

The emphasis is not on heavy industrial grade spi... s bu... ...ther on spindle... that are easy to make and have ...ew parts as possible. the ... ...ndles except o... use sealed ball bearings – the e... ...tion uses tapered rol... ...bear... ...s and thus need... to have seals installed to prote... ...e bearings. The basic ...ndle ...scribed uses th... same spindle nose as the My... ...uper 7 lathe. This allo... all ch... ...s, plates, colle... and closers designed for the ... to be used with this ...ndle. ...wever, it can b... modified for other lathe nose ... ...ards.

I... N 1-85486-149-2

27

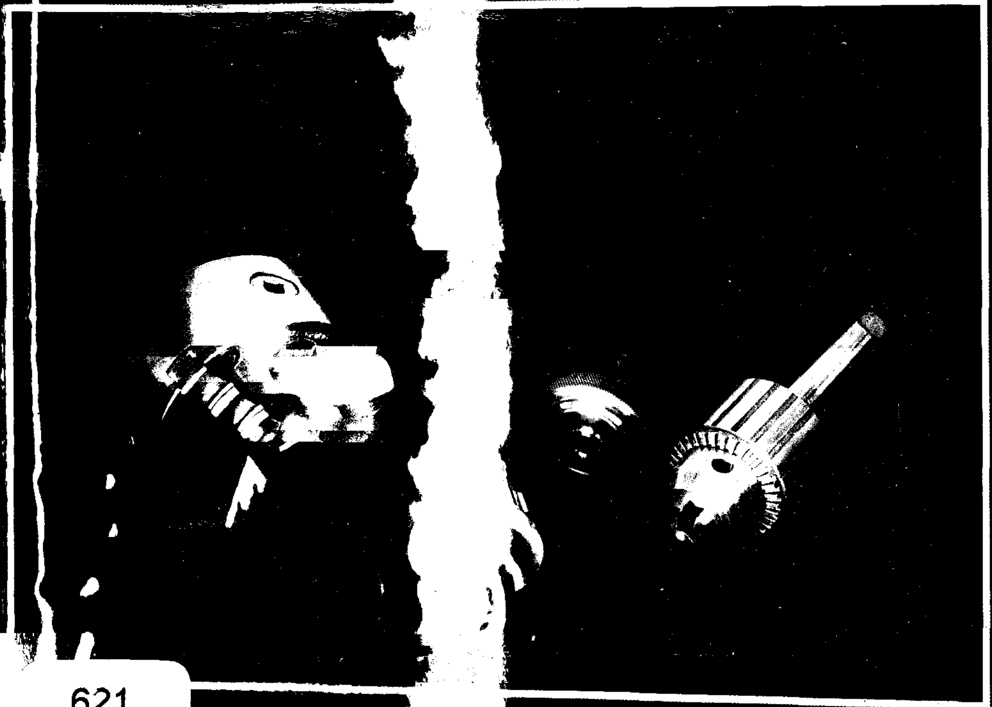
SPINDLES

HARPRIT SANDHU

NEXUS SPECIAL INTERESTS

SP... ...DLES

Ha...r... Sandhu



W...RKSHOP PR... ...ICE SERIES

NUMBER 27

Nexus Special Interests Ltd.
Nexus House
Boundary Way
Hemel Hempstead
Hertfordshire HP2 7ST
England

First published 1997

ISBN 1-85486-149-2

Typeset by Kate Williams, London.
Printed and bound in Great Britain by Biddles Ltd., Guildford and King's Lynn.

Contents

CHAPTER 1

Introduction

This is a book about making auxiliary milling and grinding spindles for use with a small lathe. Although the experienced engineer might pick up a trick or two, the book is aimed primarily at beginners. All the spindles can be made in the amateur engineer's workshop by anyone with average machining skills. The spindles are described for making on and use with the Myford Super 7B lathe, however they can be adapted for use with other lathes with relative ease.

The spindles range in size from 0.750 inches (19.05mm) in diameter to 2.250 inches (57.15mm) in diameter and are suitable for a variety of purposes. A novel design for a gear cutting frame that uses sealed ball bearings at each end is also included.

The book provides the novice amateur engineer with a ready source of information and discussion about the construction of some of the various types of spindles that are needed by the amateur from time to time. Wherever appropriate I have given reasons behind the decisions made to help give the builder more confidence in his or her decision to make any modifications for experimentation.

These spindles are not intended to be industrial grade, heavy duty spindles that will give years of service in the dirtiest environments imaginable but rather they are designed to be spindles that are easy to make and use in the amateur's workshop. I have made every attempt to keep the number of components needed to make any spindle to an absolute minimum. I have tried to minimise the need for sophisticated equipment as well as the need for highly skilled work. Of necessity, all the spindles are of one of two basic designs, each being easy to follow.

Keeping the designs simple meant that the spindles *had* to be of one or two basic designs. In one design, two bearings are used at the front end and the back bearing is free to move in the housing. Both inside and outside races are clamped on the front bearings and only the inner race is clamped on the back bearing. In the second design, only one bearing is used at each end but both the inner and outer races of each bearing are clamped or glued. The second design was slightly harder to build in that it was a little more difficult to get the spacers just right. However, you get a spindle with less axial play in the bearings. Since all spindles can be made to either design, you have a choice as to which design you decide to use on your spindle. You can also combine features from both designs into the spindle you make. (Spindles with glued in bearings are a form of clamped bearing spindles.)

Since the usefulness of a spindle is completely dependent on the accessories that can be used with it, I have used standard lathe nose threads and tapers when possible so that all the standard lathe accessories and other standard components can be used with these spindles. In particular I used the Myford Super 7 spindle nose standard with the No 2 MT (Morse taper) on the cartridge spindle in Chapter 3. This will allow you to use all the tapers, collets, collet closers, mill holders and chucks that are available for use with this standard spindle nose. The use of the No 2 MT, which allows a ½ inch shaft to be held very accurately, makes it much easier to make arbors for clock cutters etc. because these arbors can now be made with straight shanks and held accurately with relative ease.

In the small grinding spindle I considered it best if the many arbor mounted grinding wheels, cutters and arbors as well as the collets and collet closers that are available for the ubiquitous Dremel Moto Tool (widely available, but in case of difficulty contact Microflame Ltd, Vinces Road, Diss, Norfolk, IP22 3HQ; Tel. 01379 644813) were able to be used with this spindle. These wheels are very inexpensive and serve the needs of the amateur engineer well. Here my main interest was to have the ability to grind small parts and tools for projects like clock arbors, pinions and other small parts with precision. This spindle will also allow the making of small precision cutters that are often needed by the amateur engineer. With a little care and patience, it could also be used to grind fine threads.

The micro spindle was my effort at designing the smallest possible spindle with ball bearings. This has an outside diameter of 0.750 inches (20mm) and the body is 4.000 inches (100mm) long. Here again I designed with the Dremel Moto accessories in mind as a resource. This is a spindle more suited to the many lathes that are smaller than the Myford Super 7. Since I do not have access to one of these lathes, and have never used one, I was unable to offer a design for a spindle mounting that I had actually built and used. In other areas I have presented some ideas that will be useful to the more resourceful amateurs.

I have also included a couple of designs for which essentially only the drawings are included. The construction of these spindles is very similar to the construction of the other spindles in the book so the repetition of the instructions is avoided by doing this.

I have avoided using any exotic materials altogether and every component and all the raw materials should be readily available on either side of the Atlantic. I have recommended the use of free machining materials throughout. These materials are easy to use, their machinability is equivalent to that of brass. They are more than strong enough for the applications that we have in mind. Their slightly higher cost will be more than paid for by the added pleasure of using these materials. I have avoided the use of exotic tooling except for the use of the reamers for the Morse tapers. These reamers simplify making these tapers to the point that not using them would be counter productive. Since these are not tools that you need every day, it might be possible to arrange to share with other amateur engineers.

For those who prefer to work from full-sized, formal engineering drawings, these are available, for a small charge, from Nexus Special Interests Books, Nexus House, Boundary Way, Hemel Hempstead, Herts HP2 7ST. These drawings are on A4 paper and are available in either imperial or SI dimensions.

The spindles are designed to be built on a small lathe with a minimal need for milling operations. Most of the work I carried out was done on a Myford Super 7 with the average complement of accessories. I did use a 5.000 inch (10.000 inch in the USA) South Bend lathe to do the heavy work when a lot of material had to be removed. However, all this work could have been done on the Myford Super 7.

Much of the success in making anything is not simply a matter of having a set of drawings for the project but also has to do with knowing how to make the setups and in which sequence to do the work so that it turns out right. I have made an attempt to show the way in all these projects. Both setups and sequences with the reasons for using them are provided. These are especially critical in the construction of spindles that are intended to be high-speed precision tools. I have tried to show the builder how the inherent properties of the lathe and the standard components provided by the manufacturer can be used to their best advantage in building these projects.

The bearings used can be a mixed bag of metric and imperial sized bearings. In general the sizes are not critical and whatever is available in your area can be used by changing a few dimensions.

With reference to the cartridge spindle in Chapter 3: if you have a Myford Super 7 or similar lathe and you are going to make only one general-purpose spindle for your shop, this is the one that you will want to consider making. It gives you the greatest versatility of all the spindles in the book and is described in the greatest detail. Alhough this spindle might be a little larger than what you had in mind, it is very versatile. Modify the spindle nose to suit your lathe and the accessories that you have at hand if you are not the lucky owner of a Myford Super 7B lathe.

Other spindles offer special advantages that are needed under special circumstances or are better suited to smaller lathes or to special setups.

If you decide to make any of the other spindles, first read Chapter 3 a couple of times to get the principles and techniques described well in mind. It will be a tremendous help to you in building your spindle, especially if you are a beginner.

I could not resist looking into what was needed to make a spindle with tapered bearings. The design that I came up with is provided for your consideration in Chapter 13. If you first build the 2.250 inch diameter spindle and then decide to build this spindle it will be worth your while to make it 2.250 inches in diameter also so that you do not have to make another set of mounting plates. My spindle is 2.000 inches in diameter to test how small a taper bearing spindle could be. Going to 2.250 inches will allow the use of slightly larger bearings and a 1 inch diameter for the internal spindle at the bearings.

All the information and drawings needed to allow construction of the spindles are included in the book. Materials needed to make the spindles are readily available and every attempt has been made to make sure that nothing that is hard to get is included in the projects.

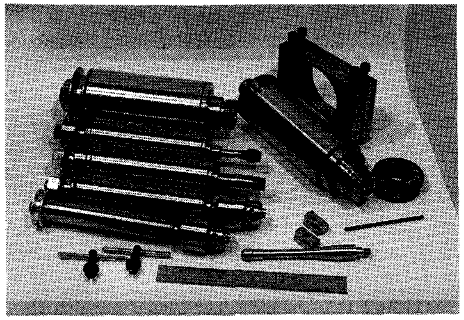
I built only those items for which there are photographs. If you do not have a photograph for reference you need to exercise more caution when building in that there is a slightly higher possibility of errors in the dimensions given for these designs. I did not build any spindles to metric dimensions so extra caution is needed with these drawings also (see Appendix 1). US sizes for the nuts and threads have been used throughout the text – please refer to Appendix 2 for UK equivalent tables.

This is my contribution to keeping this wonderful hobby strong – a hobby that has provided me with endless hours of total delight.

Should you have occasion to discover any errors in the information provided, I would appreciate it if the information could be forwarded to me so that I can make the necessary corrections as soon as possible for the benefit of future amateur engineers and experimenters who build these spindles.

Good luck and happy turning.

Harprit Sandhu
Champaign Illinois, USA
December 1996



The six spindles made by me to verify the construction methods described in the book. Improvements have been incorporated into the drawings.

E-mail: Rhinorobot@aol.com\par
Facsimile: 217-356-6944
Telephone: 217-356-9300
(Answering machine on 24 hours a day)
Snailmail: H S Sandhu, 705 West Kirby Avenue, Champaign, Illinois 61820, USA

CHAPTER 2

Designing a spindle

This chapter contains a very short tutorial/discussion on the design of the spindles in the book. (This is very much a simplified approach and no consideration is given to the making of calculations which are a must in any serious effort.)

The basic idea is that there is nothing difficult about designing a simple machine if one goes about it in a methodical way. The ideas presented are applicable to any basic design project.

The facts before us in this particular case are as follows:

- Before there is a spindle, there are drawings. It is much easier to work from a drawing that has been carefully thought out.
- Before there are any drawings, there will have been some sketches. We have to make sketches and work out the dimensions and positional relationships before we can make the formal drawings.
- Before there are any sketches, there must have been some ideas. Neither do sketches have a life of their own. They are expressions of ideas that we have about the machine that we thinking about making which in turn are determined by the uses that we will put the machine to. These are the purposes for which the machine is being designed.
- The ideas on which we are going to focus have to do with designing spindles for use by the amateur engineering community. These spindles will be used for a variety of purposes, the main ones being light milling and grinding applications.
- The best and most popular amateur's lathe on the market is the Myford Super 7B. At the risk of sounding like I have lost my mind early in the game, I will say that no other manufacturer even comes close to providing such a good lathe. For this reason we will design for this lathe.
- Most amateur engineers, in general, and in spite of some evidence to the contrary, do not have a lot of money to spend on their hobbies.

It is always a good idea to keep track of what you are thinking about by writing it down, so let us list our conclusions.

With the above facts in mind we come to the following conclusions:

- We will design relatively small spindles.

- They will be mounted on sealed ball bearings.
- They will be belt driven.
- We will design for mounting to the Myford S7 tables and slides etc.
- We will accommodate the use of Myford accessories when possible.
- We will design to allow versatility of use.
- We will keep costs down.
- We will keep down the skill level needed to build.
- We will limit the time needed to build.
- We will not use exotic materials because they are expensive and hard to find.

The Myford mounting slots are 1.562 inches (39.67mm) on centre and are suitable for hold down studs that are 0.250 inches (6.35mm) in diameter. This tells us that the spindle has to fit on a grid 1.562 inches (39.67mm) on centre. Our mounting bolts will be either 1.562 inches (39.67mm) on centre or twice that which is 3.125 inches (79.35mm) on centre.

So the mounting grid looks like Figure 2.1. We will start by placing critical components on the grid. At this stage we are working with sketches although I am showing these as drawings in the book.

If we are going to use the Myford accessories with this spindle, we need to use the same spindle nose as the Myford uses. Let us assume a 2.000 inch diameter spindle with a Myford spindle nose at one end and a pulley at the other end. We will represent all this with simple rectangles in our sketches.

Now let us position our spindle sketch on the grid. Our spindle can be positioned to use either a single grid spacing or a double spacing as the conditions dictate. The next two figures show where the spindle would be in regard to the grid for each of these mountings.

The smaller spindles will be able to make use of the type of mounting shown in Figure 2.2 even if the studs have to be within the housing of the spindle (as long as we can miss the spindle bearings).

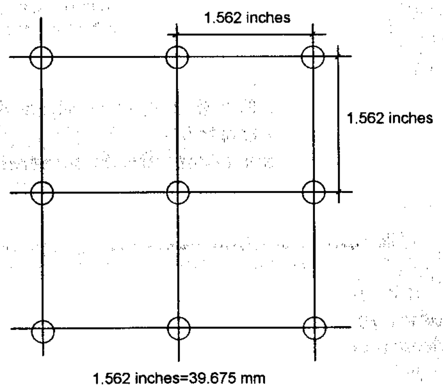


Figure 2.1 *Mounting grid for Myford S7 tables. Studs are 1.562 inches (39.67mm) on centre in both directions.*

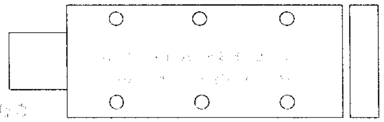


Figure 2.2 *Mounting the spindle on short spacing.*

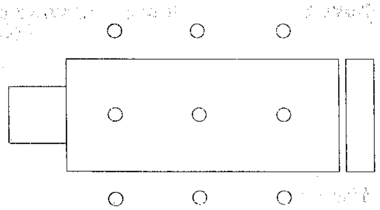


Figure 2.3 *Mounting the spindle for long spacing.*

The larger spindles will have to have the studs straddle the spindle as shown in Figure 2.3. This takes up more room but also gives us more space to work with.

Now that we know where the spindle nose is with respect to the mounting studs, we can think about placing our bearings to miss the studs. We need two bearings, one in the front and one in the back. The front bearing is more critical because it is the one that bears most of the load and for this reason it should be as close to the cutter as possible. With this in mind we will try to place the front bearing as far forward as we can and position the smaller rear bearing as is convenient.

Let us place some bearings in the spindle to see how they look for position.

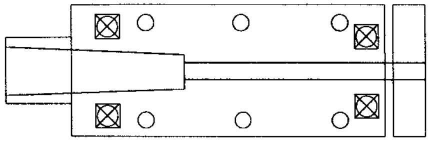


Figure 2.4 *Bearings, spindle, pulley and hole added.*

In a milling spindle, most of the load is taken up by the front bearings. Industrial milling machines often use three and four bearings together very close to the nose. We will use just one in our design. At this stage, the basic concepts are in place and we are ready to work out the details.

How we hold the bearings will be critical. The front bearings must be integral with the spindle. This means that both the outer and inner races have to be clamped tight to the housing and spindle respectively. It will be best if the back bearing is positioned exactly but, with the equipment at our disposal that does not seem to be likely, so I am going to suggest that we clamp only the inner race of the back bearing and let the outer race slide back and forth in the housing. If you analyse the loading on the spindle you will see that the axial load on the back bearing is minimal. Its major purpose is to provide radial support for the back end of the spindle. (There are other ways to control the distance between the outer and inner recess of the bearings and some of these are shown in other designs in the book.)

The concepts presented above are shown in Figure 2.5. Keep in mind that this is where we clamp the races. The races are held at their OD by the housing and at their ID by the spindle so these directions will be properly constrained if we turn the spindle parts to close dimensions.

Each set of arrows represents a clamping device. We need three clamps or nuts. The other side from each nut will be either the body of the housing or the

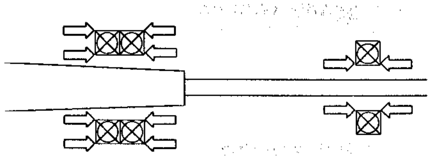


Figure 2.5 *The points where the bearings will be clamped. The double bearings are just an idea at this time to explore the possibilities.*

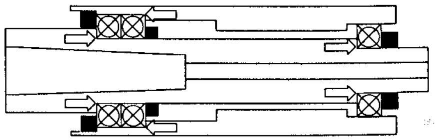


Figure 2.6 *The points where the nuts will be used.*

spindle itself. Let us draw these in.

This essentially is the end of the sketching phase. We may go through many sketches and many permutations of what we want to do but eventually we will end up here and be ready for the formal drawings. The rest of the design process has to do with the selection of the proper bearings and the design of the various components so that they will work together in the way that you want.

When all this is put together, we get a spindle that looks some thing like Figure 2.7.

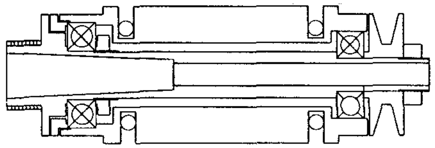


Figure 2.7 *The completed spindle design. One front bearing has been removed in the final phase of the design.*

This spindle with one row of bearings, in the front, and with some minor modifications, is described in some detail in Chapter 5.

When you design a machine, no matter how simple, you have to have the means of making it well in mind. As a part of this you should also have the machining sequences for all the machines that will create the mechanism in mind. In this way a viable product will be created. Not everything that can be dreamed up on a drafting table or computer screen can be made and not everything that can be made can be made economically. It is an important part of the engineer's art to design machines that are useful as well as viable in the marketplace. Cost and performance are the most important considerations. Next come safety, aesthetic appeal and environmental responsibility.

Each chapter in the book takes it from here and shows you what you need to do to make each of the various components that go into each spindle.

Where spindles are similar to ones that have already been discussed in detail, detailed drawings are provided with only minimal discussion. You should refer to the detailed discussion provided for the other spindles when making a spindle for which only drawings are provided.

Instead of providing imperial dimensions and converting them to SI units all over the drawings, I have chosen to provide two sets of drawings for each spindle (see Appendix 1 for metric drawings). This avoids the use of strange dimensions that I find very distracting. There is no reason to dimension 1.000 inch as 25.4mm when the proper thing to do is to make a new drawing where 25mm can be used without apology. (1.000 inch is pretty close to 25.4mm because the next three numbers after 25.4 are zeros.)

Some random thoughts on small spindle design

Collets and Morse tapers make a considerable difference in the usefulness of a spindle. A No 2 MT, which is much more useful than a No 1 MT, can be fitted in spindle that is smaller than the Myford Super 7 spindle if you are willing to take the time to make a collet closer for the Myford collets to match. Since the critical components are the No 2 MT collets we have to work to their dimensions.

The collet closer is easily made in two parts, much the way the Myford closer is made except that in our case we will silver solder the two parts together rather than forming them together as Myford does. This has to be done to get the full depth threads that are needed.

The other alternative is to "not use" a collet closer but rather to draw the tapers in with a draw bar. Morse taper collets that do this are available but the Myford collets cannot be used to do this. However, you may have to buy one ⅜ inch (approx 10mm) or ½ inch (approx 13mm) collet to hold all the arbors you make and you can buy these collets with drawbar threads in them.

It is also possible to make spindles without using ball bearings and the spindles so made can be smaller than those that use ball bearings. There may be an advantage here when outside diameter is critical. I feel that the ball bearings give a much better chance of success and that they provide the performance and durability needed.

Needle bearings are not suitable for use here (even with extra thrust bearings added).

CHAPTER 3

The basic spindle

Introduction

There are only five turned parts and two modified parts in this spindle. There are also three bearings, a key and a nut. It accommodates all Myford nose chucks, plates and accessories.

Every serious amateur engineer, who does not own a milling machine, will need to perform milling operations on something that is being held in the lathe chuck many, many times during his amateur career. In the amateur engineer's shop this is best done with a carriage-mounted milling spindle driven by an auxiliary motor.

The spindle is described as being a "cartridge spindle" – it is in the form of a cartridge that can be placed in any suitable chamber or holder. Cartridge spindles are the most versatile spindles. I selected a

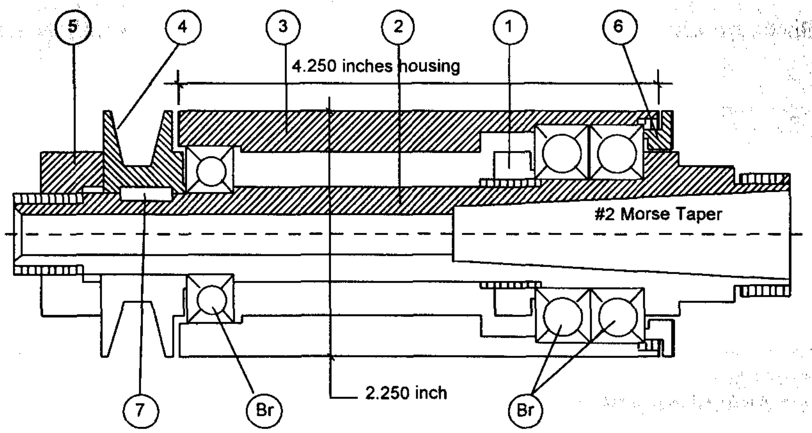


Figure 3.1 *Cross section of a cartridge spindle. Note: besides the bearings there are only 7 parts to be made.*

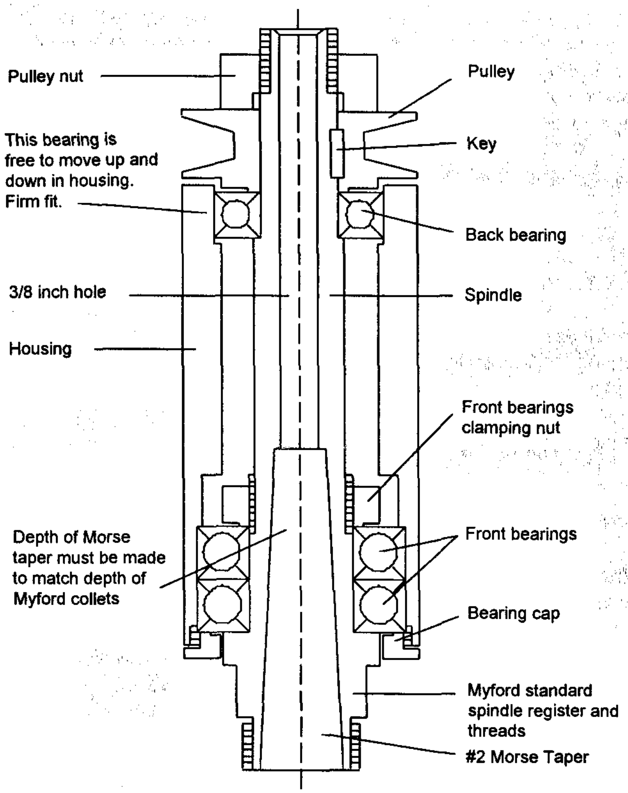


Figure 3.2 *Main features of a cartridge spindle.*

cartridge design because I had a couple of applications in mind for the spindle beyond basic milling and wheel cutting.

This chapter describes the design and construction of this cartridge spindle which is suitable for general-purpose use in the machine shop. Although it may be considered by some to be a bit large for fine work it is easier for most beginners to work on a larger spindle.

If you are going to make only one general-purpose spindle for your shop, this is the one that you will want to consider. It gives you the greatest versatility of all the spindles in the book and is described in the greatest detail. Other spindles offer advantages that are needed under special circumstances or are better suited to smaller lathes or to special setups.

Note

Do not scale any drawings in this book. Always go by the dimensions given. Both imperial and SI (metric) drawings are included in this book (see Appendix 1 for metric drawings).

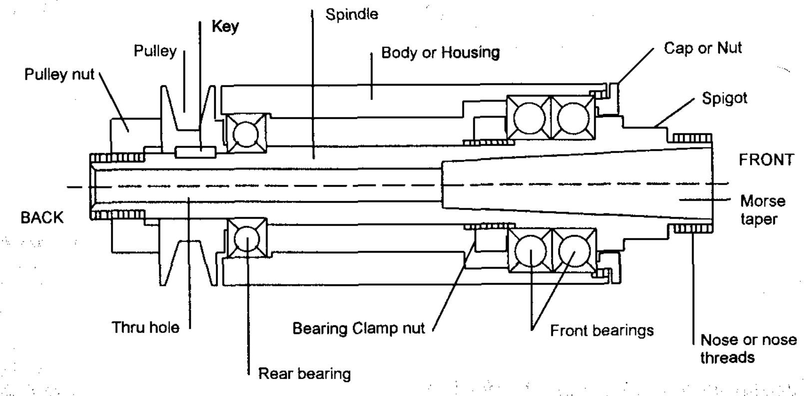


Figure 3.3 *Nomenclature used throughout the text.*

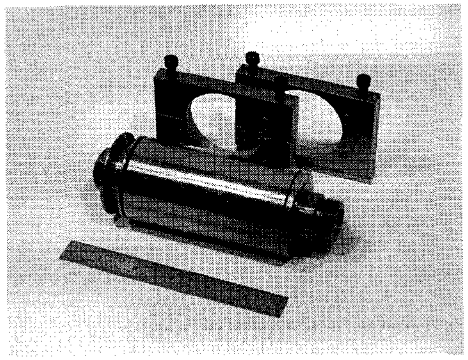
The design requirements

The more I thought about it the more I wanted to try my hand at making one of the many wonderful clocks designed by John Wilding, but one thing had to be made first – a milling spindle to cut the gear teeth. So I researched the back issues of *Model Engineer* that I have access to, one thing led to another and before I knew it I was on my way to writing this book about spindles.

My prime consideration was that the spindle should be designed to be easy to make. Anyone with average turning skills should be able to make it without difficulty. However, this is not a minor undertaking because relatively large amounts of metal have to be removed in the course of a spindle project like this.

I have two lathes in my shop, a well-equipped 3.500 inch (90mm) Myford Super 7B and a well-equipped 5.000 inch (125mm) South Bend toolmaker's lathe. I will describe the work as if done entirely on the Myford although I did do some of the work on the more powerful South Bend to speed things up where large amounts of metal were to be removed.

I decided that it would be best if as many of the Myford accessories as possible could be used with the spindle. This means that the spindle should have the same spindle nose as the Myford Super 7



The basic 2¼ inch (57.15mm) diameter spindle and its mounting clams. This spindle has the same nose as a Myford S7 lathe and can be used with all Myford nose mounted accessories.

lathe. This would allow the use of all the collets, the collet closer, the milling cutter holders and similar devices with this spindle. Of course there are times when a chuck needs to be mounted to a spindle (I had a 3.000 inch (75mm) chuck in mind but the 4.000 inch (100mm) chucks can also be used and work fine). The spindle also had to be designed so that it could be mounted on the bed of the lathe, on the cross slide of the lathe as well as on the vertical slide. All this led to the cartridge design that I chose.

I also wanted to experiment with milling threads and this spindle is designed to be heavy enough to do that. I hope it will work – at the time of writing I have not yet tried this out.

So the design requirements for the spindle came down as follows:

- Ease of construction – it is designed for the amateur.
- Low cost – free machining steel is used throughout.
- Long enough to span the vertical slide to accommodate the drive belt.
- Complete Myford Super 7 spindle nose threads for flexibility.
- Internal No 2 MT so that Myford accessories can be used.
- Common, easy to find, sealed bearings for ease of construction.
- A low maintenance design.

The uses in mind during the design phase were as follows:

- Cutting clock gears – this was my primary purpose for making the first spindle.
- General-purpose day-to-day milling.
- As the occasional grinding spindle for light grinding using arbor held wheels.
- And, very important, general experimentation.

Materials required

The materials below are required to make the spindle. See text and drawings for the dimensions of the finished parts.

A spindle nose equivalent to the Myford needs to be made of 1¾ inch (45mm) stock i.e. the diameter of the flange that backs the mounting plates for

Part name	Material*	Diameter	Length
Housing	Steel	2.250in (55mm)	4.375in (120mm)
Spindle	Steel**	1.750in (45mm)	6.750in (175mm)
Front bearing cap	Steel	2.250in (55mm)	0.375in (10mm)
Pulley	Steel	2.250in (55mm)	1.000in (25mm)
Front bearing cap			
Split collet	Steel	2.500in (65mm)	0.375in (10mm)
Nut for front bearings	Steel	1.750in (45mm)	0.500in (13mm)
Nut for pulley***	Steel	¾ by 16 thread per inch, purchased 18mm by 1.5mm	
Bearings	Purchased to suit, see discussion		

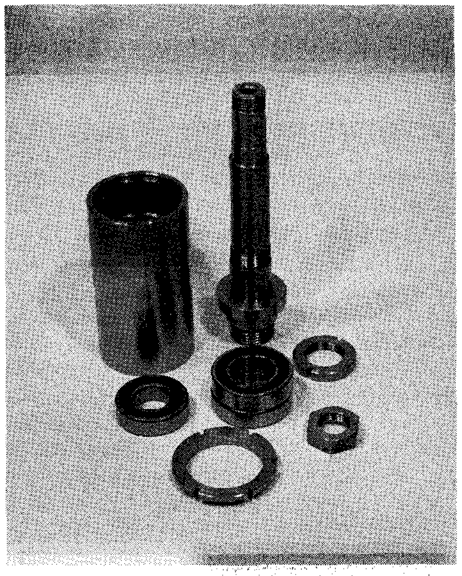
* Use free machining steel throughout.

** This part absolutely must be an easy-to-machine steel so that we can cut/ream the No 2 MT without difficulty.

*** See Appendix 2 for UK equivalent

the chucks etc. A quick look at the bearing catalogues confirmed that the spindle design could be accommodated within a 2.250 inch (55mm) diameter spindle housing with a little work. This large spindle diameter (to accommodate the No 2 MT) leads to the need for heavier bearings, which fortunately, are desirable in a milling spindle.

The spindle I made uses inch materials and metric bearings because that is the how it worked out at this time! To simplify matters, the designs presented in the book use either all imperial dimensions of all SI dimensions (see Appendix 1 for SI drawings). I intend to explain the reason for using the dimensions that I used whenever applicable. Incidentally the new digital calipers are a real convenience in that they allow you to change between inch and metric dimensions with the press of a button! Since I am not used to metric dimensions, I was able to convert to inches whenever needed to confirm that I was in the ball park. I just don't feel at home with exactly how much 7mm is but I am quite comfortable with 0.2755 inches.



All the components of the basic spindle. The emphasis is on designs that use as few components as possible for ease of construction.

Bearings chosen

Nose end bearings

Number required	2
Inside diameter	1.000 in (25mm)
Outside diameter	2.000 in (50mm)
Width	0.375 in (10mm)
Seals	Both sides
Shields	None
Type	Deep grove bearings with axial and radial load capability
Alternate	Angular contact bearings

Tail end bearing

Number required	1
Inside diameter	0.750 in
Outside diameter	1.750 in
Width	0.375 in
Seals	Both sides
Shields	None
Type	Deep groove bearing
Alternate	Standard load bearing

(*Note*: the axial load on the bearing is almost zero)

Bearings discussion

The selection of bearings is not critical but should always be considered carefully. In our case we have two considerations that will dictate our selections. We want to keep the cost low and we have to be able to accommodate a shaft that will have a No 2 MT inside it. These two considerations resulted in the selection of the bearings specified above. Many other bearings could have been used. Do not let the availability of bearing put you off – any bearing that you can get your hands on can be used.

Bearings are made in more forms than you can imagine. Our interest is in bearings that are designed for **axial loads** and **radial loads.** Axial loads are along the axis. In our case we must have sealed bearings to avoid having to fit seals. Deep groove bearings fitted up back to back (double) or angular contact bearings with seals will be the best bet. Special bearings to be used back to back are sold in pairs and ground to be a perfect pair. They are, however, more expensive and integral seals are often not available. We will use the back bearing only to hold the back of the spindle in the middle of the housing. It carries no cutting load axially and relatively little radially. The outer race of this bearing is free (but tight) to move axially in the housing. Almost all the cutting load will be taken by the pair of bearings in the front.

Sealed bearings are lubricated for life and need no attention to any further lubrication. However, the seals must be protected from swarf and dirt.

Taper bearings are best for heavy loads but are a bit more difficult to use in a spindle that is both inexpensive and easy to build. Sealing the bearings is the prime problem. Also taper bearings tend to be larger and our interest in this case is in a smaller easy to make spindle. A design with tapered bearings is included in this book for the more experienced turners. It is instructive to take a close look at the drawings and see how the bearings and seals tend to push the spindle nose further out of the bearings (undesirable).

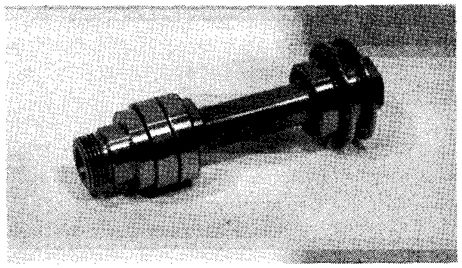
We will want to allow enough clearance between the bearings and the clamping elements to assure ourselves that there will be no rubbing between the clamps and the bearing seals. Most bearing seals are below the level of the races but we must make sure. We also want to make sure that swarf does not find its way into the space created and eventually ruin the seals.

When you are converting from metric to inch dimensions and vice versa, it is worth writing down the third and fourth decimal places in the conversions because they give an indication of the fit that we will be expecting. In close fits 0.0005 inches can make a big difference. Knowing whether is it going to be loose or tight is a help.

Spindle parts list

The following items are needed for the spindle:

Description	Qty	Notes
Front bearings	2	purchased
Rear bearing	1	purchased
Spindle	1	
Spindle housing	1	
Cap for front bearings	1	
Nut for the pulley	1	purchased
Nut to clamp front bearings	1	
Back pulley	1	
Key stock for pulley	1	brass scrap
Split bush for cap	1	
Drive belt	1	purchased
Set drawings and instructions	1	in this book
Other special or unusual equipment needed:		
No 2 MT finishing reamer	1	
⅛ inch (3mm) end mill	1	



Internal spindle assembly of the basic spindle. Note the bearing nut at the rear of the front two bearings. The pulley nut is used to hold the rear bearing tight.

Making the spindle

Sequence of parts fabrication
It is much easier to build the spindle if the parts are made in the proper order – it is easier to make the parts fit to one another.

We will make the parts in the following order:

1. Buying the bearings.
2. The nut that clamps the two front bearings onto the spindle.
3. The spindle itself (the part that spins).
4. Cutting the threads.
5. The spindle housing.
6. Split collet for holding the bearing cap.
7. The spindle front cap.
8. The drive pulley.
9. Cutting the keyway in the pulley.
10. Modifying the pulley nut.
11. Cutting the keyslot in the spindle shaft.
12. Preliminary assembly.
13. Machining the No 2 MT in the nose.
14. Cutting the spanner notches in the cap and bearing nut.
15. Cutting the belt groove in the pulley.
16. Final assembly.

1. Buying the bearings
Since everything depends on the bearings that we will be using, buy the bearings first. This is critical because the fit of the bearings to the spindle components is critical. If we have the bearings at hand, we can use them to check on the fits as we machine them. All fits are to be made as stiff, push-fits. The stiffer the better but using force is not permitted. Both the inner race and the outer race of the front bearings will be clamped so the fit does not have to be as tight as you find on some commercial products. The best fit will be one that can be seated and unseated with light taps with a light plastic mallet. Beware that this seating and unseating tends to loosen "once firm" fits. We will not be using any adhesives (this is a personal recommendation).

Buy the nut for the pulley while you are out looking for the bearings. This is a ¾–16 (see Appendix 2 for UK equivalent) nut preferably of unplated, unhardened steel.

When testing tight fits it is important that the bearings go in straight and that you have a way of getting them back out. This is one of the conditions that dictates the part-making sequence.

2. The nut that clamps the front two bearings onto the spindle
Here is the machining sequence that we will follow:

- Hold the blank in the 3-jaw.
- Face and chamfer exposed face.
- Reverse in chuck.
- Face to size and chamfer again.
- Drill through hole and open up to 0.955 inch (adjust for metric bearings).

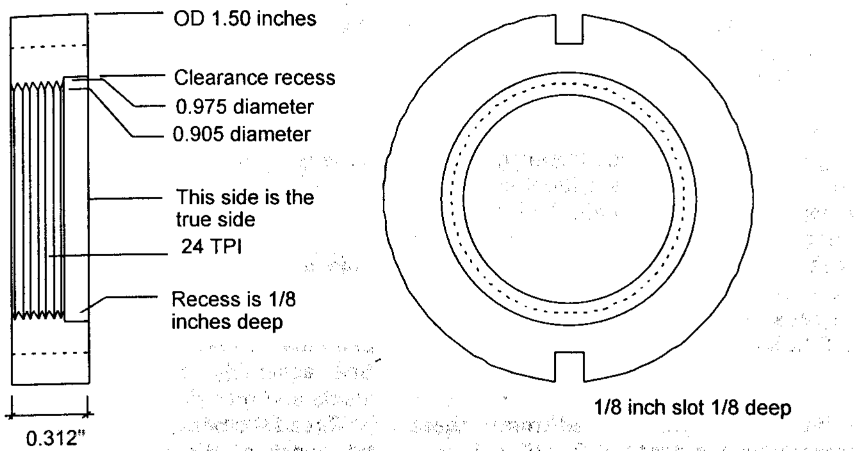


Figure 3.4 *Front bearings, inner race, clamping nut.*

- Cut recess.
- Cut threads.
- Chamfer all edges and threads.
- Remove from chuck and set aside.

Generally, if you have to cut a matching internal and external thread, it is easier to get a good fit if you make the internal threads first and then cut the external threads to match. It is easier to machine the spindle to match the nut because you can see what you are doing on the outside of a spindle as compared to the inside of a nut as you try to fit the threads one to the other. This being the case, the first thing we need to make is the nut that will clamp the inner race of the front two bearings to the spindle.

The critical items on this nut are that the threads and the face that will clamp to the inner races of the bearings. These two must be cut at one setting – this will ensure that they are true to one another. We also have to make sure that the thread diameter that we pick is small

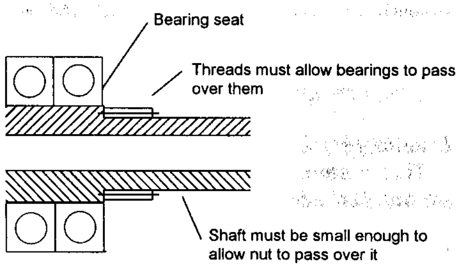


Figure 3.5 *Thread/shaft relationships.*

enough to allow the front bearings to pass over the threads on the spindle without interference. (We will be cutting the spindle threads later but we need to plan ahead and think about their diameter now.)

The inside diameter of the front bearings is 1.000 inch. We will make the thread diameter on our nut 0.020 inches less than that.

$$1.000 - (0.010 \times 2) = 0.980$$

Let us settle on 0.975 inches because this is an even full turn on the average micrometer and thus easier to read.

We have a choice of selecting either 24 tpi or 32 tpi for the threads but I recommend 24 tpi for the beginner as being slightly easier to cut. The finer the threads are, the more critical even very small mistakes become. We want to choose a multiple of 8 for our threads so that we can drop the half nut at any location (on most lathes) when we cut the threads. The pitch of a 24 tpi thread is 0.042 inches.

$$1/24 = 0.042$$

With a 60-degree thread form, these threads have a depth of 0.036 inches.

$$0.042 \times \text{Cos}(30)$$

(this will be slightly deeper for 27.5 degrees)

$$0.042 \times 0.866 = 0.036$$

$$0.036 \times 2 = 0.072$$

(multiply by 2 to correct for diameter)

This means that the internal diameter of our threads has to be 0.072 inches less than the outside diameter which is to be 0.975 inches.

$$0.975 - 0.072 = 0.903 \text{ inches internal diameter (theoretical)}$$

Place the blank for the nut in the 3-jaw and face it on one side in the 3-jaw. Turn

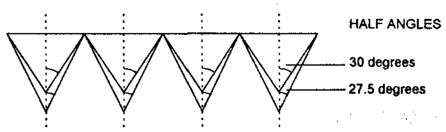


Figure 3.6 *55 and 60 degree threads. The top of the triangle is the thread pitch.*

the outside diameter to 1.500 inches or 0.500 inches more than the ID of the bearings. Chamfer the outside edge 0.030 inches – that means the face of the chamfer is 0.030 inches wide. We specify it in that way because that is the dimension that we can see on the part being machined.

Turn the nut around in the 3-jaw and face it again. Bore a 0.903 inch diameter hole in the nut. Bore a recess 1.002 inches in diameter and 0.125 inches deep in the ring. This recess permits the bearings to rest on un-machined stock. See assembly drawings. Chamfer all inside and outside edges 0.030 inches.

Thread the bored hole at 24 tpi. The total length of the thread flank is 0.041 inches (the same as the pitch on 60-degree threads) so you will have to make 8 passes at 0.005 inches each and then clean it up until the threads are right. Clean up the crowns of the threads with some emery paper to get all the burrs off and then some. Take a very slight finishing cut on the face of the nut. This is the face that must be used to clamp to the bearings and we need it to be true. The other face is not guaranteed to be true to the threads.

Chamfer the last thread on each side. The threads should always be chamfered with the thread-cutting tool.

Remove from chuck and set aside. We will cut the two ⅛ inch slots, on the perimeter, for the spanner wrench, later.

3. The spindle itself (the part that spins)

Next we will make the spindle shaft itself. This is the most critical part of the device and so should be made as early in the process as possible. I am from the downhill school – get the hard part done first and then it's downhill from there on. If you cannot get the hard part done, you will not have wasted a lot of time and

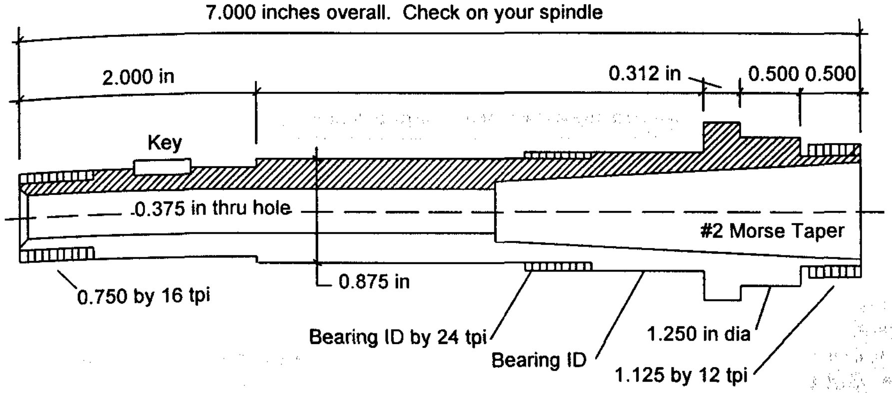


Figure 3.7 *Section along the spindle.*

money on the easy parts no matter how much fun it was (not unlike building the locomotive cylinders first).

Nose notes

First get a piece of paper and make a note of exactly how the collet closer fits on the nose of your particular lathe so that you can duplicate that fit on the spindle you are about to make. The most important part is to know how far the closer seats on the threads when closing on a No 2 MT collet. It is critical that the closer does not bottom out before the collet has closed firmly on the part being held. It would be appropriate to try more than one collet although the ones for ⅜ inch and ½ inch rods are the most important. It is worth noting that all collets are not the same and neither are all tapers. Here I do not mean the actual taper angle on the parts but rather the other relative dimensions. This is because different manufacturers follow slightly different standards.

Here is the machining sequence we will follow:

- Hold the spindle blank accurately in the 4-jaw chuck.
- Machine the exposed end carefully.
- Put a large centre on the machined end.
- Drill a ¼ inch hole as far as you can into the spindle.
- Increase hole diameter to ⅜ inch (later to ½).
- Next work between the chuck and a tailstock centre.
- Machine the outside of the spindle nose form completely. Check with a chuck and the collet closer. This must be perfect at this point.
- Mount a large face plate on lathe.
- Bolt another face plate to it, face to face.
- Clean and oil the spindle nose just made.
- Screw new spindle into second face plate, all the way.
- Set it to run absolutely true. Absolutely true, no matter how long it takes!
- Tighten the two face plates one to the other.

- Using very small cuts, with a sharp tool, face the end.
- Put a small and then large centre on the far end.
- Drill a ⅜ inch hole to meet the hole on the other side.
- Clean up the centre on this side.
- Work between the face plate and the tailstock centre.
- Machine the rest of the spindle body.
- Cut the threads for the front bearings clamp nut.
- Cut mounting for the front bearings.
- Cut mounting for the rear bearing.
- Cut threads for the pulley nut.
- Make a spacer to take place of pulley.
- Test mount front and rear bearings and clamp onto spindle with nut.
- Keyway is to be cut later.
- Remove spindle.

We have to make the spindle first because we will need to have a way to get the bearings out of the housing when we make the housing. The spindle will be our arbor and handle. It will also serve to guide the bearings accurately (when supported by the tailstock) when we test the fit of the bearings in the housing.

The most critical part of the entire spindle assembly is the part that spins. It has to be true to the axis of rotation in every way. If we get this right, we will have a good chance of having made an accurate spindle. Getting this right is pretty much a matter of building it in the right way. The most important thing is to turn all outside surfaces between the face plate and the centre and to turn the internal Morse taper in the actual bearings, i.e. in situ.

Note
No matter what anyone tells you and under what circumstances, in your shop there is nothing more accurate than work done carefully between centres in a lathe with a properly aligned headstock and tailstock. In our case we are using the second face plate as one fixing but the effect is the same. We can remove and replace the spindle with ease without losing accuracy. All accurate lathe work is done between centres. The 3-jaw chuck can never be trusted to work with absolute accuracy. Any part that has to be removed from the lathe to be checked for any reason, must be made between centres. Any part that might have to be modified at some later date must be made between centres. Any part that has to have another part mounted exactly to it for later machining must be made between centres. The 4-jaw is a very helpful device and does wonderful things but does not replace doing work between centres. These are basic lathe facts that are to be accepted as gospel by any aspiring turner.

Make sure that the tailstock centre on your lathe is aligned correctly. The accuracy of the work done depends on this. There is a section in Chapter 16 that discusses this and you will find this helpful if you have never done this before.

Note
If you are tempted to hold the nose register in your 4-jaw, do not do it. It will mar the register and you may need to remove the spindle from the lathe many times to check it. This is not a 4-jaw chuck application and cannot be done properly with a 4-jaw chuck.

Start with a 1.750 inch diameter by 6.375 inch long piece of free machining steel. Place the spindle blank in the 4-jaw chuck and adjust it to run the outer end true. Taking light cuts, face the outside face. Centre drill the face with a large centre drill. Drill a 0.250 inch and then a

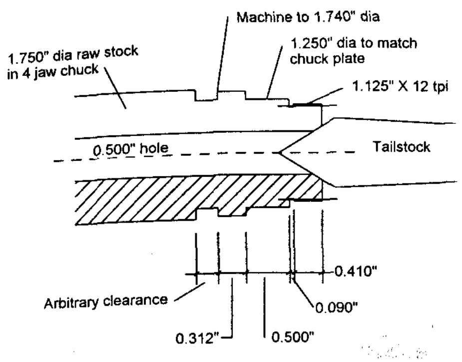


Figure 3.8 *Work required at the nose of the spindle.*

0.500 inch hole 3.000 inches into the blank. This hole has to meet the 0.375 inch hole that will be drilled from the other side. This side will be opened up to a No 2 MT in the future. If the drilling mars the centre, remake the centre by turning it.

Place a ball bearing centre in the tailstock and move the centre up to the part being machined.

Try to avoid using a pair of calipers. Measure the diameter of the register on your lathe with your 1–2 inch micrometer. We will make the diameter on our nose register match this *with this same micrometer*. This will make sure that both registers turn out to be the same diameter even if our micrometer is off by a few thou at this dimension.

Rough turn 0.950 inches of the spindle to 1.300 inches in diameter. This is the section we will form the Myford nose register and threads onto. Now finish turning this to 1.250 inches in diameter and 1.000 inch long. Machine the first 0.500 inches of this to 1.125 inches in diameter. Machine a recess 0.090 inches wide to clear the threading tool. This recess starts 0.410 inches from the end of the nose. It is to be cut in the threaded half inch and not in the un-threaded register part of the nose.

4. Cutting the threads
Twelve threads per inch is a pretty coarse thread. It is easier to cut a thread this deep in two sets of passes – this reduces the length of the flank that the tool has to cut in half. Cut the threads at the lowest speed at which your lathe will run, in back gear. We are cutting only 6 threads so it goes quite fast. Compensate for the large threads by taking only small cuts and by using a very sharp tool. There is a section in Chapter 16 on cutting large threads in two or more sets of passes.

Clean all the threads on a chuck or face plate thoroughly and use this as a gauge to test the threads that you have cut. It is important to realise that even the threads cut by the factory will not all be exactly identical and you will find that the nose

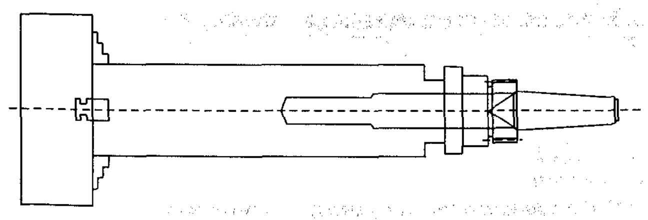


Figure 3.9 *Work done at this stage.*

that you have machined is tighter on some of your chucks and plates than it is on others. This is normal. Try all the chucks and plates that you have in your shop.

Adjust the threads and the register to get the fit you want. You should have a firm fit that can be pulled up onto the register with the threads without difficulty. It is very important that there is no play of the chuck back plate on the register.

Machine a 0.030 inch chamfer on the flange and register. Chamfer the threads with the thread-cutting tool.

If you make a mistake while making the first nose on your spindle, all is not lost. Abandon work on this side, turn the part around and make the nose on the other side. The bad side will all be machined away and no-one will be any the wiser.

We are going to make the reasonable assumption that the lathe spindle is true and that the face plates run absolutely true. If there is a question in your mind about this, mount a face plate on the *cleaned* spindle nose and plate threads

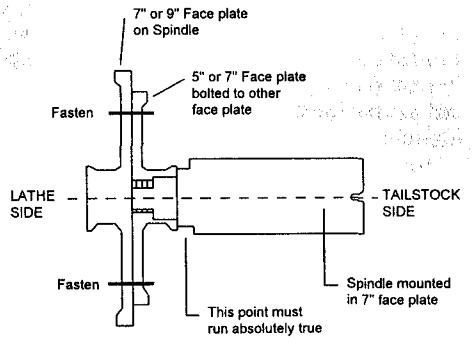


Figure 3.10 *Spindle mounted to face plates. Note that both ends of the spindle are dead on centre.*

and check it out. If your lathe spindle is not running truly, it must be fixed before we can proceed. Replace the necessary components since repairing them is quite beyond our skills. Turning the plate to run true is a solution but this plate cannot then be used on any other lathe. Do not do it.

We need two face plates for the next step. You can use the 7.000 inch plate and the dog driving plate that came with the lathe. If you do not have two plates you need to make arrangements to borrow a plate or two from a friend. Make sure that the threads on your lathe nose and the threads on both plates are absolutely clean. Make sure that both the plates run absolutely true. Check them. Do not take anyone's word for it.

Mount the larger plate to the lathe and lightly bolt the smaller plate to the mounted plate as shown in the figure. Screw the spindle that you are working on into the second plate. Make absolutely sure that the spindle that you have just machined runs absolutely true in the face plate. Make sure your spindle is fully seated and tight in the second face plate. Beginners should note that a lathe spindle tends to ride up on a thin oil film when rotated. This affects the centring of the mounted part. The test should be made on a spindle that is being motor driven at the slowest speed your lathe will permit under power. When you stop the lathe, the spindle will tend to sink towards the centre of the earth (0.0005 inches to 0.0015 inches).

Taking light cuts with a sharp tool, face the outside face. We are not trying to get the blank to the right length at this time. Centre drill with a 0.500 inch centre drill. Drill a ⅜ inch hole to meet the hole from the other side. Clean up the centre after drilling to create a true surface for the tailstock centre. At this point you have the spindle nose running true and we just drilled a centre at the other end that is at the centre point. Things should be right.

Place a ball bearing centre in the tailstock again and move the tailstock centre up to the part being machined. In this set up, the spindle face and nose should be running absolutely true as should the tailstock end. We are now ready to machine the rest of the spindle.

If you are using a solid centre instead of a ball bearing centre in the tailstock, you will have to work more carefully and at lower speeds to make sure you do not overheat, expand, and score the centre. Pay attention and keep the centre oiled and adjusted. Even a ball bearing centre will get tight so keep an eye on it. There is a lot of material to remove.

First rough machine the body of the spindle. Rough machining means leaving about 0.050 inches on all shoulders and 0.100 inches on diameters for finishing cuts. This is enough for two or three finishing cuts in the home shop.

The flange on the spindle will have a finished thickness of 0.375 inches. The nose side of this flange has already been finished.

First machine the threads and then the seating for the double bearings at the front of the spindle. Here we want a tight push-fit for the bearings. Leave this dimension a little bit oversize for now.

Make the calculations and allow for the length of the two bearings and the threads. Turn the rest of the shaft down to the root diameter of the nut threads minus 0.005 inches so that the nut can be brought up to the threads without interference. We want this diameter as large as possible so that we will have a good shoulder for the back bearing to be tightened up against. Use the nut you made earlier as your gauge.

Next machine the threads for the nut. These threads are to match the threads on the nut we made. Their crown diameter is to be just a few thou (0.025) less than the ID of the front bearings. See Figure 3.5.

There are to be no threads under the bearings. The clearance recess for the threading tool is to be right where the bearings end. We need one full thread of unused threaded length and at least 0.375 inches of threads for the nut to rest on. So machine 0.500 inches of threads. Chamfer both sides with the threading tool, and cut 24 tpi on this section of the shaft. Keep testing with the nut as you cut the threads. If you over-cut, you will have to start over again, so be careful.

Put the nut on the threads and make sure that it runs all the way past the last thread without binding. This nut has to hold the inner races of the bearing tight.

Now that we can bring the bearings up to their seating location, we can finish machining the seat. Work carefully to make sure that the surface does not get turned too far. Make sure that the centre is supporting the work properly.

Place the bearings on the shaft and tighten the nut down on them to check the fits. Remove the nut and bearings and set them aside.

We are now ready to machine the seating for the back bearing. This bearing has an ID of 0.750 inches. The shoulder formed will hold the inner race of the bearing after the pulley and pulley nut have been installed on the shaft.

Assume that the housing is 4.250 inches long as specified. We want the distance from the *front of the front* bearing to the *back of the back* bearing to be 0.187 inches less than the length of the housing or 4.063 inches. Therefore the location of the shoulder will depend on the thickness of the back bearing selected.

Turn the spindle down to the internal

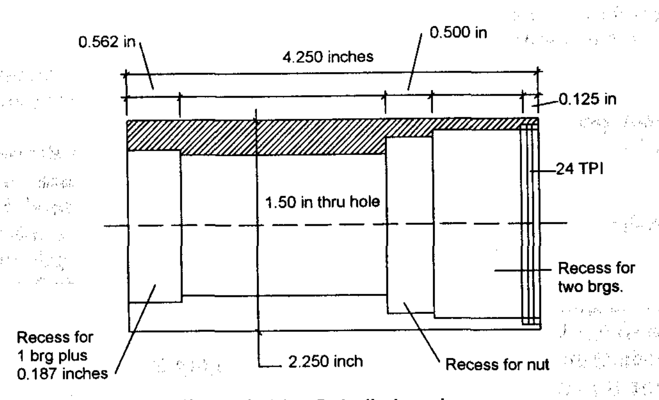


Figure 3.11 *Spindle housing.*

diameter of the back bearing all the way to the shoulder. Here again we want a firm push-fit.

Turn the rest of the shaft down to 0.750 inches for the pulley. The pulley is to be a sliding fit on the shaft so you can get it off easily. Cut 0.750 × 16 tpi threads (or match the nut you purchased) on the last half inch of the shaft. Check that your nut fits this to your satisfaction.

We are now done with the machining of the outside of the spindle except for the keyway for the pulley key.

5. The spindle housing

Now that the spindle can be used as a handle for the bearings, we can start on the housing for the spindle.

The raw material for the spindle housing is a piece of free machining steel 2¼ inches in diameter and $4\frac{3}{8}$ inches long. This allows $\frac{1}{16}$ of an inch on each side for clean up and finishing.

The housing and the spindle itself are the most critical parts of the device. It is essential that we get these working together as perfectly as we can. If you worked between the face plate and the centre and followed the sequences suggested, the spindle will most likely be OK.

Since it is not possible to turn the housing between centres, a little more skill and care will need to be exercised. The important thing is to hold the housing as accurately as possible (within 0.001 inches total indicated runout (TIR) along its length and at any point on the diameter) and keep it that way during the entire procedure for any one side of the housing. It takes a chuck with straight jaws to do this. If you use sharp tools and take light cuts, you should not move the spindle

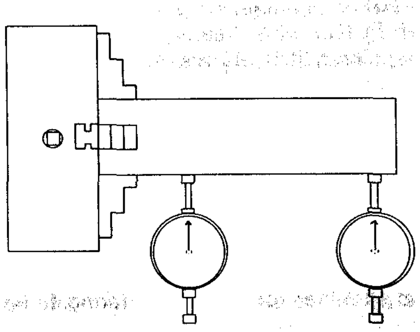


Figure 3.12 *Centre both ends of the spindle housing.*

housing in the chuck jaws. If you have a large fixed steady it can be a tremendous help in supporting the outboard end of the housing.

The front bearings are larger than the back bearing so we make the back bearing recess first. In this way if we make a mistake, we can open the recess out to be the recess for the front bearings.

The back bearing is designed to move back and forth in the housing as the spindle heats and cools (not much heating and cooling is anticipated). As such the bearing is clamped onto the spindle and is free to move in the housing. However the movement in the housing should be a firm push-fit with no play. This is the easy way to make a spindle and would not be suitable for an industrial spindle but we can get away with this for the kind of uses we are going to put our spindle to.

The sequence of operations for making the back bearing recess is as follows:

- Hold the spindle body accurately in the 4-jaw chuck for the entire length of the housing.
- Face outer end.
- Centre drill.
- Drill ½ inch hole 2¼ inches deep or deeper.
- Bore out to 1½ inch hole, 2¼ inches deep.
- Bore rough outline for rear bearing.
- Finish bore for rear bearing seating.
- Chamfer all edges.
- Remove body from chuck.

With the above in mind hold the spindle in the 4-jaw chuck and get it running true. Centre the part at the chuck end first and then use a soft mallet to move the outer end to the centre of the spindle. Slowly, gently – many small blows make up one big blow. Then re-check the part next to the chuck and adjust it. Go back and forth between these two procedures until the part is running true. Tighten the chuck jaws a little at a time as you go (but not too much or you will ruin the chuck). It might be necessary to run a smooth file lightly over the body and polish it to get the bumps and scratches out of the way of your dial indicator before you can get really serious about centring the body.

During these operations there is a large overhang outside the chuck jaws. Under these conditions it is very important to take small cuts and work with sharp tools. Using free machining materials also helps tremendously. It is a good idea to re-check for concentric rotation before you make the final cuts.

Face the housing and put in a large centre in preparation for drilling and boring. First drill a hole 0.250 inches as far as you can go. Open this hole out to 0.500 inches. Bore this hole out to 1.500 inches in diameter and 2.250 inches deep or halfway (it can be plus or minus 0.050 inches). This is a clearance dimension.

We will machine the small bearing end first. If we make a mistake and overbore this end, we can open this out for the larger front bearing end.

We have to bore a recess for the back bearing that is a firm push-fit for the back bearing. The recess has to be 0.250 inches deeper than the thickness of the bearing. The bearing sits 0.063 inches inside the recess and there is another 0.187 inches on the other side for travel. Mount the bearing on the spindle before you put it in the recess so that you have a handle to pull it out with. Guide it in with the tailstock centre so that it goes straight into the recess. Bore the recess and check with the bearing as you go. Tighter is better than looser but not too tight. There are no threads on the housing on this side. Chamfer all edges.

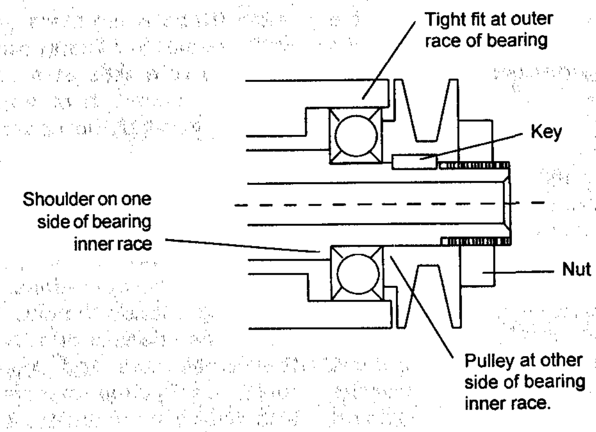


Figure 3.13 *Partial section showing how the back bearing is held.*

Release the body housing from the chuck and turn it around end for end.

We have the following jobs ahead of us on this end of the housing.

(a) Size the housing for length.
(b) Cut the threads for the cap that will tighten down on the bearings.
(c) Cut the recess to clear the nut that clamps the bearings to the spindle.
(d) Bore hole for the two bearings – must be done last.

The sequence for doing this is as follows:

- Hold the spindle body accurately in the 4-jaw chuck.
- Face outer end and size housing for length.
- Centre drill.
- Drill ½ inch hole to meet existing hole.
- Bore out to 1.250 inch hole to meet hole from other side.
- Bore rough outline for nut, bearings and threads.
- Cut threads.
- Bore the clearance for the nut.
- Bore for bearing seating.
- Chamfer threads and all edges.
- Remove body from chuck.

The critical part of making the housing is to make sure that the recesses for the bearings at the ends of the housing line up properly. This means that the two recesses are on one and the same axis – not just both at the centre of the housing but both on one and the same axis. It needs some thinking about to fully comprehend what is required. So think about it and get your plans firmly in mind. See Figure 3.15.

Face the housing and turn it down to its proper length. It needs to be 4.250 inches long. Centre drill it. Drill through as far as you can with a ¼ inch drill and then open this out to ½ inch. Next bore in halfway or more to meet what was bored from the other side. This is a clearance dimension and is not critical but it is a good idea to be precise in all things you do.

Rough bore out the entire recess before you do anything else. Rough bore the recess for the nut behind the bearings. Since you already have the spindle bearings and nut in hand, you should get the dimensions from them.

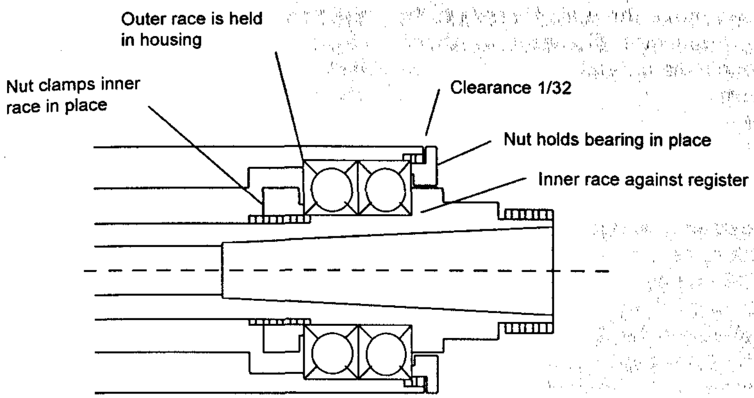


Figure 3.14 *Partial section showing how the front bearings are held.*

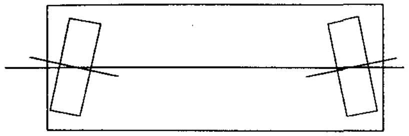


Figure 3.15 *This is what we do not want.*

Next we will address the threads in the spindle housing. These threads are for the cap that will clamp the outer races of the two front bearings. The threads need to clear the 2.000 inch bearing OD by about 0.005 inches so we will make the recess 2.010 inches in diameter and 0.125 inches deep. At 24 tpi this will give us three threads of engagement with the cap. Since this is barely enough, we will form the clearance recess for the thread cutting tool just past the 0.125 inch mark. It takes another 0.040 inches to do this.

Threads like these are best cut while rotating the spindle manually. Remember that there are only three threads to cut. I leave the half nut engaged all the time and use the handle on the spindle to do all the work manually. Actually there is no choice in the matter – it is about the only way you can get the job done right. We still have to pull the tool back out of the threads before we back the carriage up but the technique saves a lot of time.

Check the threads with a magnifying glass as you go. About 7× to 10× is a good magnification for a shop glass. Look to make sure that you have full depth, clean threads with clean crowns and gul-

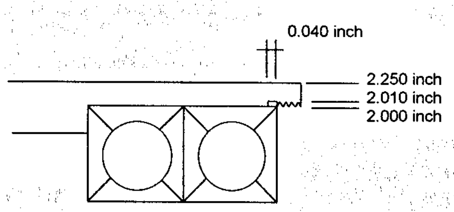


Figure 3.16 *Detail of threads at the front bearing outer race.*

lies. We will make the male threads to fit these so the exact diameter of these threads is not as critical as getting good thread form.

Once the threads have been cut in the housing it is time to bore the recess for the nut that holds the two front bearings. Check dimensions from the nut at hand and proceed accordingly.

Now the critical part. The bearings are each 0.500 inches thick so they will take up 1.000 inch. Added to this we need 0.125 inches for the threads for the cap so that the total depth of the recess for the bearings is 1.125 inches from the face of the housing. The outside diameter of the bearings is 2.000 inches. We need the bearings to be a push-fit in the recess.

When boring to a fixed depth, it is best if you can set up a stop for the carriage. A micrometer stop is the ideal, but an ordinary stop will do at a pinch. Having a stop gives you one less thing to worry about when you are doing a close tolerance job.

Once you are satisfied with the fit of the bearings, clean up and polish all surfaces. Chamfer all edges and threads. Remember that the threads are always chamfered with the threading tool. Make sure that the bearings are actually seating all the way into the recess. This can be confirmed by taking accurate measurements from the front face of the housing with a depth gauge.

Take the housing out of the chuck. Now you can put the back bearing in the back recess and put the spindle and bearings into the housing from the front. It should run smoothly and without binding or friction if you have done your work right.

6. Split collet for holding the bearing cap
Home-made split collets are a good way to hold thin parts in a 3-jaw chuck firmly and accurately. In general split collets need to be made of material that is 0.250 inches in diameter larger than the part that you are trying to hold. Since we are going to hold a 2.250 inch part, we need a blank about 2.500 inches in diameter and about 0.375 inches thick (or long). This will clean up nicely to form a collet 0.250 to 0.312 inches thick.

Hold the work in the 3-jaw with the jaws reversed. Bore out the collet so that the internal diameter is about 0.250 inches less than the outside diameter of the part to be held. In our case this will be 2 inches. This is not a critical dimension.

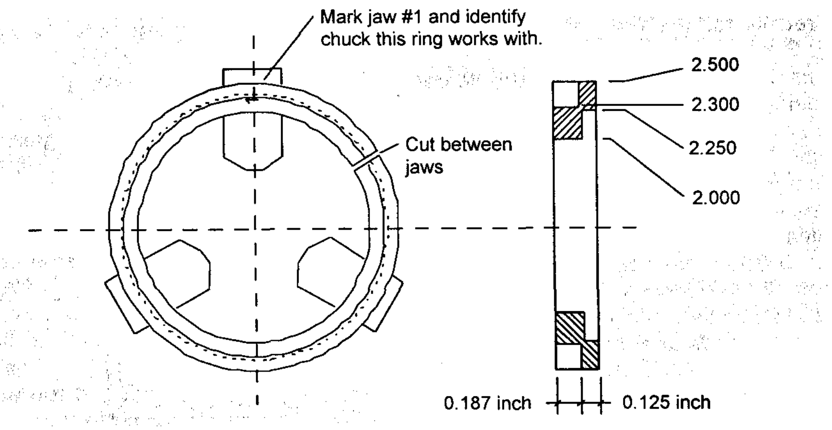


Figure 3.17 With the exception of the 2.250 inch holding dimension, the dimensions of the split collet are not critical.

Notes:

(a) We need a 0.125 inch or longer register to hold the collet adequately in the chuck. We need a recess of about 0.125 inches to hold the part in the collet. Unfortunately 0.125 and 0.125 makes 0.250 so if we are not careful, the register and recess will run into one another and we will not be able to hold anything! We have to keep this in mind when making the split collet and we have to leave a little material here and there to hold everything together. It is easiest to make it so that the register diameter is larger than the recess diameter. See Figure 3.17.

(b) Be sure to mark the location of chuck jaw number one on the collet before you remove it from the chuck. Also mark the identification number of the chuck on the collet. The split in the collet should be between two jaws and not at a jaw. This collet is good only for holding this one diameter in this one chuck.

(c) We need at least three threads to assure ourselves that we will get proper engagement. Theoretically, one thread could be sufficient but we need two to make sure that we get contact all the way around and we need the third thread because we may leave one thread un-threaded to guarantee that clamping is actually taking place. The threading tool clearance recess gives us clearance past the threads.

The following notes are applicable to all thread cutting but especially so to the finer threads: when cutting the finer threads, the profile of the thread-cutting tool becomes critical because any imperfections in the profile will lead to imperfect threads and on small threads we do not have a lot to play with. It is also essential that the tool be mounted to meet the work at the right angle. Honing the thread-cutting tool on all cutting surfaces is recommended. A sharp tool will form cleaner threads, a dull tool will tend to tear the work. This can be seen quite clearly under a 10 power magnifier. Examine the work after the first cut to make sure that the tool is cutting clean.

We need to clamp at least 3/32 inch of the rim of the bearings. All shoulders that meet the bearings should be at least that high. If more material can be provided, the contact area or shoulder should be made the same size as the race of the bearing. This applies to both inner and outer races. Needless to say, in no case should the clamping surfaces touch the seals on the bearings. On most bearings the inner race rotates in the seal and the outer race is fixed to the seal. On most sealed bearings the seals will be below the bearing races but we must make sure that they actually are.

7. The spindle front cap
Now that we have a way of holding the spindle cap, we can machine it.

You will need one piece of 2¼ inch diameter free machining steel 0.375+ inches long for the front cap for the housing. This is the same material that the spindle housing and the pulley are made of.

Put the material in the split collet and face it. If the blank you got is not cut square to the axis of the rod or if there is a rough saw cut, take these into account when clamping the part so that it will face true. Clean up the face. Put a slight chamfer on the outside edge, about 0.030 inches wide.

Turn the part over and turn down the portion that is going to be threaded to the right diameter. The diameter should be 0.080 inches greater than the inside diameter of the part that is going to fit these threads, in this case the body of the spindle housing. The bore of the spindle housing for the bearings was 2.000 inches. We made the inside diameter of the threads 0.010 inches greater than this or 2.010 inches so that we would not disturb the bearing seat. Threads at 24 tpi have a double depth of 0.084 inches so we have to start at a diameter slightly over 2.100 inches and work down from there. Cut a recess at the shoulder to clear the thread-cutting tool at the end of the cut. This should be about 0.030 inches wide and 0.040 inches deep (radius).

Make sure that the blank actually seats firmly in the split collet. Take light cuts with a sharp tool when working with a large piece in a split collet. Use a hone to get the best edge that you can and round the tool nose slightly. The purpose of a round nose is to give you a finer finish. Generally, the larger the tool nose the smoother the finish (within limits of course).

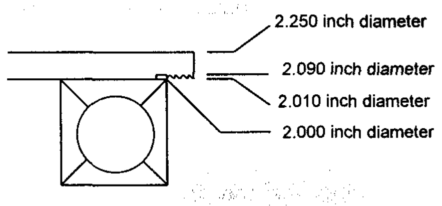


Figure 3.18 *Approximate dimensions of what the nut has to match.*

When cutting anything over 20 threads per inch, be particularly careful to make sure that the thread crowns do not interfere with the base of the thread on the nut. If you start getting a point at the thread crowns when cutting the threads, file them down immediately or you are liable to get an erroneous fit. (This condition makes the nut seem tighter than it really is.)

Once the fit gets close, take two passes at each setting and cut only 0.001 inches on each setting. File the crowns of the threads down as they are created. Try the nut after every pass. Check the thread crowns after each pass. Now is not the time to make a mess!

The threads that this cap has to fit have already been cut in the housing for the spindle. You will recall that these were to have an inside diameter of 2.010 inches but it is worthwhile checking this again before starting.

We need a register that is 2.100 inches in diameter and 0.157 inches long for the threaded portion of the cap. On this we will cut 0.125 inches of threads and allow 0.032 inches for the recess on the inboard side to clear the threading tool. We can cut 3 threads at 24 tpi on a register 0.125 inches long. We will cut these threads by turning the spindle by hand. After each pass check the fit of the threads with the body of the spindle. Stop cutting and clean up your work as soon as the threads start to engage. Smooth down the crowns and cut the threads 0.001 inches at a time until you get the threads just right. Without the bearings in the housing, the cap should thread all the way into the housing. With the bearings there in place there should be a 0.032 inch gap.

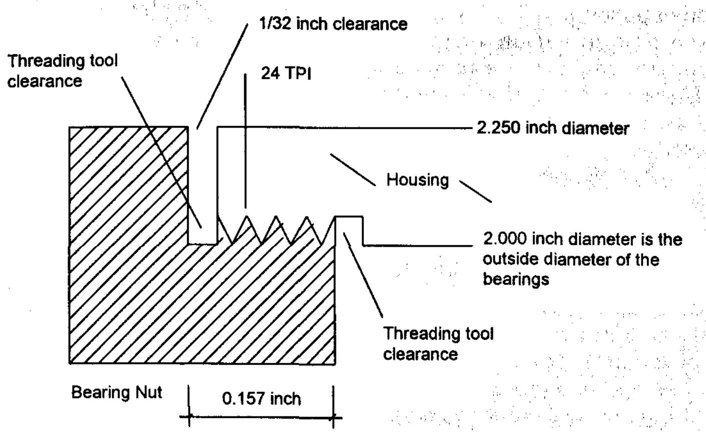


Figure 3.19 *Section across the bearing nut (cap) perimeter.*

Bore the hole in the cap out to 1.375 inches in diameter before removing from the collet. This hole should be bored at the threading setting to be completely true to the thread axis. We are looking for a hole that is 0.004 inches larger than the spindle flange i.e. 0.002 inches clear all the way around.

Now place the bearings on the spindle and put the works in the body. Tighten the cap onto the body and check the clearance between the cap and the body. It should be between 0.030 and 0.035 inches. If it is not, you can adjust it by machining the cap at the appropriate location.

Chamfer all edges and threads and set the cap aside. We will cut the 6 castellations for the spanner wrench in it later on after we set up to do all this and similar work, at one time, in the lathe.

Notes:

(a) The ring clamp is threaded into the housing to hold the bearing outer race because this form of bearing clamp allows us to have the smallest possible outside diameter for the housing. In this case the housing will be 0.250 inches larger than the largest bearing (in diameter). This gives 0.125 inch of wall on either side. If we wanted to bolt the bearing clamp on, we would need at least 5/16 inch on each side and maybe more. Bolting down is also more work.

(b) When a milling cutter cuts, it pulls the swarf out of the cut. This in turn pulls the cutter into the cut. This pull has to be taken up by the front bearings and these are held in with the cap we are machining. So it is important that these threads fit well and seat as perfectly as possible. Full threads that engage fully are needed.

8. The drive pulley

Now is the time to decide what kind of pulleys you are going to use to drive this spindle. Make the back of the spindle to suit your particular needs. The description covers the standard for pulleys with a 0.750 inch hole and an 0.125 inch square key (as found in most hardware stores in the USA).

The pulley should be cut to match the belt that you are going to use. The drawings show a pulley that will work with belts that are ⅜ inch to ½ inch at the widest part of the belt. The narrower belt is easier to use and is more than adequate for everything you will want to do with a spindle like this. It is also more flexible. Buy your belt first and then work to it. The belt top should be even with the outside of the pulley when it is seating right.

The pulley is made from a piece of free machining bar stock 2.250 inches in diameter and 1.000 inch long. This is made of the same stock as the housing and cap.

The intent of the design is to allow any standard run-of-the-mill pulley with a ¾ inch bore and a key slot to drive this spindle. The 2.250 inch pulley shown is the standard pulley for this spindle and is suitable for most milling applications. It can be replaced with ease so you can change your mind later if you like. Note that even keyed pulleys have to be nutted down because the back bearing on this spindle (which bears no axial load) is held with this nut. Do not use the set screw in these pulleys.

First mount the blank accurately, centred in a 4-jaw chuck. Lightly face the part and chamfer.

"Mount parts accurately in the 4-jaw and centre them" means that the total out of round from side to side on the dial indicator is less than 0.001 inches not counting the blips caused by scratches and imperfections on the surface. The part should be checked for "on centre" on each end if it sticks out of the 4-jaw over 2.000 inches. The condition of the chuck you are using has a lot of effect on alignment. Worn and abused chucks are harder to use.

The 0.750 inch shaft for the pulley is intended to be long enough to allow you to mount standard pulleys on it. There may be a need for some modification of a commercial pulley to prevent interference with the back bearing and housing. Select a pulley with a keyway rather than one needing a flat for a set screw.

I have designed the pulley so that it is the same diameter as the spindle housing. It is better to do it this way because a larger pulley tends to get in the way most of the time and is not needed for the high-speed work this spindle will be used for most of the time.

The sequence of operations for making the pulley is as follows:

- De-burr the blank.
- Hold the stock in the 4-jaw chuck and centre with ¼ inch sticking out.
- Face the stock.
- Turn a boss 3/16 inch long and 1.375 inches in diameter on face.
- Centre drill and drill out to ½ inch.
- Bore out to 0.740 inches.
- Ream or bore to 0.750 inches for a light push-fit on the 0.750 inch spindle shaft.
- Hold in 4-jaw chuck by the register.
- Check centring and axial alignment with the back of the spindle in the bore and a centre supporting the spindle head from the tailstock.
- Tighten down the chuck as you centre the pulley.
- Remove spindle.
- Face pulley to correct thickness.
- Cut keyway.
- The belt groove will be machined later after mounting to the spindle shaft to guarantee absolute concentricity.

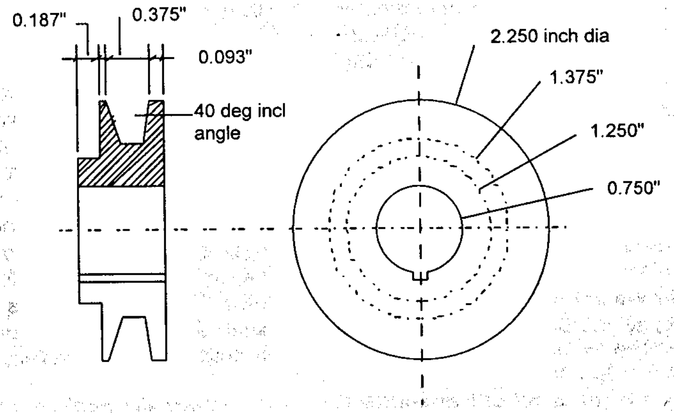


Figure 3.20 *Section across the pulley/pulley dimensions.*

I recommend a 2.250 inch diameter drive pulley as this is the same size as the body of the housing. If you would like to fit a smaller or a larger pulley, that can be done.

First hold the pulley stock in a 4-jaw chuck and machine one face of the pulley. Holding the stock deep in the chuck will ensure that the body of the material is held accurately in the chuck so that it gets faced at right angles to the axis.

Drill a 0.500 inch hole in the pulley and bore this out to 0.740 inches and then ream to 0.750 inches. We will cut the pulley groove between centres after mounting the pulley on the spindle. It cannot be done at this time because we still need the blank to drive the spindle when we machine the Morse taper. The forces required to do this are quite large and would ruin a finished pulley. More on this later.

I have selected bearings with integral, double seals. When clamping the inner and outer races of these bearings it is important that the seals not be touched by the clamping faces. To ensure this you should turn away about 0.010 inches on the entire face of the pulley boss except for the part that is going to clamp to the inner race. Take a close look at the bearing seals to see what you need to do.

9. Cutting the keyway in the pulley

The keyway in the pulley can be cut by using the lathe as a shaper. The pulley is held square in the chuck and a key-shaped cutter is held dead on centre height in a boring bar in the tool holder. The lathe chuck is held firm by some method and the key cutter is moved across the pulley bore manually by traversing the carriage. It is possible to take cuts of about 0.005 inches with each pass.

Depending on how carefully the cutter has been made, it may be necessary to make a holder that will allow the finished keyway to be broached by a square tool of the right size. The holder is a 0.750 inch shaft which has had half the keyway milled into it. The other half of the keyway is in the pulley. The tool is a standard 0.125 by 0.125 inch turning tool that is ground completely flat and sharp at the cutting face. It can be pressed through with the tailstock for the final pass. If you have a larger drill press this can also be done in the drill press.

Careful filing can also be used to finish the keyway.

10. Modifying the pulley nut

You will need to purchase a ¾–16 (see Appendix 2 for UK equivalent) unplated nut and modify it. See the drawing for the modifications required.

Unfortunately large, unplated, commercially made nuts are not guaranteed to have the threads either in the centre of the nut or particularly in line with the axis of the nut. I was surprised to discover this (or I may have got my hands on a particularly bad nut). This being the case, each side of the nut should be re-faced after it has been mounted on straight, lathe cut threads. I used a ¾–16 (see Appendix 2 for UK equivalent) nut and machined it down to about 0.375 inch. The inside of the nut is relieved to allow more of the shaft to be available as seating for the pulley. Do not use a lock washer under this nut as these tend to

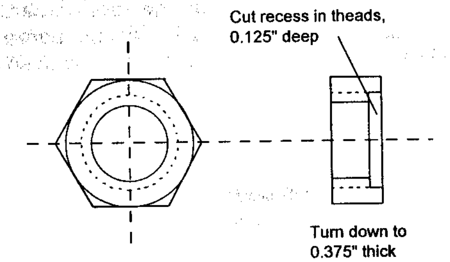


Figure 3.21 *Modification of a commercial ¾–16 nut.*

gouge the surface against which they work. A plain washer may be made up if you like.

11. Cutting the keyslot in the spindle shaft

Use your vertical slide and a small angle or vice to hold the spindle at the right height to cut the slot for the key. It is also possible to clamp the shaft to the lathe cross slide with the right amount of packing under it to do this.

Cut the slot 0.063 inches deep with a 0.125 inch diameter milling cutter. Two or three passes should be sufficient to get the depth you need. The slot should go almost to the shoulder for the bearing. It does not have to be cut across the threads and a short slot (0.500 inches) just under the pulley is OK.

Clean up your work with a smooth file.

12. Preliminary assembly

A word of caution here – do not use any adhesives, anywhere, if at all possible, if you ever want to take any part of this spindle apart. The design does not lend itself to disassembly if things are glued together. However, adhesives can be used on the inner races of the double bearings only and nowhere else. Do not do it.

First, clean everything, especially all threads and all bearing surfaces. Then lightly oil or grease (white lithium) everything for rust prevention and ease of assembly.

Push the back bearing into its recess. It has to be able to move in this recess as the spindle warms up in use, so it should not be glued under any conditions. Do not allow this bearing to fall out as you proceed with assembly.

Put the two front bearings on the spindle and nut them down as tight as possible with the nut that holds them in place. Be careful that you do not damage the castellation.

Push the spindle in from the front. The installed back bearing will hold the spindle at centre and make it easier to line things up.

Screw in the front cap and tighten it down good and tight but again be careful that you do not damage the castellation.

Install the key on the back of the spindle and push the pulley onto the spindle.

Install the nut on the back of the spindle and tighten it. If all is well we are now ready to machine the Morse taper in the nose. We will machine the pulley groove later. Right now we need the pulley as it is to hold it in the 4-jaw as our driver. Take it all apart.

13. Machining the No 2 MT in the nose

First we need to set up the compound slide at the Morse taper angle. We can use a No 2 MT plug to help us. See Figure 3.22. It is preferable to have a "steeper than needed" taper as opposed to a "shallower than needed" taper.

Once the compound is adjusted we can remove the taper and mount the spindle on the lathe as shown in Figure 3.23.

We will drive the spindle with the pulley held in the 4-jaw and support the nose end in a fixed steady. We will do this after centring and aligning the work as perfectly as we possibly can.

Hold the pulley end of the spindle in the 4-jaw chuck and support the nose end with a centre in the tailstock. Adjust the 4-jaw until the spindle is perfectly centred. Using the tailstock keeps that end aligned. Tighten down snug on the pulley – we will be taking some heavy cuts with the reamer and we need to hold on tight. While still in this position, position the fixed steady on the spindle at the nose bearing to support it firmly.

The sequence for doing the work is as follows:

- Hold the spindle accurately in the 4-jaw chuck by the spindle pulley.
- Put the tailstock centre in the centre in the nose.
- Centre accurately in the 4-jaw.

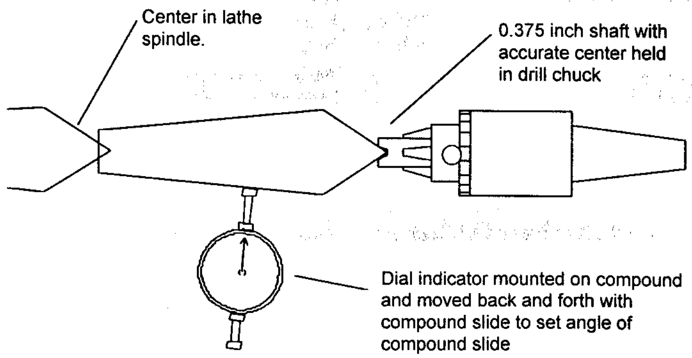


Figure 3.22 *How to set up the taper angle on the compound slide. Mount the dial indicator in compound and adjust until compound is parallel to the taper body. A steeper taper is preferred.*

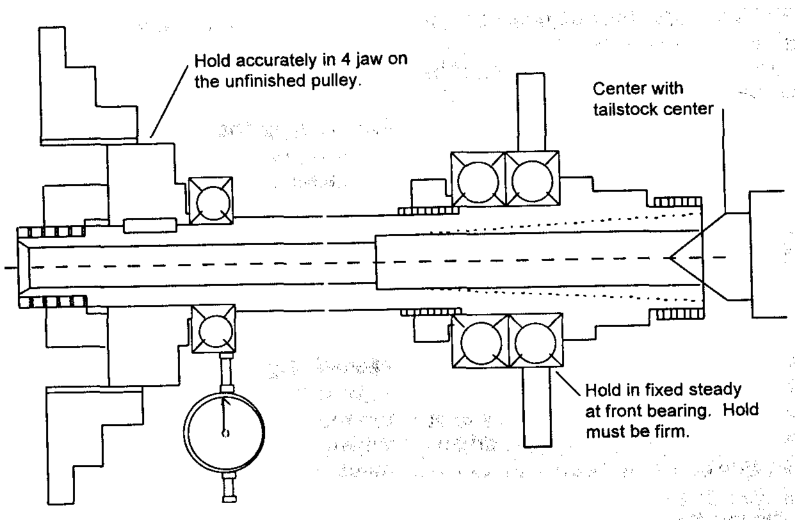


Figure 3.23 *How to set up to machine the No 2 MT.*

- Set spindle to run absolutely true at the 4-jaw.
- Mount the fixed steady at the double bearings and set.
- Rough bore the Morse taper hole with the compound slide.
- Finish ream the Morse taper hole and adjust for depth.
- Remove spindle.

The depth of this Morse taper is critical because it has to be such that the Myford collets will close properly when the collet closer is screwed down on the nose threads. The best way to make sure that this will indeed be the case is to have a collet closer and a half inch collet along with an accurately made (ground if possible, use an old ½ inch end mill shank) half inch rod in hand while the machining is being undertaken. We will need to have about half a turn left to go on the collet closer when the shaft is tight in the collet.

The easiest and only way to make an accurate Morse taper hole is with a Morse taper reamer. If you cannot afford a reamer, borrow one or if that is not possible, have a local machine shop do the work for you. The spindle can be held in a 5C or larger collet to do the work fairly quickly.

These notes will be of assistance if you have never done anything like this before now. Morse tapers are about 0.500 inches per foot or 1 in 24. The various Morse tapers (No 1 to No 6) are not all at the same taper. The fit to the taper is very sensitive to the angle of the taper. There is no realistic possibility that we might harden, temper and then grind this taper. It is not in the cards to have equipment like that in the shops of hobbyists and amateurs. With a little care, an unhardened taper will take us to the end of our days. The best way to ensure a fit is by trials and scraping after using a Morse taper reamer. It is not possible to bore a taper because even on a 5.000 inch lathe like my South Bend, the travel on the compound is only 2.000 inches and we need to bore about three deep! So it would take a much larger lathe to do the job. Rough bore in sections, use the reamer and then scrape to fit if need be. You should not have to scrape if you have a reamer in good condition.

In my opinion, taper attachments are not the panacea they are touted to be for making internal No 2 MTs so do not spend your money and time buying or borrowing a taper attachment for this project.

The taper reamers come in two forms, a roughing reamer and a finishing reamer. You can do without the roughing reamer but you do need the finishing reamer. The roughing reamer looks just like the finishing reamer except that it has some tiny scallops cut into each of the cutters to break up the chips.

If you have a choice, get a reamer with a flat at the end of the Morse taper tang. This is very helpful if you manage to get the reamer stuck in the spindle for any of a number of reasons. If the reamer gets stuck, it will come loose in the tailstock (not good) and you will have to release it from the spindle. If there is no flat on the tang, and no hole in the spindle, you are in trouble because there is now no way to get a wrench on the reamer. Discard the spindle and discard the reamer and start over.

The reamers are to be used for the final sizing of the taper only. The length of cut along the reamer is so long that it is very hard to hold the reamer in the tailstock when making these cuts. Work carefully and use lots of cutting oil when making these cuts. Take very light cuts and work slowly to avoid getting the cutter stuck in the taper. Here again I caution you not to start unless you have the hole through the spindle in place so that you can knock the reamer out if you have to.

It takes a 9/16 inch hole to start the reamer in the spindle and it is possible to go all the way to the finished taper from this hole with just the reamer (if you are using free machining steel). However this makes a lot of work for the reamer and will shorten the life of an expensive tool, so take the time to rough bore the spindle first.

Since no-one I know has drills over 0.500 inches in diameter in his home shop, we cannot step-drill the hole and will have to bore most of the hole for the Morse taper (No 2). First bore in about 0.062 inches at 0.685 inch diameter as a marker. Make the bore so that it is tight on a taper at the inside end and loose on the outside and not the other way around – we want the taper to be bored steeper than it needs to be. Watching the outside end so that it does not get too large is made easier by making the 0.685 inch section indicated above. When it gets close, start using the reamer. Use the slowest back geared speed on the lathe. Be absolutely sure to put the 3/8 inch thru-hole in the spindle, as suggested above, before you start. That hole will help you knock a stuck reamer out of the taper.

As you proceed, check the depth of the reamed hole with the collet and the collet closer. It is imperative that this does not become too deep. The spindle is almost done – now is not the time for inattention to details.

Clean up, chamfer and polish all surfaces. Remove from chuck in preparation for final assembly.

14. Cutting the spanner notches in the cap and bearing nut

Before we can get to final assembly, we need to cut the 0.125 inch wide notches in the nut for the front bearings and in the front cap. We will cut 2 notches in the bearing nut and 6 in the front cap. We do not actually need 6 but 6 look best.

Use a 0.125 inch diameter cutter held in a collet in the lathe spindle to do the cutting. If you have made the George Thomas dividing head, I do not need to tell you how to cut the notches. If you have not, you should consider making this excellent tool. I will describe how to do it without the dividing head.

Hold the nut and then the cap in the 3-jaw and mark out two and six equally spaced marks on them respectively. A tool mounted at centre height will allow you to engrave a diameter accurately. You can engrave three equally spaced diameters by indexing on each of the 3 jaws of the 3-jaw chuck. This gives 6 equal divisions.

Next set up a small angle plate on your vertical slide and place stops on the angle plate so that you can cut the 0.125 inch wide by 0.125 inch deep slots in the nut and cap. You should be able to cut 0.062 inches at a time without difficulty. The cross slide and carriage are locked in place and the cuts are taken by moving the vertical slide up and down. Work carefully so that you get a nice looking job.

Deburr the parts.

15. Cutting the belt groove in the pulley
First get the belt you will be using – a ⅜ inch wide belt is fine and a smaller belt will work too. The forces we intend to transmit with this belt are quite modest. A small section is more flexible and easier to handle.

Set the spindle with the pulley mounted on it up between centres on the lathe. The included angle in the pulley is 40 degrees (or to suit your belt). First rough machine the groove with a parting tool. Next set the compound up at 20 degrees to the cross slide, or to suit your belt, and finish cut one side of the belt groove all the way. Set the compound to –20 degrees and cut the other side. Finish the bottom of the pulley groove. Make sure that both sides of the pulley are even. Chamfer and polish up your work.

16. Final assembly
Clean all parts and oil lightly.

Assemble as before but this time tighten everything down for good.

Happy machining is around the corner. The spindle will be ready for its first job as soon as we can mount it. A simple but versatile mount for the vertical slide will be described in the next chapter.

Notes and comments

- If you want to take the big hexagonal nut off the back of the spindle, hold the front of the spindle in a 3-jaw chuck with soft copper or aluminium packings and use an (adjustable crescent) wrench on the nut.
- Make the key for the pulley of brass for ease of filing. Brass is more than strong enough to carry the load being transmitted.
- The hole through the spindle has to be at least ⅜ inch in diameter because the draw in bolts for some of the Morse No 2 milling holders use this size to pull the taper in. Since this hole is drilled in a ¾ inch part of the shaft, this hole could be made ½ inch without encountering any difficulties. This would allow larger parts to be held through the spindle but can also cause out of balance of problems at high speed if everything is not centred in the spindle properly. Unless you have some overwhelming reasons, leave this at ⅜ inch at this time. In any case you should avoid draw bolts as bad practice and use the collet closer method as being the most suitable for high-speed work.
- The back bearing has to be smaller than the front bearing to allow the nut to be placed on the front bearings. Also it is easier if both bearings are not the same size because then the shaft does not have to be the same size all the way between the two bearings and we will not have to make a close-fitting tube to space and clamp the two bearings (as would be needed in some of the designs presented later on).

CHAPTER 4

Mounting the spindle

Introduction

There are a number of ways that a basic spindle can be used on the lathe, but this spindle is different. Since we have a full lathe spindle nose on this spindle, we can mount chucks on it. This means that we can actually hold things in the little spindle and use the lathe spindle to do the machining. A whole mass of accessories come to mind – but not now and not here!

The basic mountings that come to mind immediately are:

- On the vertical slide, both horizontally and vertically (or at any angle if you have a swivelling slide), this being the standard use.
- On the cross slide at centre height for special functions. Cross drilling and keyway cutting are obvious examples of often needed operations at centre height.

We will worry about the use of the spindle on the vertical slide and lathe carriage only.

Parts needed

The vertical slide mounting consists of two split plates that clamp the spindle in the position desired. The mounting is fairly simple and flexible.

To mount the spindle to the vertical side, the following items are needed. The dimensions given are the finished dimensions of the parts.

2 Pcs	Steel, 4.000 inches × 2.500 inches. Plates need to be 0.500 inches thick.
4 Pcs	Steel, 0.500 inches round × 2.625 inches long as spacers.
4 Studs	0.250 inches × 3.125 inches long with washers and nuts.
4 T nuts	Machined. Make each from 0.750 inch diameter × 0.375 inches long shafting.

Once we have the materials in hand, we are ready to begin machining.

Standard clam shell mount

First we will address the clamping plates. The sequence of operations is as follows:

- Cut plates approximately to size with a saw.
- Square and size plates in lathe or in a milling machine.
- Blue and mark up the plates.
- Drill one of the ¼ inch holes in the face of one of the plates.
- Use this hole as a guide to drill the 4 holes in the other plate.
- Clamp the two plates together.
- Drill the other three holes in the first plate.
- Deburr all holes.
- Bolt the two plates together.
- Mount flat in 4-jaw chuck and centre.
- Bore out hole to accept spindle through both plates.
- Mark edge of plates for the four 17/64 inch holes.
- Centre drill in 4 locations from both sides (8 locations total).
- Drill ¼ inch hole from each side so that they meet.
- Open holes out to 17/64 inch and drill through.
- Stamp number stamps to match the units.
- Unbolt plates.
- Cut plates in two.
- Mill sawn faces so all plates are the same size.
- File all edges.
- Make the 4 optional spacers.

The raw material for the plates is nominal 0.500 inch mild steel plate. You need enough stock to make two finished 4.000 inch by 2.500 inch plates. Try to get the most free machining material that you can find – it makes it a lot easier to do the work. Life is too short to spend it filing rusted hot rolled girders.

Cut the material and then face one long side on each plate so that you have a true surface to work from. File the burrs off the machined sides. File all edges to remove all burrs. In these operations it is important that the machined faces be at right angles to the plate faces.

Next machine the side opposite the first side that you machined. Again file the burrs off. Check that you have plates that are exactly 2.500 inches wide and that the sides are parallel. This is important. Coat with layout blue and mark up the plates so you can see what you will be doing in the next steps.

Machine the third side of each plate. File the burrs off. Make sure that each corner is exactly 90 degrees before you go on. If not, make the necessary adjustments and re-machine the side. Machine the final side to make the plates to size. File off all burrs on all 12 edges of each plate. At this stage the plates should be to size and you should be able to put them together in any way you please and not be able to tell that there is any difference between the plates.

Re-blue one plate and mark on it one of the four 17/64 inch holes on the plate face. Mark this hole very accurately and check your work. First mark the hole with a light centre punch. Then look at it with a magnifying glass. If it needs to be moved over you can do it with a heavier punch and a hammer. Just hammer the centre punched hole over to where it needs to be. This hole will be used as a guide to drill all the other holes in the faces of both plates so it is important to get this right. Centre drill this hole and then drill it through 17/64 inch. Deburr both sides of the hole. Now clamp the two plates together four times in the four possible orientations and drill through with this hole as a guide. Using the drilled plate as a guide drill the

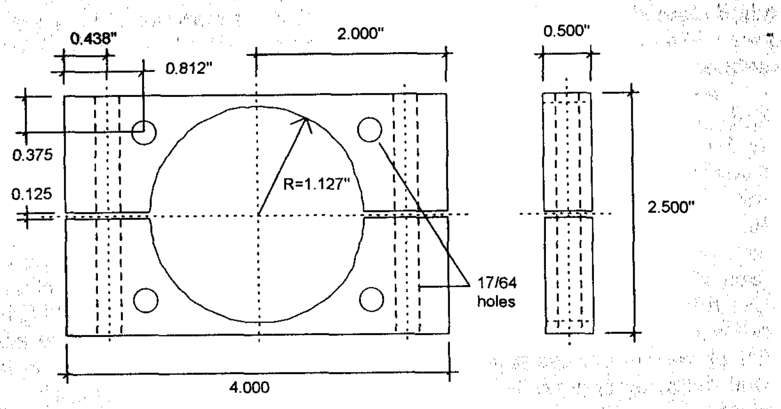


Figure 4.1 *Clamp plate dimensions.*

remaining three holes in the first plate.

We can now clamp the two plates together with four 1¼ inch long by ¼-20 (see Appendix 2 for UK equivalent) bolts. Mark the exact centre of the hole for the spindle. This should be done as accurately as possible and it is well worth the time to make a centring button and screw the button to the centre with a 6-32 screw. The button can then be adjusted until it is exactly in the centre of the two bolted plates. Chapter 16 contains instructions on how to make a set of centring buttons. These have also been described from time to time in *Model Engineer*. You may prefer to use a published design. It will be well worth your time to make a set of buttons.

The two-plate assembly is now mounted in a 4-jaw chuck. Centre the plates with the centring button which is already at the exact centre of the plates. Make sure that the plates are flat in the chuck. Remove the centring button and drill a small hole at the centre through both plates. Open this out to the largest drill in your collection and then bore it out so that it is a nice fit on the spindle body. Check the dimension to the edges and make adjustments as necessary as the work progresses. You should be able to put the spindle into the bored holes with the slightest bit of jiggling. The fit should be a close sliding fit so that when you cut the plates in two and re-bolt them together, the spindle is held snugly and firmly. When unclamped we want it to come loose with ease. We need the hole to be from 0.002 to 0.004 inches oversize.

In a design like this the clamping hole should always be slightly oversized – smaller holes would mar the spindle at the jaws each time you used them.

Remove the bolted assembly from the chuck and re-blue the 4.000 inch by ½ inch sides. Mark the plates to drill the four 17/64 inch clamping holes that go through the width of the plates. The holes are intended to match the slots in the Myford system. These slots are 1 9/16 inches on centre, so the holes need to be 3⅛ inch apart. Mark these holes from both sides and centre drill at each of the 8 locations. Drill to the centre of the plates from each side with a ¼ inch drill.

Then drill through at each of the 4 holes with a 17/64 drill. The slightly larger drill is needed here to allow the plates to clamp the spindle without the bolts binding in the holes. It also gives you a little adjustment room. Deburr your work.

While the plates are still bolted together, use your number punches or a centre punch to mark all the mating surfaces that will be created when the plates are sawn apart. This will make things easier during reassembly.

Unbolt the plates and saw them in half lengthwise as shown on the drawings. Put all four halves in the mill or the 4-jaw chuck and mill down the sawn surfaces for clean up. Remove all bolts and file all surfaces and edges to remove all burrs.

It is well worth the time to make the 4 spacers that will hold the plates exactly 3⅛ inch apart on centres. In the main, the spacers make it easier to mount the spindle. The spacers should be made of ½ inch rod and should be exactly 2⅝ inch long. Centre drill each end, drill with a No 7 drill ⅝ inch deep and tap each end ¼-28 (see Appendix 2 for UK equivalent) for a cap screw.

Make the washers out of machined 0.500 or 0.750 inch material, 0.125 inches thick with a 0.250 inch hole through them for a close fit on the studs.

Mounting the spindle on the vertical slide

The two split plates when assembled to the four spacers will provide a footprint that will place the mounting studs on a 3⅛ inch by 3⅛ inch grid. That is the same as the standard spacing for the slots on the vertical slide and on the cross slide table. The spindle can be mounted in either direction on each of these surfaces.

The goal in Figure 4.2 is to have a very compact mounting that is as close to the mounting surface as possible for rigidity. It is the intention of the design that the clams be near the bearings for maximum rigidity although that is, of course, not

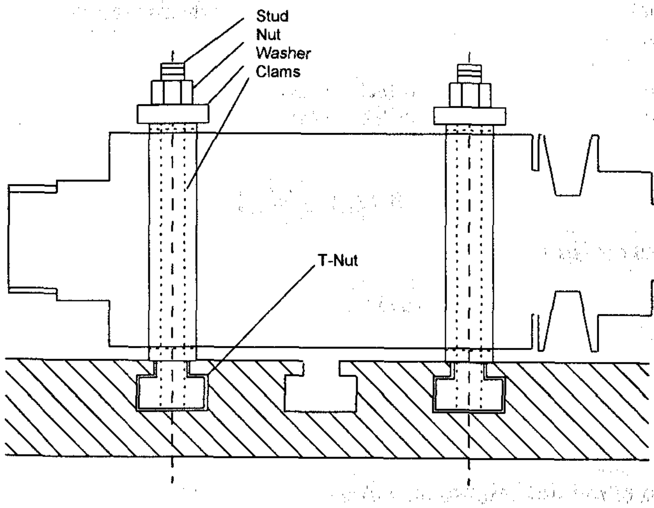


Figure 4.2 *Cross section of spindle mounting.*

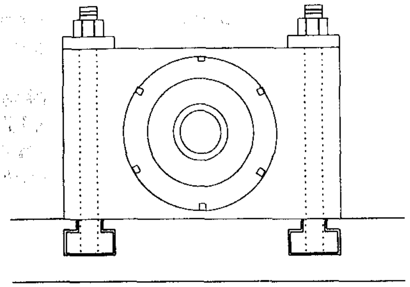


Figure 4.3 *Front view of the mounting.*

absolutely essential. If the mounting is to a vertical slide, the studs should be kept as short as possible to avoid interference with the "chuck end" parts of the lathe.

When mounting to the vertical slide it is often necessary to make sure that the axis of the spindle is orthogonal to the axis of the lathe. This is best accomplished by confirming that the slide is actually parallel to the face of the chuck and parallel to the cross slide before mounting the spindle.

The cross slide should be made parallel to the chuck face by bringing it up to the chuck or a face plate as it is being mounted. When the spindle is mounted to the vertical slide its face has to be made at right angles to the bed. This can be done by using a machinist's square between its face and the bed of the lathe.

When mounting to a swivelling vertical slide it is best to mount at 0 degrees with the swivel set at 0 degrees and then to adjust to the angle that may be desired with the swivel.

Mounting on the cross slide

Mounting at the cross slide almost invariably means that we are going to mount at the lathe centre height (if not, we use the vertical slide to attain the height that we need or to make a cut).

To mount at exactly the centre height of your lathe, you need to make a block spacer that mounts on the carriage. This spacer needs to be of a height that will bring the spindle centre to the exact lathe centre height. Since each lathe is slightly different in this dimension, you will have to determine the proper thickness of the spacer for your particular lathe. For reference purposes, the approximate thickness of this spacer is 1.062 inches.

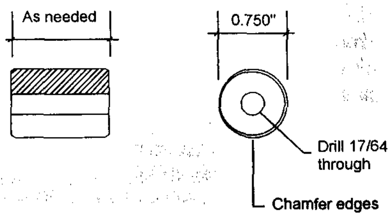


Figure 4.4 *Optional spacers for plates.*

Since the loads transmitted by the spindle can be controlled with the depth of cut that is taken, it is possible to use four spacers instead of a block. These spacers can be 0.750 inches in diameter with a 17/64 inch hole in them. Longer studs will have to be made to allow the clamps to be bolted down with the spacer in place.

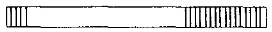


Figure 4.5 *Studs for mounting spindle.*

The end of the stud that fits into the T nuts should be threaded so that the stud will not go all the way through the nut. This keeps the nut from breaking the slots in the table if over-tightened. It is also worth the trouble to make the nuts so that a stud cannot be threaded through them past the bottom face for the same reason.

Figure 4.6 *T nuts for mounting spindle.*

The T nuts should be made to suit the T slots on your lathe*. The T nuts for mounting the spindle to T slots are easy to make from a piece of 0.750 inch diameter rod. First machine 4 short cylinders each 0.375 inches tall. Drill and tap a ¼ – 20 (see Appendix 2 for UK equivalent) thread in each cylinder but not all the way through the cylinder as discussed above. The last thread should be left unfinished.

Machine off 0.125 inches or as needed for your slots from one side of each nut. Set up again to machine off another 0.125 inches from the other side.

Now, keeping the un-threaded end of each cylinder in mind, machine the steps in the nuts.

Driving the spindle is covered in Chapter 14.

*These are available from various suppliers, ready made or threaded. A.J. Reeves & Co (B'ham) Ltd or A. Marks (Modelog) are two suppliers.

CHAPTER 5

A smaller No 2 Morse taper spindle

I felt that this spindle design represented the smallest spindle that one could make and still preserve the No 2 MT and thus the Myford collets and tool holding feature. The spindle fits in a 2.000 inch by 2.000 inch steel bar housing.

The cartridge spindle described in Chapter 3 is a relatively large spindle for use on a small lathe and can get in its own way when working in close quarters. A part of the problem are the clam shells that mount the spindle, which although very versatile, do take up a lot of room. In this next design, the mounting is formed by the housing itself. Although the 2.250 inch round housing is replaced by a 2.000 inch square housing, the elimination of the mounting makes this effectively a much smaller device.

This spindle is similar to the basic spindle but omits the ability to mount a chuck on the spindle nose. Doing that allows a smaller spindle to be fabricated that can get into smaller, tighter spaces.

The major change in the design of this smaller spindle is the omission of the register that centres the chuck on the spindle nose. This allows us to reduce the outside diameter of the spindle from 2.250 inches down to 2.000 inches. The spindle can be made either with a round body that is 2.000 inches in diameter or housed within a square bar with a section 2.000 inches by 2.000 inches. Using the square bar makes it easier to mount the spindle to flat surfaces that have the Myford standard T slots cut in them. It is also easier to clamp a rectangular section in all kinds of strange setups that amateur engineers find themselves dealing with.

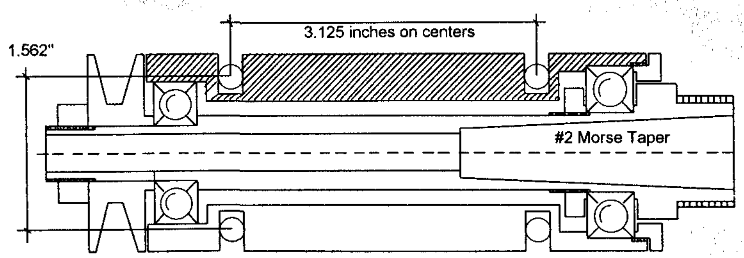


Figure 5.1 *A smaller No 2 Morse spindle housed in a 2 inch square bar housing.*

Note
Eliminating one front bearing allows us to use a smaller overhang at the front of the spindle. This is desirable for stability during heavy cuts.

The general construction of the spindle follows the construction of the cartridge spindle. The emphasis in these instructions is on the differences between the cartridge spindle and the small No 2 MT spindle.

About 2.000 inches in from the big end of a No 2 MT, the taper is less than ¾ inch in diameter and so can be made to fit in a 0.750 inch shaft. There is not a lot of material left but there is enough for our light duty spindle. That dimension is the basis for selecting the inside diameter of the main bearings to be ¾ inch. These bearings are smaller than the bearings that were used on the cartridge spindle and thus the outer dimension of the housing is reduced. More importantly, the mounting slots can now be milled right into the spindle housing.

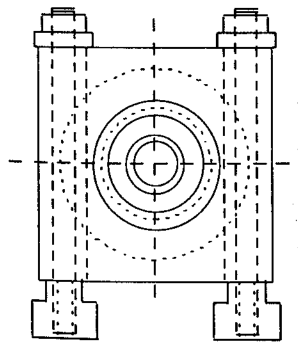


Figure 5.2 *Front view of spindle, 2 inches square.*

Eliminating the register for the chuck also eliminates the need for the flange that the chuck tightens up against. This too allows the spindle to be made smaller. However, we still have to provide a shoulder for the bearings to tighten up against and a smaller flange face to protect the bearing seals. The outside diameter of the bearings determines the outside dimension of the spindle. If you can find smaller cross section bearings, this outside dimension can be reduced further. I picked the "easiest to find" bearings. We will need about 0.125 inches of material past the outside of the bearings on all sides to allow for the threads for the bearing cap.

The spindle cannot be made any shorter because we still have to be able to span the table that we will mount the spindle to, on the vertical slide. One side has to clear the cutter and the work and the other side has to clear the driving pulley. That pretty much sets the length. However, there may be an advantage in making the spindle longer – it would be stiffer. You may want to consider this on your spindle. You will still have to design for slots that are 1⁹⁄₁₆ and 3⅛ inches on centre.

We will make the components of the spindle in the following order:

1. Buying the bearings.
2. Front bearing, inner race clamping nut.
3. The spindle itself (the part that spins).
4. Block style outer housing.
5. Drive pulley.
6. Front bearing cap.

7. Cutting the pulley grooves.
8. Cutting the notches in the bearing cap and bearing nut.
9. Cutting the keyway in the shaft and in the pulley.
10. Making the No 2 MT.
11. Final assembly.

1. Buying the bearings

As usual, before you do anything else, buy the bearings. In this case the inner diameter of the bearings is critical because the dimensions are so tight. In a way this is the squeezed version of the basic spindle in the previous chapters. Do not buy a bearing that has an ID of less than 0.750 inches or an OD over 1.850 inches. The bearings that we need are as follows.

Bearing dimensions

Front bearing	
Outside diameter	1.750 in (45mm)
Inside diameter	0.750 in (20mm)
Thickness	0.437 in (12mm)
Shield	Both sides
Type	Light duty or deep groove
Rear bearing	
Outside diameter	1.500 in (38mm)
Inside diameter	0.625 in (16mm)
Thickness	0.375 in (10mm)
Shield	Both sides
Type	Light duty or deep groove

2. Front bearing, inner race clamping nut

The first thing we need to make is the nut that clamps the inner race of the front bearing.

The nut is made from a slice of free machining steel 1.250 inches in diameter and 0.375 inches long. It can be made in the 3-jaw chuck. File the edges so that you can hold it squarely in the 3-jaw. Face and chamfer one face. Reverse in the chuck and face and chamfer the other face – this will be the true face that has to clamp up against the bearing. We will identify this face by the step that will be machined on to it. Drill a ½ inch hole in the disk and open this hole out to 0.700 inches in diameter.

Cut threads at 24 tpi in the bore. These are to fit on the threads on the spindle shaft which will be at 24 tpi on 0.740 inches. Once the full threads have been cut smooth down the inside crowns with some emery paper make another pass with the threading tool to clean up the threads again. Chamfer the first and last thread with the threading tool. Mark the true face with a line across a diameter. This can be done with a cutting tool set at dead centre. We will use this line to cut the two spanner notches later on when we have the vertical slide set up for all our slide work.

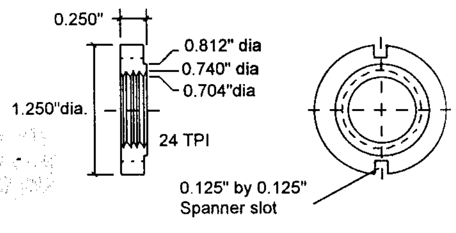


Figure 5.3 *Front bearing, inner race clamping nut.*

3. The spindle itself (the part that spins)

The spindle proper is made from a piece of free machining steel 1.500 inches in diameter and 6.500 inches long.

Unfortunately one end of this spindle cannot be held with a face plate, as was done with the first spindle, because this spindle does not have the full Myford nose on it. So all finished work has to be done with centres at both ends. However, you can hold the one end in the 4-jaw for a while. Do not use the 4-jaw again once you remove this first setting.

Hold the blank accurately in the 4-jaw. Be sure that both ends are running true – it is important that both centres be in line at both ends of the spindle. Face the part and drill a centre in it. This centre has to be large enough to allow a ⅜ inch hole to be drilled into the centre and still have some centre left. If you do not have a large enough centre, turn the centre. Drill a ¼ inch hole in the spindle as far as it will go, open this out to 0.375 inches in stages and make it 3.500 inches deep. This hole must meet the Morse taper and hole put in from the other side.

Turn the spindle around in the 4-jaw and repeat the operations just performed. When facing far away from the chuck it is necessary to use very light cuts and sharp tools. If an appropriate steady rest is available, it should be used.

We now have a 1.375 inch diameter shaft with a 0.375 inch hole in it with centres on both sides.

Remove the 4-jaw and thoroughly clean the taper in the spindle nose. Place a centre in the lathe nose. Mount the dog driving face plate on the spindle and get a suitable dog mounted to the spindle blank (if you do not have a large dog, you may have to fabricate one for this job). Place a ball bearing centre in the tailstock. We will do the rest of the work between centres.

Bring up the tailstock with a running centre in it to support the work. Turn 0.625 inches of the shaft down to 1.125 inches in diameter. Cut a groove ⅛ inch wide and $\frac{1}{10}$ inch deep 0.437 inches from the end as a clearance for the threading tool. Thread the rest of the turned section to 1.125 × 12 tpi. Match these threads to your collet closer. When cutting such

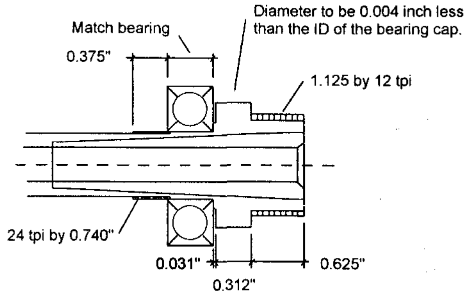


Figure 5.4 *Spindle nose dimensions – there is no allowance for mounting a chuck.*

large threads it is necessary that the threading tool be very sharp because the flank of the threads gets rather large. It is also possible to cut the threads in two sets of passes so that the flank remains half as wide. The thread is cut to half its depth, the tool is then moved over half a thread pitch and the other half of the thread is cut. Use your collet closer as a gauge for these threads. These threads will never mount a chuck so their fitting accurately to a chuck back plate is not relevant. Chamfer the threads with the threading tool. There is a section in Chapter 16 on cutting coarse threads with two sets of passes.

Turn the next 0.375 inches of the spindle down to a 1.375 inch diameter shoulder. Turn the shoulder into a 0.312 inch wide flange and chamfer both sides. Polish clean.

This completes work on this end of the spindle for now. Turn the spindle around between centres and remount the dog to the spindle, making sure that you protect the threads already cut with appropriate soft materials.

The front bearings have an inside diameter of 0.750 inch so we can turn the entire shaft down to 0.760 inches all the

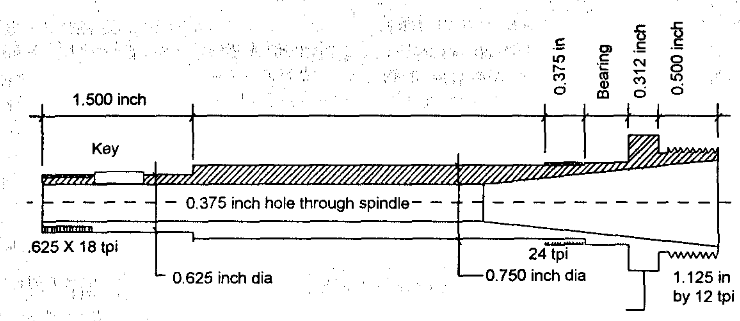


Figure 5.5 *Spindle dimensions.*

way to the shoulder behind the threaded nose. Leave about 0.030 inches on the shoulder for the final finish cuts.

The front bearing is 0.375 inches thick and we need a 0.250 inch space for the nut to hold the bearings so we can turn all but the 0.625 inches (0.375 + 0.250) next to the shoulder down to the root diameter of the bearing nut threads. At 24 tpi, the double depth of the threads is 0.070 inches. So we can turn the shaft down to 0.680 inches – this will form the shoulder for the back bearing. This bearing has an inside diameter of 0.625 inches. We will cut the shoulder for the smaller bearing later. Right now our interest is in fitting the front bearing and its clamping nut.

We can now fit the front bearing. Turn the bearing seat down to 0.750 inches to make a bearing a push-fit onto the shaft. Remember to use a cool shaft and a warm bearing when making the fit. You can get a better fit it you take the time to do this. This is critical on large parts but even on relatively small parts like these there is a noticeable difference.

Before we cut the threads, we need to have the nut they will fit to at hand. That was the reason that the nut was made first.

The threads are to be cut at 24 tpi. As always, go slowly until you get the nut started on the threads. On fine threads, a couple of thousandths or so can make a big difference – we want a snug fit on the threads. We need a minimum of about three threads or ⅛ inch of threads to engage. Cut a recess at this point to accommodate the threading tool – this will also form the clearance for the nut. The left edge of this recess is to be just past the bearing seat. It should be barely wide enough to accommodate the

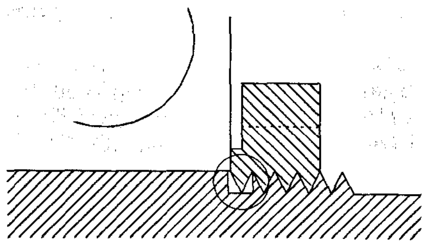


Figure 5.6 *Detail at the nut that clamps the inner race of the front bearing. Note how the clearance for the threading tool extends to just under the bearing and how the crowns of the threads are just a bit smaller than the bearing ID.*

threading tool, about one and half threads or 0.060 inches wide and 0.035 inches deep.

When you cut the threads, their crowns will deform slightly and become higher than the 0.750 inch diameter of the bearing seats. The crowns have to be filed down lightly to bring them back down to just under 0.750 inches in diameter. Adjust the threads to match the threads on the nut that you made.

The shoulder to clamp the back bearing is 4.250 inches from the shoulder for the front bearings. Check the drawings and check again against your work. Measuring from the front of the front bearing to the front of the back bearing. The shaft should be machined down to 0.625 inches in diameter past this point with a straight shoulder for the back bearing. This should be a push-fit for the back bearing and for the drive pulley which will have a 0.625 inch reamed hole in it.

Cut ⅝–18 (see Appendix 2 for UK equivalent) threads on the spindle shaft past the seating for the bearing. Match these threads to the nut purchased to clamp the pulley and the back bearing.

This completes the outside of the spindle except for the keyway. We still also need to machine the No 2 MT in the spindle. We will do that in situ after the spindle has been assembled to ensure that the Morse taper and the spindle axis are completely co-linear.

4. Block style outer housing

I will not describe the machining of a round housing because, for other than its dimensions, it is identical to the machining of the basic spindle housing.

It is easier to make the round housing than it is to make the block style housing, but then you do also have to make a set of clam shell holders for the round housing. The block style housing described

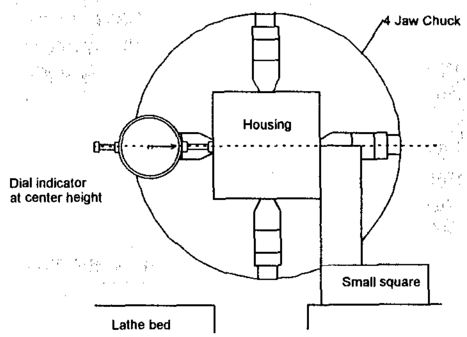


Figure 5.7 *Setting up the block for machining.*

next in great detail is the preferred housing for this spindle.

Taking the time to make the block style body for this spindle will give you an easier to mount spindle. This applies to all kinds of mountings whether they be to a table, to a slide, to a tool post or some lash up you have to use for a special project.

The raw material for the body is a piece of free machining steel 2.000 inches by 2.000 inches × 5.250 inches long. These are the finished dimensions.

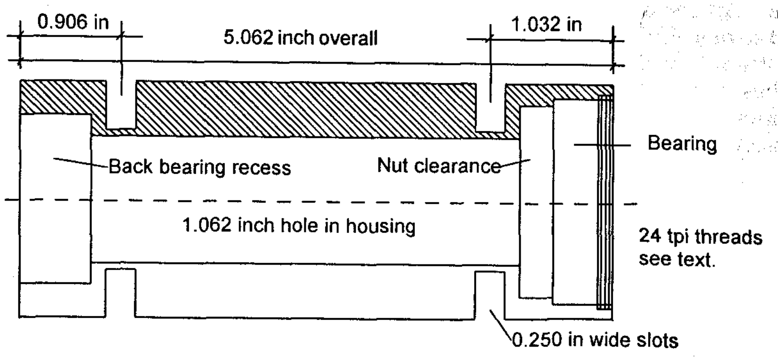
Do not finish face the two ends of the block yet. We do not want to do this in a mill either – we want to use this operation to confirm that the block is mounted accurately in the chuck. First mount the piece in the 4-jaw as accurately as you can. Use a dial indicator to make sure that opposing faces are equidistant from the centre of rotation and use a machinist's square laid on the lathe shears to make sure that each face is perfectly vertical when you take your measurements.

Once you are satisfied with the setup, take a very small cut across the face of the part until you get to a diameter of 2.000 inches. If this is centred perfectly on the face of the block, you have it right and can go ahead and face the centre of the part and put in a centre. (Face the centre only, to avoid making an intermittent cut that might move the part in the jaws. Once the centre is in place, you can make the intermittent cut.) If not, adjust the part and take another light cut to see if the centre is right. You have to be in the centre from all four sides. There is 1/16 inch or so of extra length on each side to play with. Keep in mind that the finished block is to be 5.062 inches long.

Once you have the centre drilled in the body, put in a ball bearing centre in the tailstock, to support the far end and face the part. Again, you need to use the centre support because you will be taking intermittent cuts and these have a hammering action that tends to move the part in the chuck. *The solution is not to overtighten the chuck (and thus ruin the chuck for future work) but to use a centre and do it right.*

Turn down 3/8 inch of the block to 2.000 inches in diameter. Chamfer the corners of the block. We will need this 3/8 inch as a surface for the fixed steady during later work. It is also a reference that we can centre on if we ever need to mount the body accurately in a 4-jaw again. Some workers claim that a rotating centre is not quite as precise as is a fixed type, but for our purposes, provided the rotating centre is of good quality, it is more than adequate. To some extent this type is better able to take up forces engendered by expansion of the work as it heats up than are fixed centres.

Remove the centre and drill a 1/2 inch hole at least halfway or as far into the block as your equipment will allow you to go. Bore this out to 1.000 inch diameter halfway into the part. Next, using the rear bearing as a guide, bore a recess that is a tight push-fit on the bearing. This recess should be 5/8 inch deep or about 1/4 inch deeper that the bearing is thick. The spindle is designed to allow the bearing to move in this recess (there will not be much movement) but the fit should be a very firm push-fit. If you overbore this side, all is not lost, you can open it up for the larger bearing at the front of the spindle housing.



This housing is to be made of 2.0 inch by 2.0 inch bar stock.

Figure 5.8 *Details of housing.*

Lightly chamfer all edges and go over all surfaces with some 400 grit emery paper.

Turn the block around end for end and do the other side just as you did the first side, keeping in mind the changes in the dimensions. The finished length of the body should be 5.062 inches. We need the unturned portion of the block to be at least 3-5/8 inches long to allow hold down bolt slots that are 3 1/8 inches on centre to be cut into the block. These slots must not interfere with the locations of the bearings – study the drawings to get the design firmly in mind.

Drill a 1/2 inch hole to meet the hole from the other side. Bore this out to 1.000 inch diameter halfway into the part to meet the hole from the other side. There are three distinct recesses that have to be made on the front end of the housing: (1) The recess for the bearing cap, (2) the recess for the bearings themselves and (3) the recess for the nut that holds the bearings.

First rough bore the front of the housing for these three recesses, then finish the recesses in the order described below.

(a) Threads

The diameter of the bore for the cap threads should be 0.005 inches larger than the outer race of the bearings and 0.187 inches deep. Cut a threading tool clearance recess at the inner end of the 0.187 inch bore and thread the outer part of this bore to 24 tpi. We will cut the cap threads to fit this thread so the finished diameter of the threads is not critical. The thread form is critical and should be made as close to perfect as possible. We cut this recess and the threads first so that the seatings of the bearings will not be disturbed once they have been cut.

(b) Recess for nut

Bore out the recess for the clamp for the bearing inner races. This is a clearance recess and does not have critical dimensions. The aim is to clear the nut by about 0.050 inches or so on all sides.

(c) Bearing recess

When using the bearings as a guide in the next step, make sure that you do not get them stuck in the recess because you have a lot of machining to do after cutting the bearing seats. It is best if the bearings are not in the housing when you do this so that they do not get contaminated with swarf. Be sure to use the spindle as a holder and guide for the bearings when you are test fitting them. Use the tailstock to keep the axes aligned.

Using the front bearings as a guide, bore a recess that is a tight push-fit on the bearings. This recess should be 1/8 inch deeper than the bearing is thick. The bearing outer races will be clamped in this recess. If you overbore this side, you will have to start again, so be very careful.

Lightly chamfer all edges and go over all surfaces lightly with some 400 grit emery paper.

This completes the lathe work on the housing.

Remove the housing from the 4-jaw and prepare to take it to the milling machine. First mark the locations of the 4 slots that you are about to mill. Then check them against the surfaces on which you are going to mount the spindle. Only then, cut the 4 slots for the mounting bolts. The slots are to be 1/4 + inch wide by 0.406 inch deep and 3 1/8 inches apart on their centres.

Go over the entire housing with a smooth file and emery paper and clean it up. Use the file to chamfer all edges.

This completes the outer housing.

As stated before, the machining of the round housing is similar except that no mounting slots will be needed. Please refer to the detailed descriptions in Chapter 3 on the basic spindle for details.

5. Drive pulley

A pulley 2.000 inches in diameter is shown in the drawings. The pulley should be made to suit the uses intended by the user for his spindle. Since the spindle is capable of heavy work, a larger pulley arrangement may be in order for some users.

6. Front bearing cap

The bearing cap is made out of a slice of free machining steel 2.000 inches in diameter and 0.375 inches thick. This is more than we need but we will machine the excess away after it is removed from the lathe. The threads are cut to match the housing threads and are at 24 tpi.

Mount the part in the 3-jaw and face it. Turn 3/16 inch of the part to 1.850 inches in diameter (0.100 in diameter more than the OD of the bearing). This will provide enough material to cut the threads needed. Provide a threading clearance after the ⅛ inch for the threads. Make this 0.062 inches wide and 0.035 inches deep.

Drill a ½ inch hole through the part and bore this out to 1.127 inches. Check this against the spindle nose – this hole should be 0.002 inches larger than the spindle at the bearing shoulder. It should just barely clear the spindle so that the two do not touch when the spindle is running. Any space we allow is a door for dirt so keep it as small as possible. *Do not* chamfer the edges on this hole. Polish the surfaces but keep the edges sharp.

Cut 24 tpi threads on the section just machined. When cutting relatively fine threads, there is a problem with the threads suddenly becoming loose. Fine threads are ready when they go on but they are still relatively tight. By the time you smooth the crowns and clean them up, the fit will be perfect. That is what we want.

Test the cap on the housing with the bearing in place. The bearing must be mounted on the spindle with the back bearing in place to make sure that it is in

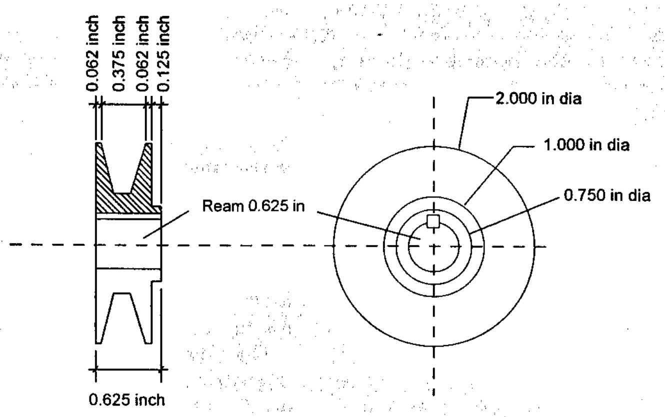


Figure 5.9 *Driving pulley.*

the housing straight *and to make sure that you can get it back out again.*

When the bearings are clamped tight, there should be about 0.030 inches between the cap and the housing. If there is too much, machine the front on the cap where it touches the outer race of the bearing. If there is not enough turn back the shoulder until you get it the way you want it. Chamfer all edges and polish.

Now hold the housing in the 4 jaw and get it running exactly true. Turn the face of the cap down until you have ⅛ inch exposure at the outer edge. Chamfer and polish.

We will cut the notches for the spanner later when we have the vertical slide set up.

7. Cutting the pulley groove

The pulley groove is to be cut with the pulley mounted to the spindle and the work will be done between centres. It is helpful to have the belt that you are going to use in hand when doing this work. The design calls for belts that are 3/8 inches wide as the wide end of the "V". If such belts are not available to you, you might want to consider changing the dimensions so that they fit the belt that you intend to use.

Mount the back bearing and the back pulley to the spindle and tighten with the pulley nut – this should be done only after the keyway has been cut in the shaft. We need to use the key to make sure that the pulley does not slip on and score the shaft when we start the machining process.

Set up the lathe to turn between centres. Be sure to protect the spindle from the dog when you clamp the dog to the spindle. (If using a stepped pulley the spindle should be assembled with the large pulley next to the bearing.) The forces are higher when using a large pulley so this should be taken into consideration.

First machine the finished outline of the pulley and then machine the pulley groove. The included angle of the groove should be 40 degrees and the width of the groove should be such that the top of the belts sits even with the pulley flange.

First rough machine the grooves with a tool with an approximately 40-degree included angle. Then set the compound over to give a 20-degree cut and cut one side on one groove. Then cut the other side with a −20 degree cut. Widen the groove slowly until the belt seating is right. Only then go to the next groove – if you try to do all the grooves at once, you are more likely to make a mistake.

Once the groove is right, chamfer all edges and polish the entire pulley with 400 grit emery paper.

8. Cutting the notches in the bearing cap and bearing nut

Set up the vertical slide with an angle plate on it and cut the two spanner slots on the bearing nut you made. The notches should be ⅛ inch wide and ⅛ inch deep. Make the cuts by moving the vertical slide up and down. File off the burrs.

Using the same setup, cut the six slots in the bearing cap. These slots too should be ⅛ inch wide and ⅛ inch deep.

9. Cutting the keyway in the shaft and in the pulley

Detailed instructions for cutting the keyway in the shaft and in the pulleys are given in the Chapter 3 on the basic spindle.

10. Making the No 2 MT

Next drill a ½ inch hole 3.500 inches deep to clear a No 2 MT. You do not need to drill all the way through – all you need is the space for the taper.

Rough bore this out to accommodate a No 2 MT and ream it for the right depth for a No 2 MT collet. Detailed instructions for doing this are provided in Chapter 3.

11. Final assembly

Clean and lightly oil all the parts. Slip the front bearing onto the spindle and tighten the clamping nut onto the spindle.

Put the back bearing in the housing. Put the spindle through to the front and the back bearing from the front and put the pulley on the spindle. Place the nut on the shaft to hold everything together.

Put the front bearing cap on the front threads and tighten down. Tighten the back nut on the spindle.

The spindle is ready for use.

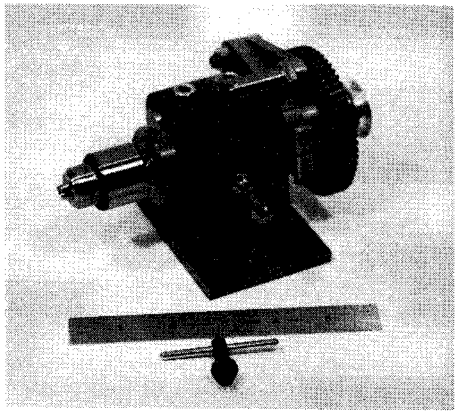
CHAPTER 6

The micro spindle

This spindle represents the smallest spindle that can do useful work in the amateur's shop. The limiting factor is the 0.250 inch portion of spindle shaft in the bearings. Any shaft smaller than that would tend to be a bit too flimsy for our purposes.

The most intriguing part of this spindle is that it fits in a George Thomas dividing head to provide instant location at exact the lathe centre height. This is a quickie project – I built one in about two and a half hours.

Unfortunately, it is just about impossible to mount the Dremel Moto Tool (DMT), and other tools like it, on a lathe tool post with any rigidity and repeatability. Added to this is the problem of a rather large amount of axial play in the spindles of these high-speed motorised tools that



Three-quarter inch spindle mounted in Thomas dividing head. This is the easiest way to get a small spindle mounted at exact lathe centre height.

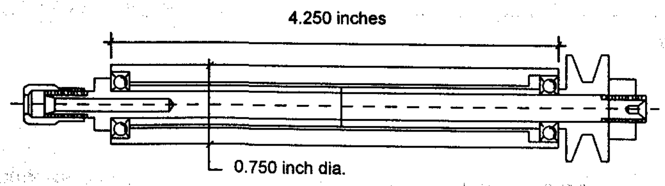


Figure 6.1 *Section across the micro spindle.*

makes their use problematic. The micro spindle will mount everything that the Dremel Moto Tool will hold and you can use it on the tool post of your lathe without difficulty. It can also be mounted to the Dickson type tool holders with their quick change capability.

This is a small spindle, only 0.750 inches in diameter with a main body length of 4.250 inches. It uses the DMT collets and collet closers and so can be used with all the accessories available for these tools. It is designed to be used at high speeds just like one would use the DMT although it would be hard to spin it at 30,000 rpm.

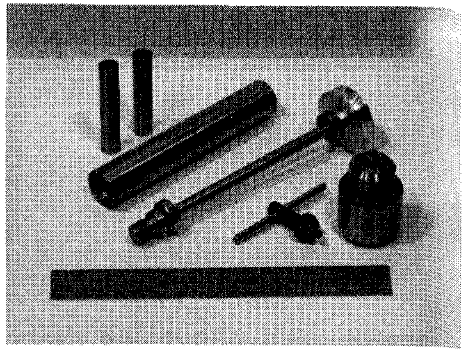
The spindle is similar to the other spindles with the caveat that the smaller design requires the use of more "watch making" like techniques and is thus more unforgiving of even small mistakes. The smaller components used allow the use of the Myford lathe collets for holding the parts. However, the most demanding aspect of construction is the cutting of the recesses to hold the outer races of the bearings. Free machining materials are recommended and brass may be considered for the housing. It could also be used for other components except for the spindle itself.

Bearings

As usual we start with the bearings. The bearings I used were as follows:

Inside diameter	0.250 in (6.35mm)
Outside diameter	0.625 in (15.88mm)
Thickness	0.187 in (4.75mm)
Seals	Both sides
Shields	None
Number needed	2

These are very common, easy to find bearings and they are quite inexpensive.



All the components of the ¾ inch spindle. This and the other smaller spindle use adhesives to hold the outer races of the bearings in place in the housings.

The sequence for making the parts of this spindle is as follows:

1. Housing.
2. The spindle.
3. Spacers.
4. Pulley.
5. Making the spindle nose.
6. Final assembly.

1. Housing

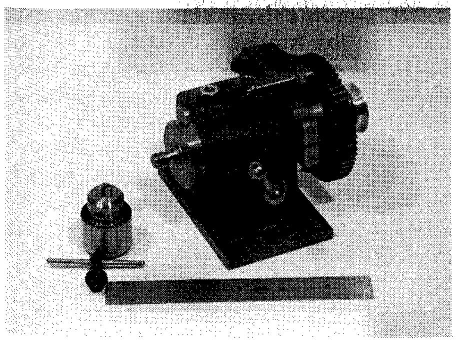
The housing is made from a piece of 0.750 inch free machining stock 4.375 inches long (finished to 4.250 inches).

There are two types of free machining materials that you should know about if you want to enjoy making a lot of small steel parts. One is the Leadloy type of material that has lead added to the iron to make it more machinable. The other is the top of the line free machining iron bar that has tellurium added to it to further enhance machinability. If you can get a piece of one of these you will indeed be in clover. (*Note*: tellurium is toxic and will give you a bad case of immediate garlic breath if you ingest it. Do not weld or silver solder.)

Incidentally, free machining materials do not weld well. In layman's terms that which makes it easier to machine makes it harder to weld. The name for this phenomena is "lead shortness" which means that the melting point and strength performance of the material is shortened or reduced. This interferes with weldability by interfering with proper puddling of the weld.

The housing is not identical at both ends – the back end has a 0.030 inch deeper recess in it.

Hold the material in the 4-jaw and centre it accurately. The centring should concentrate on the outer end of the bar. Face the bar and centre drill it. Drill a 0.437 inch hole a little over halfway through the bar. Bore a bearing recess 0.190 inches deep (to match your bearings) and 0.625 inches in diameter in the bar. Check this with the bearing held on a ¼ inch screw held in the tailstock. Using this technique allows you to have a handle on the bearing and it allows you to guide the bearing straight into the bored hole. The recess should be a easy fit on



The ¾ inch spindle mounted in Thomas dividing head with chuck removed to show spindle housing flush with dividing head face.

the bearing with 0.001 or 0.002 inches or so clear all the way around. Use Loctite anaerobic glue to hold the bearing's outer race.

Chamfer all edges. Polish up your work.

Turn the work around in the 4-jaw chuck and turn the housing down to size. The finished dimension is 4.250 inches.

Re-centre your work and machine the recess in the other side just like you did on the first side. On this side the recess should be 0.030 inches deeper than the bearing thickness to allow some adjustment allowance for the bearing spacers.

Chamfer all edges. Polish up your work.

This completes the housing.

2. The spindle

The spindle is the most critical part of the project. We will make the spindle out of a piece of free machining 0.500 inch steel rod 5.75 inches long. (Since I was obliged to build a number of spindles and did not want too many with Dremel Moto noses on them, I built my micro spindle with a threaded Jacobs 1B chuck on it. However, I think the Dremel Moto nose is more appropriate if you have small cutters and high speeds in mind, if not you really need to build a bigger spindle!)

You need to have a Dremel Moto collet closer, a ⅛ inch collet and a ⅛ inch shaft in hand before you proceed with the next phase of the work.

Set up to work in collets. Start by putting the spindle blank in the 0.500 inch collet and centring both ends, then with 1.000 inches sticking out, face and turn 0.750 inches of the shaft down to 0.375 inches in diameter so that you can hold it in a smaller collet against the shoulder just created. This area will be turned down later to form the spindle nose. We cannot do this right now

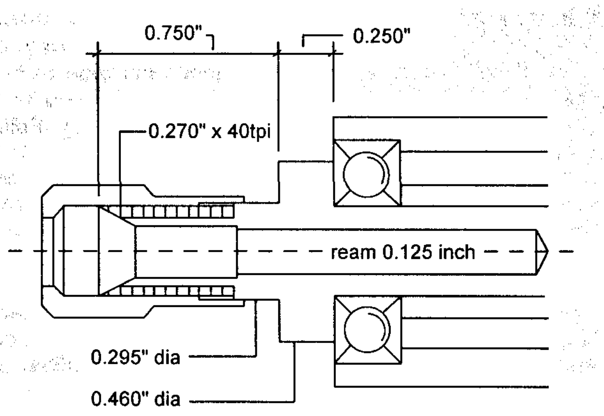


Figure 6.2 *Spindle nose details (see Chapter 16 for detailed Dremel collett dimensions).*

because we need to hold this end in the collet. Chamfer all edges for now to make it easier to put this turned part into a collet.

All the rest of work on the spindle will be done between collets and the tailstock centre to ensure that all surfaces are completely co-linear with the axis of rotation.

Mount in a 0.375 inch collet and leave 0.250 inches for finishing the flange. The rest of the spindle can be tuned down to 0.250 inches in diameter. First turn the remainder down to 0.450 inches with a sharp tool in one pass. Make a note of the cross slide setting that gave you this diameter – this is for making an accurate assessment of how parallel the lathe is cutting. Polish this and then measure both ends. It is important that both ends be the same diameter to ensure that the lathe is cutting parallel. If it is not we have to adjust the tailstock to make it cut parallel. There is a discussion on lathe adjustments in Chapter 16 – read that and adjust the tailstock if needed. Get it as good as you can. If you cannot get it exact, it should cut so that the headstock side of the work is bigger.

Keep turning down until you have reduced the spindle to 0.270 inches in diameter. A slender shaft means you have to take small cuts and use a sharp tool. Measure again to see how your lathe is doing. These measurements tell you where the thick parts are so that you can respond accordingly.

Next reduce the 0.270 dimension to 0.250 inches in two equal passes. Note how far you moved the tool in the first pass and note how much was cut from the shaft. Use this knowledge to make an adjustment on the second pass to end up at 0.2505 inches. Remove the last half thousandth by using a file and polishing with 400 and 600 grit emery paper. The bearings should be a firm sliding fit on the shaft from one end to the other. It is permissible to thin the centre down by a bit to make the slide easier.

Once you get the bearing started on the spindle on the right-hand side, you can use a file and the emery papers to work down the spindle ahead of the bearing as the bearing is moved farther and farther to the left.

Die cut the threads at ¼–28 (see Appendix 2 for UK equivalent) tpi for the pulley nut.

Finish the flange that forms the protection for the bearing seals. The flange is to have a finished dimension of 0.250 inches (width).

3. Spacers

We drilled a 0.437 inch hole in the housing. The spacers we make have to fit within this so we will make them 0.375 inches in diameter with a 0.250 inch reamed hole through them. The spacers are best made as two spacers – that will reduce the depth of the holes to be drilled and reamed. The overall length of the spacer has to be 4.250 inches minus the thickness of two bearings. If the bearings are 0.190 inches thick, the spacers have to total a theoretical length of 3.870 inches. That is the theoretical distance for a perfect fit but we want them to be a bit longer than that to start with. Check this with your setup. After the spacers are in place the spindle should move back and forth in the housing about 0.030 inches and both bearings should be flush with the housing face when the spindle is pushed back from the front.

Start with two pieces of 2.0 inch long and 0.375 inch diameter pieces. Hold them in the 0.375 inch collet and drill a $^{15}/_{64}$ hole through each one, half from each side. Ream this out to 0.250 inches. Accurately face all four ends to be square and clean and very lightly chamfer each end using 400 or 600 grit emery paper. We will machine one end down when we make the final adjustments. The spindle should fit in these spacers as an easy fit.

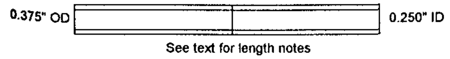


Figure 6.3 *Spacer dimensions.*

Remember that one of the bearing recesses in the housing is 0.030 inches deeper than it needs to be. Assemble the spindle, bearings, pulley and spacers outside the housing and adjust the unfinished spacer until the housing ends and the bearing ends are the same distance apart. The 0.030 inch allowance will give the extra space needed to ensure that it all works without binding.

4. Pulley

The pulley dimension may have to be adjusted to match the drive belt you have in mind.

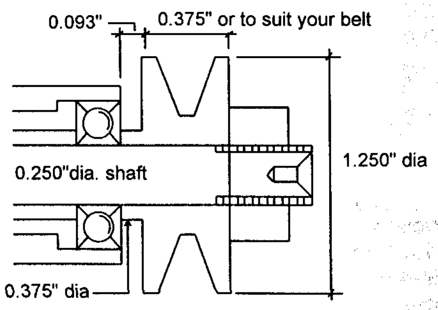


Figure 6.4 *Pulley dimensions.*

The pulley is turned from a piece of free machining aluminum 1.250 inches in diameter and 0.625 inches long. Hold in the 3-jaw and face. Turn a 0.375 inch diameter boss 0.093 inches long on the pulley. Drill and ream a 0.250 inch hole through the pulley. Chamfer all edges. Turn around in the chuck and face other side for a finished length of 0.468 inches or to suit your belt. Chamfer all edges. The groove to match your belt will be cut later.

5. Making the spindle nose

Get out your Dremel Moto collet closer and go over it with a pair of calipers i.e. get to know its dimensions. You will be building to your closer's dimensions with my notes as a guide only.

We still have the front end of the spindle to finish. Put a 0.250 inch collet in the lathe to hold the spindle in the collet with the nose sticking out. Turn the nose down to 0.290 inches in diameter to match the un-threaded part of the collet closer. Turn the flange down to 0.250 inches thick if this has not already been done. The outside diameter of the flange is not critical and is specified as 0.460 inches to clean up the 0.500 inch rod. Chamfer edges.

Put a centre on the nose and drill a 0.109 inch hole (7/64), 1.000 inch deep in the nose. Ream this out to 0.125 inches. Drill 0.172 inches (11/64) in diameter for 0.600 inches deep for the collet shaft. Clean up the centre again with the centre drill.

Cut 40 tpi at 0.270 inches on the nose for 0.375 inches. Make the threads a good fit for the collet closer. The threads may have to be slightly smaller as may be needed for your particular closer. After the threads are cut, make sure that the end of the nose has a slight flat on it for the jaws of the 3-jaw chuck that Dremel provides.

Mount an arbor and wheel on the finished nose and satisfy yourself of accurate operation.

6. Final assembly

Clean and polish all components. Do a dry run assembly to make sure that everything will work on final assembly.

Loctite the bearing in the shallower of the two recesses in housing. Make sure you do not get adhesive anywhere it does not belong. Wipe and clean up any spills. Let it set.

Push the spindle through the first bearing. Slip the two spacers on from the other side and prepare the second recess for the other bearing. Put some Loctite in the recess and spread around carefully. Slip the second bearing in place and follow up with the pulley and nut. Tighten down immediately, before the adhesive can start to set.

Check for free operation. Allow the adhesive to set for 12 hours.

Holding the nose flange in a collet and supporting the pulley end in the tailstock, cut the pulley groove to match the belt that you intend to use with this spindle. Clean up and polish your work.

This completes the spindle.

Note that this is a throwaway spindle. You cannot take it apart and fix anything once the adhesives have set. That is the price we paid for ease of construction.

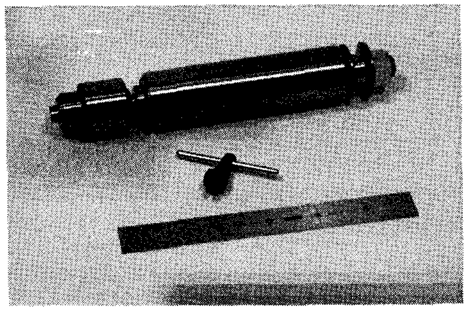
CHAPTER 7

1.000 inch diameter spindle (25mm)

Introduction

The spindle described in this chapter is very similar to the 0.750 inch diameter micro spindle in Chapter 6 except for dimensions. Please refer to the detailed building instructions in that chapter. Only those items needing special attention on this spindle are discussed in this chapter.

This spindle will be of interest to those who thought the 0.750 inch diameter spindle was a bit too small – this is a larger version of that spindle. The inner spindle diameter has been increased from 0.250 inches to 0.375 inches making this spindle considerably stiffer.



The 1 inch diameter spindle; a larger, more substantial version of the spindle described in the previous chapter. Construction methods are identical.

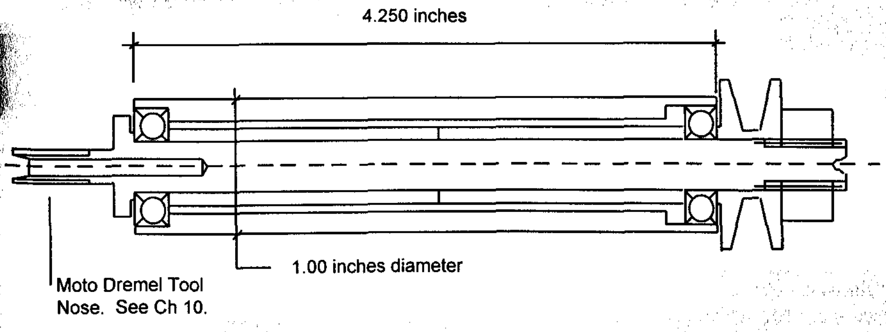


Figure 7.1 *1 inch diameter spindle with Dremel Moto Tool nose.*

Even a spindle 1.000 inch in diameter is too small to try to make devices to clamp the outer races of the bearings – at these sizes I thought it best to use adhesive techniques. Once we get to 1.500 inches in diameter, other techniques can be used more easily and the time investment required starts to pay off.

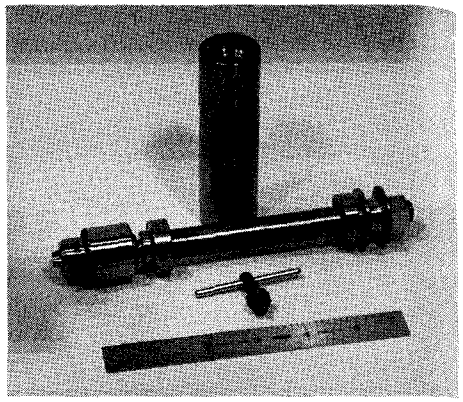
Bearing selections

Quantity	2
Outside dia. bearing	0.875 in (22mm)
Inside dia. bearing	0.375 in (10mm)
Bearing thickness	0.312 in (8mm)
Seals	2 Both sides need to be sealed

List of raw materials

Description	Diameter	Length
Outer housing	1 inch (25mm)	4.375 inch (115mm)
Spindle	0.750 inch (20mm)	7.000 inch (180mm)
Spacers	0.5 inch (14mm)	5.000 inch (125mm)
Pulley	1.25 inch (32mm)	0.500 inch (15mm)
Pulley nut*	3/8–24 tpi, 10×1, purchased	

*See Appendix 2 for UK equivalent



The internal components of the 1 inch diameter spindle. The smaller spindles use spacers between the bearings.

Special considerations

Please follow the instructions for the 0.750 inch diameter micro spindle for making this spindle.

Anaerobic adhesives need about 0.001 to 0.002 inches for the adhesive between mating parts. The outer races of the bearings are held with adhesive. This allowance should be allowed for these fits.

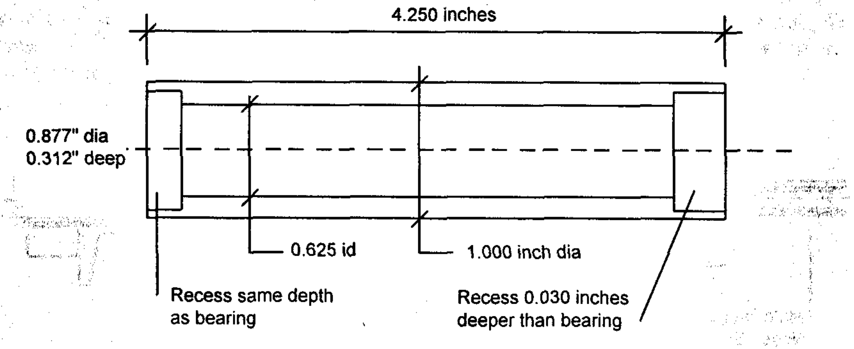


Figure 7.2 *Spindle housing dimensions.*

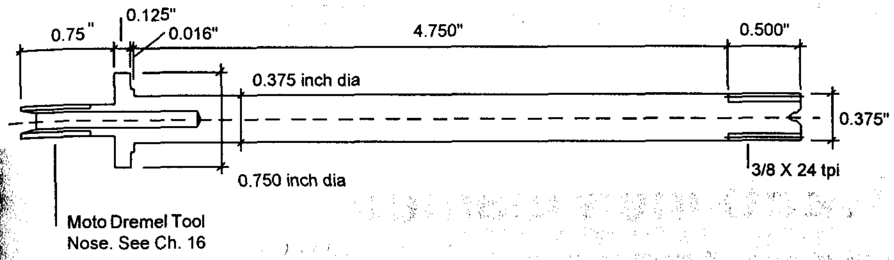


Figure 7.3 *Spindle dimensions.*

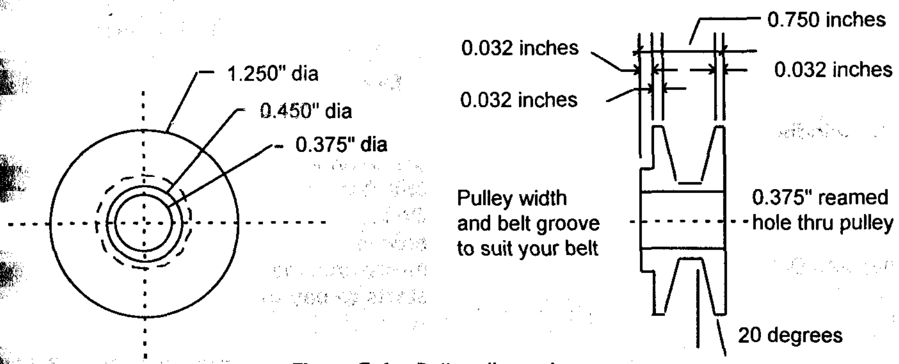


Figure 7.4 *Pulley dimensions.*

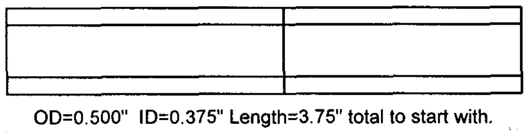


Figure 7.5 *Spacer dimensions (see discussion in Chapter 6).*

Drawings

These small spindles are very easy to make, have very few parts in them and go together quickly. They are essentially throwaway spindles that use anaerobic adhesives to hold the outer races of the bearings. They will not be easy to take apart to replace the bearings.

Do not scale the drawings – use either the given dimensions or calculate a value from given dimensions. Non-critical dimensions can be made to suit your needs.

CHAPTER 8

1.250 inch diameter spindle (32mm)

Introduction

The spindle described in this chapter is again very similar to the 0.750 inch diameter micro spindle in Chapter 6 except for the diameter dimensions. Please refer to the detailed building instructions in that chapter. Only those items needing special attention on this spindle are discussed in this chapter.

This spindle will be of interest to those who thought that even the 1.000 inch diameter spindle was too small. This is a larger version of that spindle. The main spindle diameter has now been increased from 0.250 inches to 0.500 inches. This makes this spindle stiff enough for more serious work.

Even a spindle 1.250 inches in diameter is almost too small to try to make arrangements to clamp the outer races of the bearings. At these sizes I thought it still best to use adhesive techniques. Once we get to 1.500 inches in diameter, other techniques can be used more easily and the time investment required starts to pay off.

Bearing selections

Quantity	2
Outside dia. bearing	1.125 in (28mm)
Inside dia. bearing	0.500 in (14mm)
Thickness	0.375 in (10mm)
Seals	2 (both sides need to be sealed)

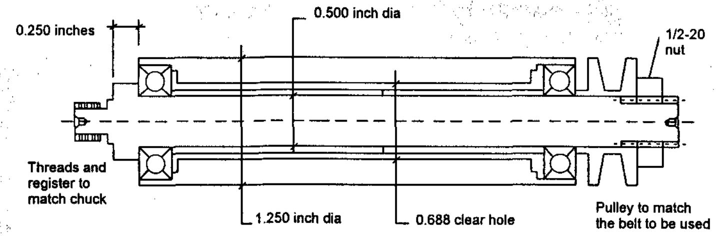


Figure 8.1 *1.25 inch diameter spindle with Jacobs 1B chuck threads (it can also be made with the Dremel Moto Tool nose on it).*

List of raw materials

Description	Diameter	Length
Outer housing	1.250 inch (32mm)	4.375 inch (112mm)
Spindle	0.750 inch (20mm)	7.000 inch (180mm)
Spacers (16mm)	0.625 inch (105mm)	4.000 inch
Pulley	1.250 inch (32mm)	1.000 inch (25mm)
Pulley nut*	½–20 tpi, 12×1.25, purchased	

*See Appendix 2 for UK equivalent

Special considerations

Please follow the instructions for the 0.750 inch diameter micro spindle for making this spindle.

Anaerobic adhesives need about 0.001 to 0.002 inches for the adhesive between mating parts. The outer races of the bearings are held with adhesive. This allowance should be allowed on these fits.

This is a substantial spindle and is shown with a spindle that will accept the Jacobs 1B chuck – this chuck will hold a 0.250 inch tool. A larger chuck and a larger driving pulley could have been accommodated. The spindle could be made longer and modified to accept 4.000 inch grinding wheels on a half inch arbor. See drawings for the 1.500 inch diameter spindles to see how this may be done.

In my opinion this is the smallest "substantial" spindle. However, it still uses adhesives to hold the bearings in place and I felt that a serious spindle should not be designed to use adhesives so that it can be rebuilt over the years.

Drawings

Do not scale the drawings – use either the given dimensions or calculate a value from given dimensions. Non-critical dimensions can be made to suit your needs.

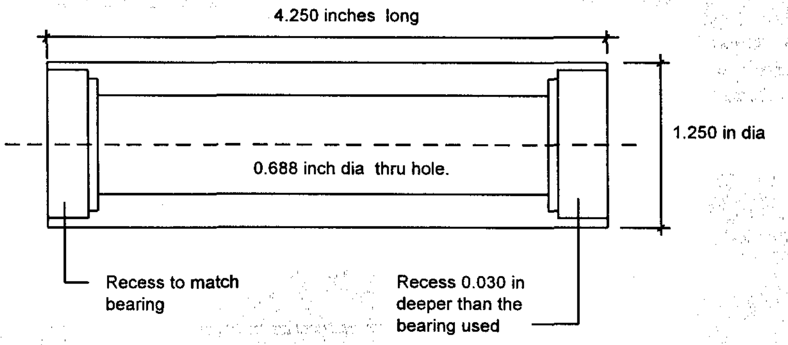


Figure 8.2 *Spindle housing dimensions.*

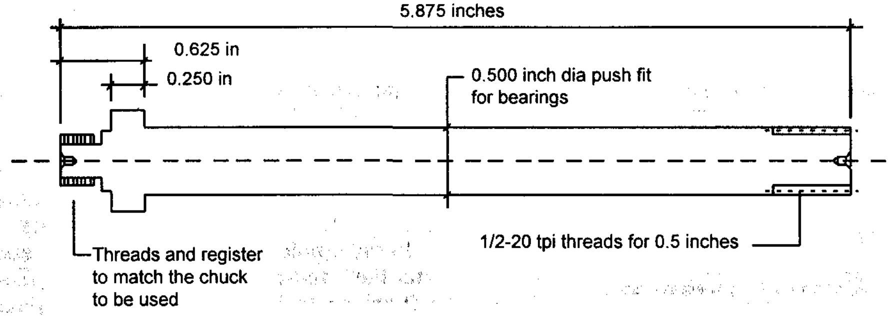


Figure 8.3 *Spindle dimensions.*

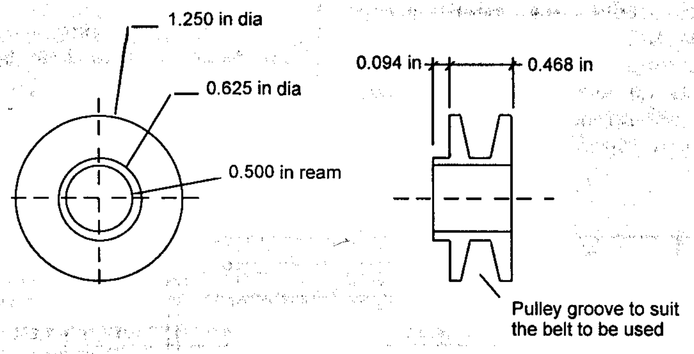


Figure 8.4 *Pulley dimensions.*

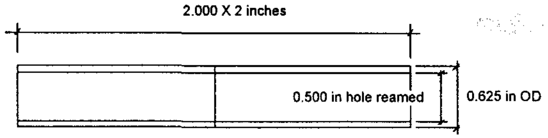


Figure 8.5 *Spacer dimensions.*

CHAPTER 9

Light, tool-post, OD grinding spindle

We now shift to making two high-speed grinding spindles.

My interest in clock making created a need for a whole host of new tools. Among these are a number of spindles that are needed specifically for this specialised work.

Two spindles designed by me will be described: one for external grinding (this chapter) and one for internal grinding (Chapter 10). The spindles themselves are of similar design but the method of holding the grinding wheels and the sizes of the wheels are different enough to make it worthwhile describing the two units separately.

Tool-post grinder spindles have to run at relatively high speeds for a sustained time and cannot usually have conventional seals at the bearings. Friction at the seals may create more heat than can be dissipated during operation to be generated which, in turn, creates special problems for the amateur engineer. In industrial applications this is handled by using labyrinth seals and (even pressurised) mist coolant systems. We could use a simplified non-contact sealing

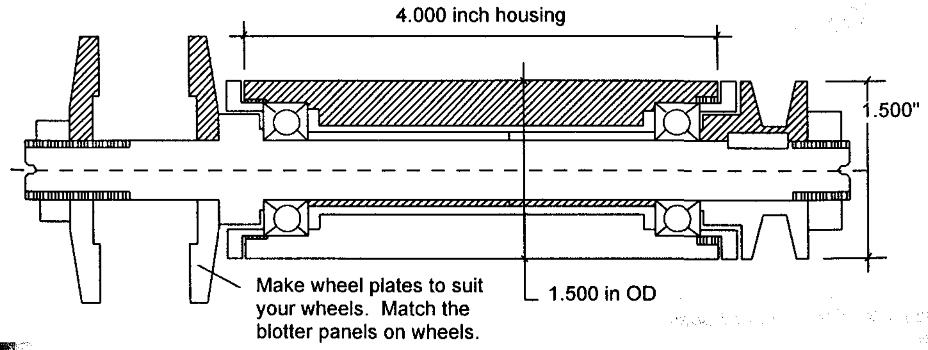
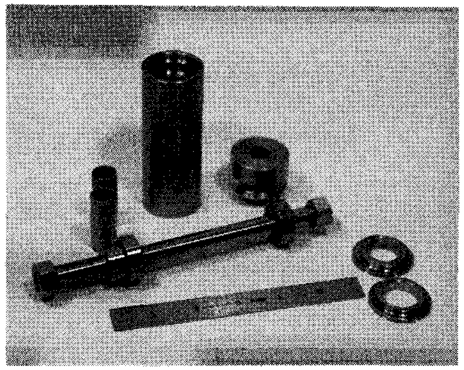


Figure 9.1 *The external grinding spindle for approximately 4 inch diameter wheels.*

arrangement but mist coolants are out of the question. Not having seals really causes too many problems to think about (immediate bearing failure for one) so we will opt for sealed bearings and accept the fact that we cannot have *long* grinding sessions with this spindle.

The spindle described by Professor Chaddock for the Quorn tool grinder is an excellent spindle for our applications with one exception – it uses spring loaded bearings that are essentially (as far as we are concerned, and for our applications) loose in one direction. If we could guarantee that we will never grind in this one direction (as he could with the Quorn) we could use his spindle but that we cannot do.

The modifications I have made overcome the above problem as simply as possible i.e. this was the simplest scheme that I could come up with. The scheme is not ideal but the design does allow the bearings to be replaced with ease in the future if undue wear should occur. I estimated the useful life of a grinding spindle used by an amateur engineer to be about 240 uses (twice a month for 10 years) of about 10 minutes each, or 2400 minutes (about 40 hours). With a little care this spindle should do that.



All the components of the external grinding spindle. The exterior housing for this spindle is identical to the housing of the internal grinding spindle described in the next chapter.

The spindle is designed to use a 4.000 inch or smaller diameter wheel and to run at between 3000 and 5000 rpm. These limits are placed more by the grinding wheels available than by the spindle bearings. The maximum safe operating speed for each wheel is marked on the wheel by the manufacturer.

The spindle is designed so that the grinding wheel is as close to the front bearing as possible. This is important both for rigidity and for keeping the bearings clean. The laminar air flow at the wheel is intended to sweep the air from the near bearing and up to the wheel periphery. This feature should be preserved by builders.

Bearing selections

The bearings selected are as follows:

Quantity	2
Bearing OD	1.375 in (34mm)
Bearing ID	0.500 in (14mm)
Thickness	0.375 in (10mm)
Seals	Double seals

The key to getting the bearings to fit properly is the use of an adjustable (by machining) spacer between the two inner races of the bearings. The spacer is made in two parts and then one of the parts is made smaller and smaller until the exact fit is achieved. This is not as hard as it seems and if you over-cut the spacer, a new spacer can be made in a few minutes (and you have the short spacer to measure, to know how much was too short!). This is not how we manufacture spindles but in the amateur's workshop whatever

works is acceptable for our "one of a kind" projects.

Materials needed

The following raw materials are needed to make this spindle. As always all steel should be purchased as free machining steel.

Qty	Description	Diameter	Length
1	Outer housing	1.500 inch (38mm)	4.125 inch (110mm)
2	Bearing caps	1.500 inch (38mm)	0.375 inch (10mm)
1	Inner spindle	1.000 inch (25mm)	6.500 inch (165mm)
2	Bearing spacers	0.625 inch (16mm)	2.000 inch (50mm)
1	Pulley	1.500 inch (38mm)	0.900 inch (25mm)
1	Nut for pulley*	½–20 tpi, 14 × 1.5, purchased	
1	Key for bearing	⅛ × ⅛ 3mm × 3mm brass is recommended	

*See Appendix 2 for UK equivalent

The parts should be made in the following order for ease of fabrication:

1. Outer housing.
2. Bearing caps.
3. Inner spindle.
4. Bearing spacers.
5. Pulley.
6. Nut for pulley.
7. Key and keyway for the pulley.
8. Finishing operations.
9. Plates for the grinding wheels.

1. Outer housing

As always make the parts that have the internal threads in them first and then make the parts with the male threads to fit them. This means the housing has to be made before the bearing caps. The housing is identical at either end, each end holding a bearing that is clamped by a bearing cap.

The housing is made from a piece of steel 1.500 inches in diameter and 4.125 inches long. Hold the housing in the 4-jaw and centre as accurately as you can. Make sure that the part is parallel to the spindle shaft – if you do not get this right, the bearings will bear at one side only and premature failure will result. Place a centre in the end and drill this out

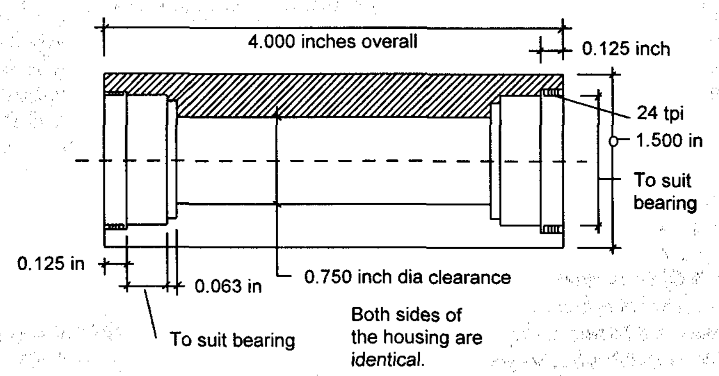


Figure 9.2 *Outer housing dimensions - the ends are identical.*

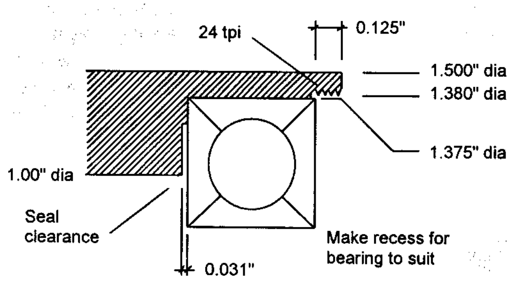


Figure 9.3 *Detail at bearing recesses at either end of housing.*

to 0.500 inches in diameter and 2.250 inches deep. Bore this out to a diameter of 0.750 inches for a clearance diameter. We can do half the work from each side.

Next bore and thread the section that accommodates the bearing cap. The inside diameter of this recess should be 0.005 inches larger than the OD of the bearing or 1.380 inches. Make the bore for this 0.187 inches deep and cut a threading tool clearance recess in the last 0.060 inches. Cut 24 tpi inside this recess as shown on the drawing. The exact diameter of the threads is not critical but they need to clear the bearings and should be well formed so that they will hold securely. Chamfer the first and last thread with the thread cutting tool.

We can make the recess of the bearings next. The bearings need to be a firm push-fit in the housing. The recess for them should have a total depth of 0.125 inches plus the thickness of the bearings. The bearings are nominally 0.375 inches thick so the total depth of the recess should be 0.500 inches. After the recess is formed, turn the clearance for the seals (its dimensions are not critical). Chamfer all edges and polish your work.

2. Bearing caps

The bearing caps are made from the same material as the housing. Two slices 0.375 inches long are needed. Measure the housing and make the cap with the larger threads first – that way if you make a mistake, you can make it into the smaller cap.

Start by making a split collet for the caps. A detailed description of how to make a split collet is given in Chapter 3. (Blank needed = 2.000" dia by 0.437" thick.) File the burrs off the cap blank and hold it in the split cap. Machine a register 0.156 inches long and 0.080 inches larger in diameter than the inside diameter of the threads in the housing. This is 0.005 inches larger than you need (theoretically) for 24 tpi threads but it is better made larger than smaller. Cut 24 tpi on this register as described in Chapter 3. This has to match the threads on the housing. Once the threads are right, chamfer and polish your work.

Repeat this for the cap for the other end of the housing. We will cut the slots for the spanner wrench, in the caps, later when we have the vertical slide set up on the lathe.

A grinding spindle needs to have a substantial inner spindle to make sure that

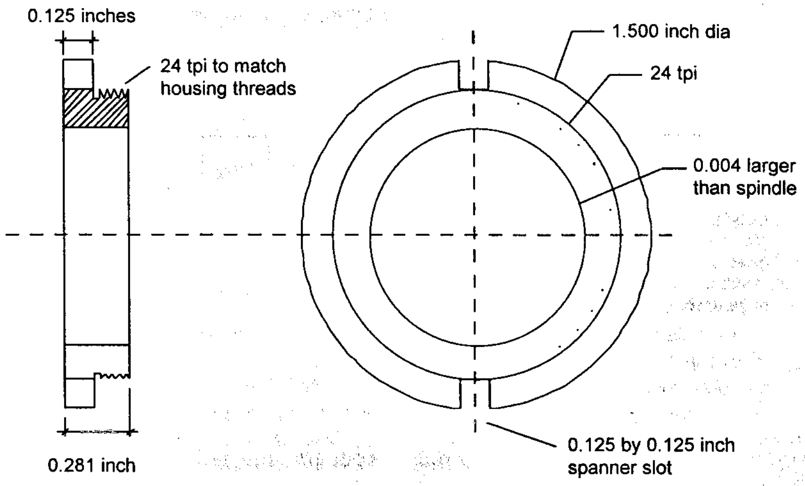


Figure 9.4 *Bearing cap dimensions - two are needed.*

the wheel is held rigidly when is use. Although we can get away with smaller spindles for the tiny Dremel Moto wheels, a three to four inch wheel running at four to five thousand rpm needs to be supported substantially. The minimum diameter at any point on this spindle is 0.500 inches.

The spindle is made from a piece of steel 1.000 inch in diameter and 6.000 inches long. The work is all to be done between centres. Hold the spindle in the 3- or 4-jaw chuck and face and centre each end.

Start by making the end that holds the grinding wheel. If the design provided does not suit your particular needs, now is the time to decide what you want your spindle to do and design an arbor and wheel holding arrangement to suit. If you do not know what you want, you can leave this section un-machined at this time. Since we have centres on both sides of the shaft we can come back to finish this work with no problems.

Wheel notes: all grinding wheels have a maximum rpm that you can run them at printed on the wheel. This rpm should not be exceeded at any time under any circumstances. A wheel that is cracked should not be used. An uncracked wheel, suspended from a piece of string, will ring when struck with a piece of hardwood. Grinding wheels should always be held in blotting paper like pads. These pads distribute the clamping forces on the wheel. The arbor plates should be designed to suit the wheels that you have in mind and should match the diameter of these soft paper pads. Do not over-tighten the plates onto the wheel or there will be a danger of damaging the wheel.

Turn the spindle around between centres and machine the main shaft to suit the bearings. The bearings need to be a firm fit on the shaft. If you intend to do high-speed work with this spindle, the section that mounts the pulley will need

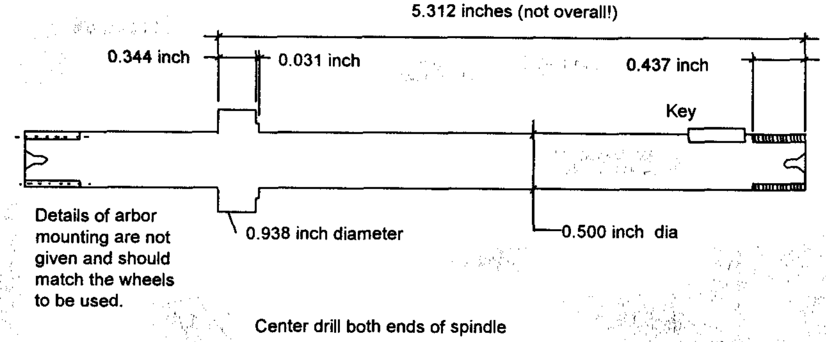


Figure 9.5 *Spindle dimensions.*

to be made smaller to allow a smaller pulley to be mounted. See also the pulley description for the ID grinding spindle.

4. Bearing spacers

The theoretical distance between the inner races of the bearings is 3.250 inches. This has to be spaced with either one or two spacers however, it is easier to make two spacers.

The spacers are made of 0.625 inch free machining stock. Make the inside diameter of the spacers 0.500 inches. Ream to be an easy push-fit over the spindle. The work has to be done in the 4-jaw chuck after carefully centring each spacer. The Myford collets will not hold 0.625 inch stock. Start by making the longer spacer 1.750 inches long. Make the shorter spacer 1.625 inches long or longer if you have a concern about the exact measurements. It will be OK provided it is too long.

Make the ends of the spacers completely flat and chamfer and polish all edges so that you get perfect fits when you assemble them to the spindle.

Clean up and check for proper fit. You need the spindle, the bearings, the spacers, the pulley and nut. Clamp one of the outer races into a recess machined in the spindle housing with a bearing cap. Make sure the bearing seats to the bottom of the recess. Pass the spindle through this bearing and place the two spacers on the spindle. Place the second bearing on the spacer and push it into the recess and tight to the spacers. Put the other bearing cap in place finger tight.

Put the pulley and nut on the spindle and tighten it down.

The bearing nuts are threaded at 24 tpi. This means that one revolution on the nut moves it in 0.0417 inches. We know that the second bearing that we mounted is not seated in its recess but we do not know how far it is from the bottom of the recess.

Tighten down the second bearing nut finger tight and mark the position of the nut relative to the housing. Now loosen the first nut all the way and tighten down the second nut all the way keeping track of how far the second nut had to be tightened. If you had to tighten it 1.75 turns to make the bearing seat it means it moved.

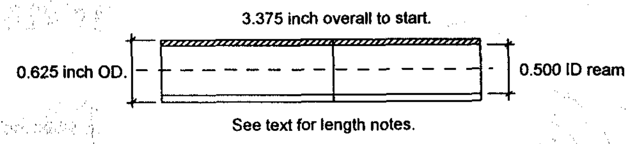


Figure 9.6 *Bearing spacer dimensions.*

$$0.040 \times 1.750 \text{ inches}$$

or

$$0.070 \text{ inches}$$

If we take 0.070 inches off one of the spacers, we should be able to tighten both caps down tight. The bearings might be a bit tight or a bit loose at this time and some final adjustments will be needed. Since we do not want to have to make a new spacer we should remove material a little bit at a time until we get it right. That is how to get the bearings just right in the housing.

Another technique is to remove both bearing caps and hold the housing of the spindle in the 4-jaw and the tail of the spindle in the tailstock. Place a dial indicator against the spindle shaft or the pulley and move the spindle gently in and out with the tailstock. Measure how much the spindle moves – you want to end up with an end play of between 0.001 inches and 0.002 inches. At that stage you will not be able to feel the play but you will be able to measure it with the dial indicator. Some play is needed to allow an oil film to build up under the bearings when the bearing are run. This film will eliminate the last bit of play when the spindle runs.

It is very important that you work with sharp tools when making very fine cuts. Steps of 0.0005 inches taken with a piece of emery paper (400 grit) can be enough in the final stages. A dull tool will tend to grab suddenly and take a bigger cut than you wanted. Tools can be kept really sharp by carefully honing them prior to cutting. If you have built the Quorn tool and cutter grinder you will indeed be in luck here. If not, just before your critical cuts are to be made, it might be worth your while to take half a dozen tools to someone who has and have them sharpened.

Once you have the fit you want, the spindle will run completely freely and you will not be able to detect any end play with your hands. Run the spindle for two timed minutes at 3500 rpm. It should warm up enough that you can feel it warm up slightly but it should not get hot. If it starts to get at all hot, stop immediately and determine the cause. Fix it.

Once the spacers are right, each of the end caps for the bearings can be tightened down on the outer races – doing this should not affect the fit of the bearings. If it does, it means that the bearings were not fully seated and that therefore the spacers are still too long.

5. Pulley

The pulley shown is made of 1.500 inch stock. The material needs to be 1.000 inch long.

Machine the pulley as described in Chapter 3. Make the groove for the belt to match the belt that you intend to use.

6. Nut for pulley

Use a ½–20 (see Appendix 2 for UK equivalent) purchased, unplated nut for the back of the spindle. Turn the nut down to be 0.312 inches thick. This can

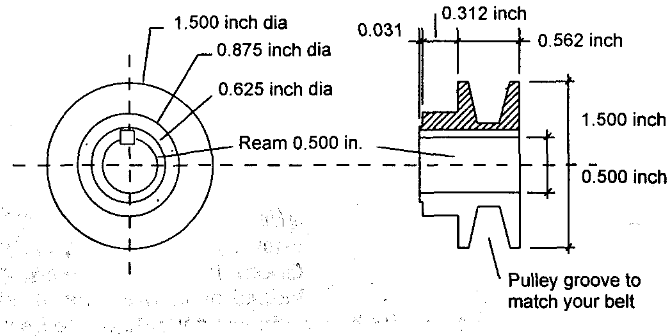


Figure 9.7 *Pulley dimensions.*

be done on a bolt held in the 3- or 4-jaw chuck to ensure that the faces line up with the axis of the nut.

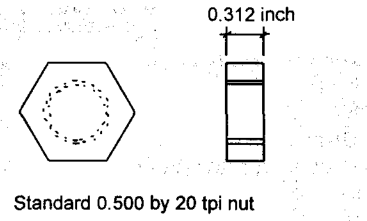


Figure 9.8 *Pulley nut dimensions.*

7. Key and keyway for the pulley
File the key for the pulley from a piece of scrap brass. Instructions for cutting the keyway in the pulley and in the spindle are given in Chapter 3 on the basic spindle.

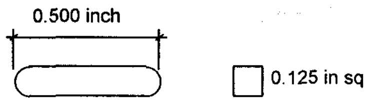


Figure 9.9 *Key dimensions. File to fit keyway by hand.*

8. Finishing operations
We still have the caps to face and to cut the six notches for the spanner wrench.

Hold the spindle housing in the 4-jaw chuck and centre it. Machine the face of the bearing cap to give you a flange 0.125 inches thick at the spanner notch. Chamfer each edge. The clearance between the flange and the housing should be 0.032 inches. Cut the spanner notches as described in Chapter 3.

9. Plates for the grinding wheels
Make the plates to match the wheels that you intend to use. The two plates that go on either side of the grinding wheels can be made from either ¼ inch plate or from slices cut from bar. In either case first machine each blank to a flat plate ¼ inch thick and 2.000 inches in diameter with half an inch hole in it. The hole should be a close fit on the spindle shaft.

Next make a collet chuck to hold the plates and machine the cross sections to match the drawings. Machine the recess first and then the taper out to the outside diameter. That way you will have no difficulty holding the plates. These plates can be made from thinner material but that is harder to do for beginners.

CHAPTER 10

Light, tool-post mounted ID grinding spindle 1.500 inch diameter (38mm)

The design of this spindle is very similar to the design of the OD grinding spindle described in the last chapter. Please refer to that information for details of construction. This chapter concentrates on the machining of the quills and other differences between the spindles.

The differences are:

- The wheel mounting arrangement has been modified to allow the wheels to be mounted at the ends of removable quills that can reach into small recesses.
- This spindle has to run at above 10,000 rpm so a smaller pulley needs be provided at the driving end of the spindle (or a larger one at the motor).
- The spindle quills are designed for use with standard Dremel Moto Tool collets, closers and accessories.

The arbors for this spindle are designed to use the many grinding wheels and arbors provided by the Dremel Moto Company as a part of their hobby Dremel Moto Tool offerings. These pre-mounted

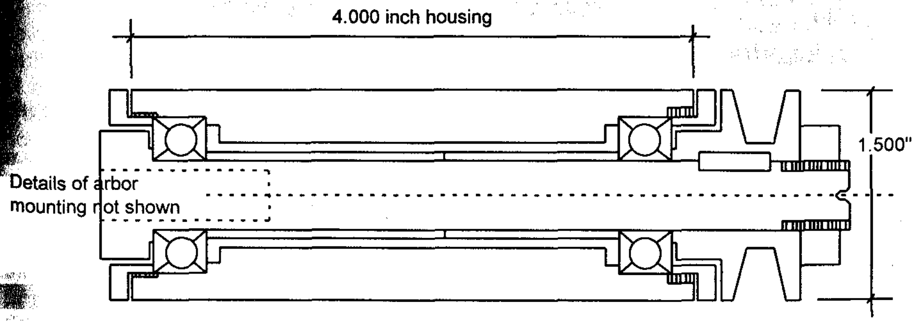


Figure 10.1 *Cross section of ID grinding spindle. The parts of the spindle shown above are identical to the OD grinding spindle.*

wheels and arbors provide an inexpensive source of quality grinding wheels for the model engineer. A wide variety of wheels, small cutters and arbors is available.

In the United States these wheels are provided with 0.125 inch diameter arbors. A 3mm arbor would be very close to this size and there may be other manufacturers in Europe who provide 3mm arbors for their European customers – if this is the case where you buy wheels, you need to modify your quills to accept the arbors that you are going to use.

Raw materials

The following raw materials are needed to make this spindle and its accessories. Use free machining steel throughout.

Qty	Description	Diameter	Length
1	Outer housing	1.500 in (38mm)	5.000 in (130mm)
2	Bearing caps	1.500 in (38mm)	0.500 in (15mm)
1	Inner spindle	1.000 in (25mm)	6.000 in (155mm)
1	Bearing spacers	0.625 in (16mm)	4.000 in (105mm)
1	Pulley	2.000 in (50mm)	1.200 in (30mm)
1	Nut for pulley*	12 × 20 tpi	14 × 1.5mm
2	6 Quills	0.625 in (16mm)	3.000 in (80mm)
1	Quill holder	1.000 in (25mm)	2.000 in (50mm)
1	Key for pulley	0.125 in sq key stock 3mm sq key stock	

*See Appendix 2 for UK equivalent

Bearings

See Chapter 9 on the OD grinding spindle – the same bearings are to be used for this spindle.

Sequence for making quills

The quills are made in a sequence that is not intuitive because two sets of precision operations have to be undertaken on each quill and the work is not done between centres. Special holding fixtures are required.

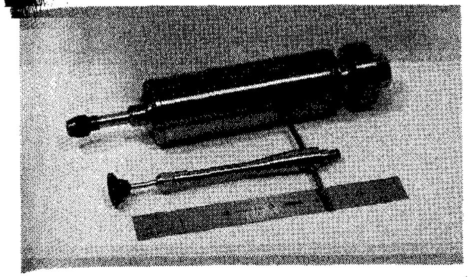
Here is an outline of the sequence:

- Decide how many quills you would like to have.
- Machine the recess in the spindle for the quills.
- Make the two holding fixtures to match the spindle recess exactly.
- Leave second fixture in chuck and do not remove.
- Machine the spindle end of each quill and check with loose holder for proper fit.
- Cross drill and ream each quill for tommy bar.
- Hold each quill in the still chucked fixture and fully machine collet end.
- Machine down shaft of each quill.
- Finish up.

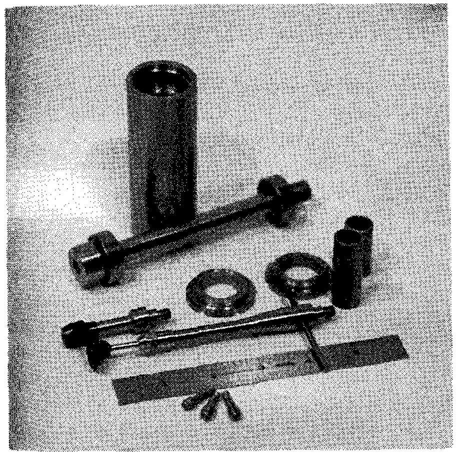
Making the grinder spindle

The main difference between this spindle and the OD grinder spindle is in the way that the quills need to be mounted to allow them to be removed and replaced with repeatable accuracy. This requires that each quill register to the spindle in the same way that a threaded lathe chuck registers onto a lathe spindle on the Myford SB7.

First make the part of the spindle that is held in the bearings and the housing in the same way that you made the spindle for the OD grinder. The finished distance from the front of the front bearing to the front of the spindle should be 0.469 inches. Allow enough material to allow this to be finished to this dimension.



The internal grinding spindle. The extra space at the driving pulley is for a second belt for higher grinding speeds. The second quill has the tommy bar used to install and remove the quills in it. Both collet closers and the collets are made by Dremel.



All the internal components of the internal grinding spindle. The longer quill is holding a small cupped grinding wheel.

Put a centre on each end of the spindle and then work between centres. The quill end is to be finished last.

Once the body of the spindle is completed, set the lathe up for using the collets. Hold the spindle in a 0.500 inch collet and make absolutely sure that it runs true with a dial indicator. If there is a slight out-of-round indication, try rewiping the taper clean and rotating the collet in the taper to see if you can eliminate the last bit of out of round. The more accurately you work now the more precise the operation of the spindle will be.

Face the spindle to give it an exactly 0.469 inch length by 0.740 inch diameter face. Chamfer each side lightly. Next we will make the recess that the quills will mount in. The operations are to be identical to those we will use for making the holding jig and test jig for the quills. In fact, we want the face of the spindle and the face of the jigs to be absolutely identical so that the quills will mount to each of them as if they were one and the same. Be sure to use the same reamer, taps and overall procedure. See the detailed description under "holding and testing jigs" below.

The spindle mounting in the housing itself is identical to the mounting for the OD grinder spindle.

Holding and testing jigs

We have to make two holding jigs – one as a holding jig to make all of our quills in, and the other as a test fixture. They should be as identical as you can possibly make them. These jigs are to have the exact same geometry as the quill receiver in the spindle. We are going to use the same mounting principle as we use for threaded lathe chucks: a register for centring and a threaded section to pull the quills into the spindle head. This is a good way to mount parts that need to be removed and remounted many times.

Make two fixtures but do not remove the second one from the chuck. Use the 4-jaw to hold a piece of ¾ inch free machining steel 1.500 inches long. Leave it sticking out of the chuck 0.5 inches. Use

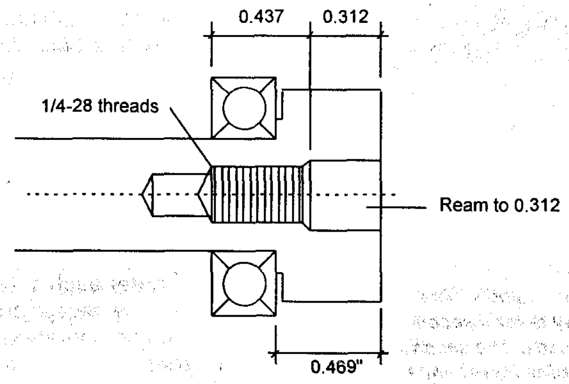


Figure 10.2 *Spindle nose details and quill mounting recess.*

a dial indicator to centre the part accurately – this is to allow us to replace the part in the 4-jaw if it ever becomes necessary. (Re-centring is to be avoided but we might have to do it in spite of our best efforts so we might as well get prepared for the worst now.) Face and lightly chamfer the part and centre drill it with a centre drill. Whenever you make a jig, you should turn a true surface on it that can be used for future re-centring (if the need ever arises).

Drill with a No 3 drill exactly 1.000 inch deep and tap the hole ¼–28 (see Appendix 2 for UK equivalent) with a tapered tap followed by a bottoming tap. Use a thread cutting lubricant as it helps to cut clean threads. Blow out the chips. Take a look at the threads cut with a magnifying glass and try the threads with a brand new high-quality machine screw. The fit should be perfect – if it is not, get a new tap and start over. It is important to get this step right.

With a sharp boring tool, bore the threaded hole out to 0.300 inches in diameter exactly 0.312 inches deep. Ream this out to 0.3125 inches. The threads at the end of the reamed hole will get deformed during these operations. Carefully clean the threads out again with the tap, making sure that you do not get the tap cross threaded in the threads.

Face the part very lightly to clean it up and chamfer the edges and polish smooth. When you make the quills, check that each quill can be screwed down into this setup all the way. All fits should be without any shake whatsoever. A very small taper is tolerable on the quill register to ease assembly but should be avoided.

Drill and ream a 3/16 inch cross hole in the first holder you made for a tommy bar for tightening it down on the quills as they are made and checked. The hole should be across the unmachined end of the holder. Here we are talking about the holder that is loose and not the one that is to remain in the chuck.

Do not remove the second holder from the 4-jaw until *all* quill machining operations, on all the quills, have been completed. Even then *do not remove* this holder from the 4-jaw chuck unless you need the chuck for another operation.

If you need to remove the chuck to use the lathe, remove the chuck with the

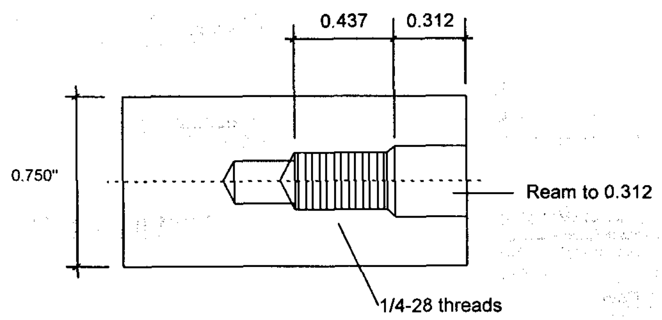


Figure 10.3 *Cross section of two quill holding fixtures.*

holder in it, then you can put it back and do more work. If for no other reason, it is worth it to have a spare chuck or two for occasions like this. Incidentally, there are times when you should seriously consider doing work like this in the 3-jaw and not in the 4-jaw because you can use the 4-jaw to do the work of the 3-jaw but not the other way around. So if you want to tie up a chuck with a setup for a relatively long time, tie up the 3-jaw chuck, (or a face plate) if at all possible.

Making the quills

Mount the 3-jaw chuck.

The quills that hold the grinding wheels need to be made so that they will run as true as possible. Most users will need only two quills (a short one and a long one) but if you think you will need more than two quills, they should all be made at the same time so they will all have identical fitting and running characteristics.

Each of the quills has to have the Dremel Moto collet system nose formed on it on one end, and the mounting threads for the grinder spindle cut at the other end. The space in between is a spacer and could be made to any shape desired by the user. I show a straight design.

The quills are all made from ½ inch diameter free machining steel. Cut all the quill blanks to the desired overall lengths. The two basic quills need to be 1.500 and 2.500 inches long overall – overly long quills are hard to use.

Start by cutting a centre, the mounting threads and registers on all the quills at the same time. Next drill the cross hole for the 0.125 inch tommy bar in all the quills. The tommy bar is needed to mount the quills tightly in the holding jig for the next operation.

Start by taking a blank and holding it in the 3-jaw with 1.000 inch of blank sticking out. Face it and place a small centre in the end of the blank. Turn down 0.375 inches of the quill to 0.250 inch diameter. Cut a threading tool clearance at the end of the turned part. Using the lathe start cutting 28 tpi on the quill – this will make the threads straight. Using a tailstock die holder clean up and size the ¼–28 (see Appendix 2 for UK equivalent) threads. Make sure that the threads go all the way to the shoulder recess by reversing the die and recutting the threads. (Use a die with the jackscrew that lets you adjust the diameter of the threads. Adjust it to cut large threads, then adjust the diameter downwards until you get the fit you want.)

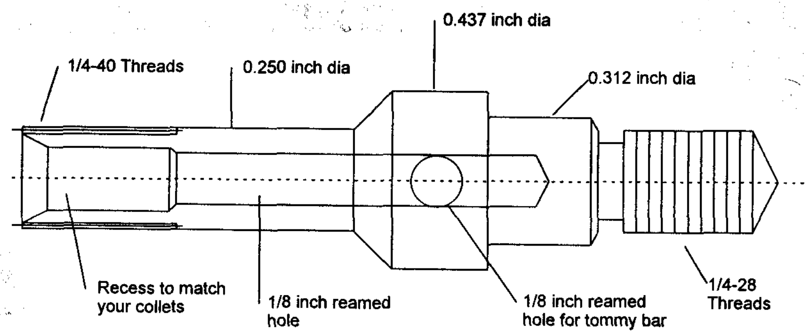


Figure 10.4 *Cross section of quills.*

Machine the next 0.250 inches of the blank to a diameter of exactly 0.312 inches. This diameter may have to be slightly more or less than 0.312 inches depending on the size of the hole that was made by your reamer in the holding fixture you just made. Adjust this dimension for a firm fit. Terminate with a clean shoulder at the unmachined end. Chamfer all edges lightly. Remember that all threads should always be chamfered at 60 degrees with a thread cutting tool.

Repeat these operations on all the quills that you are going to make. I suggest that you make a half a dozen quills while you are at it.

A quarter inch from the shoulder, drill and ream an 1/8 inch hole across each arbor for getting a purchase on the quill with a tommy bar. The hole must be reamed to give it a good close fit on the tommy bar. If you do not ream it, it will be loose on the bar and soon the hole will get deformed and look terrible. The cross drilling can be done by holding each quill in a 3-jaw chuck held in the Thomas dividing head and drilling the hole with the lathe spindle. The tommy bar hole should be chamfered very lightly at each end.

It is worth repeating that if you have not built the George Thomas dividing head you are working with one hand tied behind your back. A book that describes the construction of this tool is a "must read" for any serious amateur.

The registers on the arbors should be a firm enough fit in the spindle and need the threads to pull them in all the way. This means that a thread or two should be fully engaged before the register starts to engage. This is a good rule for all fits that use a register and a thread to mount an attachment accurately. The fact that this rule is not followed is what makes it hard, sometimes, to get a Myford chuck back onto the lathe nose. The register and threads should not engage at the same time.

That is all that is needed on one end of each of the quills. Make as many quills as you think you will need, then make a couple more because you will eventually need them and it is easier to make them now.

Machining the quill shanks and collet recesses

Remove the 3-jaw and put the 4-jaw, with the holding fixture still in it, back on the lathe spindle.

Screw the shortest quill into the holding fixture and use the tommy bar to tighten down. Bring the quill length down to size as per your requirements. Face the end of the quill and centre drill it with a small centre drill. Bring up the tailstock with a ball bearing centre in it and work between the centre and the holding jig from here on. Turn the outboard 1/2 inch of the quill to exactly 0.280 inches in diameter. We are making this 0.005 inches oversize at this time on purpose. Turn down from here back so that you leave 1/8 inch unmachined to the right of the tommy bar hole. The shape of the quill between the holder and the collet closer is not critical and you can make it as simple or as elaborate as you like.

Note

It is possible that Dremel Moto (and especially other European manufacturers) are providing their customers with 3mm shanks on their grinding wheels and tools instead of the 0.125 inch shanks used in the USA. If this is the case you have to ream to fit the shanks you will be working with and make the collet recess and the hole behind it to match.

The threads for the US Dremel Moto collet closer are 0.277"-40 threads and should be cut to fit a collet closer nut purchased from the manufacturer. Dremel Moto makes a number of collets for their many tools. I think the best collets for our use are the number 203, 204 and 205 collets. You need to purchase only the 0.125 inch collet – these collets all use the standard closing nut. Measure the actual nut that you purchase and work to it.

I originally designed the high-speed grinding spindle to allow me to grind the tiny spindle ends (at the end of the shafts) that are needed when making clocks. It can also be used for grinding threads and for a number of special toolmaking operations. It is not suitable for extensive internal grinding because the tiny Dremel Moto grinding wheels can do only so much. However, they can touch up internal surfaces to provide that final touch that is needed so often.

Before you start on your half-completed quills, and maybe ruin one, it will be well worth your trouble to try making a Dremel nose on a piece of free machining scrap. There is nothing in this world like experience.

Lathe cut 0.277"-40 threads on the nose to fit the collet closer for the Dremel Moto Tool. This should be a close fit with as little play as possible – there is not a lot of room to play with at 40 tpi so go very carefully. Back the centre off and replace with a drill chuck. Drill a 7/64 inch hole in the quill, all the way through the shortest quills and 1.000 inch deep on all other quills. Ream this out to 0.125 inches. Use a Dremel Moto grinding wheel arbor to check this hole for size and conformity. (To repeat my earlier statement, it is possible that European manufacturers are providing 3mm shanks on the grinding wheels. If this is the case you have to ream to the right size to fit the shanks you will be working with and make the collet recess etc. to match.)

You will most probably be using wheels with 1/8 inch arbors. Measure your 1/8 inch collet and form the nose of the quill to accept this collet. Drill 5/32 inches 3/8 inch deep and cut a taper of 60 included degrees. Refer to drawings but check with what is being provided by your Dremel dealer before you proceed.

Place a grinding wheel arbor in a collet and tighten down the collet closer. Start the spindle and check for proper operation. The wheel should be held tight and run completely true – if it does not, you have some detective work to do, so that you can determine what went wrong. Do it, find the problem and fix it.

Clean up the quill and turn down the neck. Remove the collet closer, collet and wheel and deburr, chamfer polish up the quill. Unscrew it from the fixture and store it. The first quill is ready for use.

Repeat these operations on all the quills that you will be needing. The only difference will be in the lengths of the quills and their longer shanks. All other dimensions are to remain the same.

Dremel Moto also make a very nice small, accurate chuck that fits on these threads. This chuck needs a flat section at the end of the quill to allow the chuck jaws to ride on. Cut this flat. You will want to have one of these chucks on hand to hold odd-sized shanks.

Pulley

The pulley can be made the same as the OD grinding spindle pulley if you do not have extreme high-speed operations in mind.

The smaller grinding wheels have to run at a minimum of about 15,000 rpm to cut effectively. The Dremel Moto runs at a maximum speed of about 30,000 rpm. Let us assume that we have a 1750 (1450 in GB) rpm motor for our spindle. This means we need an 8.6:1 driving ratio between the motor and the spindle. Let us further assume that a 6.000 inch

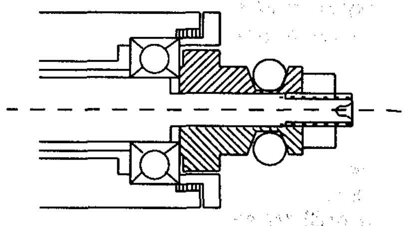


Figure 10.5 *Design sketch for a small driving pulley.*

diameter pulley can be found for the motor without difficulty. This means we need a pulley with an effective diameter of 0.697, say 0.700 inches or less on the spindle.

The sketch in Figure 10.5 shows how you can make a small pulley for the end of the spindle shaft. You can reduce the shaft down to 0.250 inches for the pulley to mount on and leave about 0.032 inches of material on the belt itself under the belt on the pulley.

It is unlikely that we will do this with run-of-the-mill "V" belting. I suggest that we use the now readily available 5 or 7mm round polyurethane belting stock and make up a belt to suit our needs. Instructions for using the polyurethane belting come with the belting.

CHAPTER 11

Simple No 1 Morse taper spindle

If you have never made a spindle before and you need a small spindle, you will want to take a close look at this design. This is a good project for a beginner as a first spindle. It is a light, fast spindle and it can be used on the smaller lathes. It is simple and is designed especially for the beginner. The compromises accepted in the design are intended to make the spindle easier to make.

Morse tapers hold tools accurately and there are times when a smaller spindle is needed. This No 1 MT spindle is designed to have an outside diameter of only 1.500 inches. Only tooling with a No 1 MT shank can be used with this spindle. The taper is drawn into the spindle with a drawbar. There are no provisions for threads on the spindle nose and so no chucks or nose type collet closers are either needed or supported. The bearings are glued into the housing for ease of construction.

The tooling for this spindle would either be cutting tools that already have a No 1 MT on them or are mounted on arbors that have a No 1 MT. Tooling for cutting clock gears and pinions is available for this taper. Arbors for mounting drill chucks are also available for this taper.

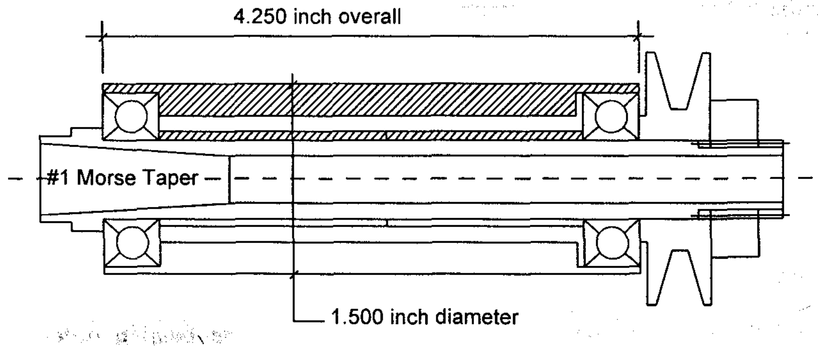


Figure 11.1 *Cross section across spindle.*

Certain small lathes (Sherline) use this taper in their spindles. The spindle is best suited to light tasks and is not heavy enough for all but the smallest milling cutters and drills nevertheless many, many useful and interesting things can be done with these.

The bearing arrangement for this spindle is a simplified version of the other arrangements in this book. One bearing is used in front and one bearing is used in the back of the spindle. This is a simple arrangement that serves the purposes we have at hand. It is not claimed that this is best way to do the job, only that is a simple way to do it and that it works.

It is not realistic to expect that a beginner can bore an accurate No 1 MT recess. The taper could be bored but it is not worth the effort. (The tapered plug would be easier to make and even then it is not recommended that you try making one of these.) Unless you have access to a reamer (either borrowed or bought) to do the job right, I *do not* recommend that you make this spindle. If you must have a spindle this size, you should consider using a steeper home-made taper that is drawn in with a draw bolt or consider one of the other spindles. Consider a 20-degree (or less) included angle as a starting point for your experiments.

In order to keep the design as simple as possible, the spindle uses double sealed bearings that are exposed on one side (the other side faces the innards of the spindle). If the seals or bearings get compromised, it is the design intent that the bearings cannot be replaced, the spindle must be discarded. This decision trades ease of construction with durability. Here durability is being considered the low priority item for an infrequently used item. This is true for many model engineering applications, so in a way these are throwaway spindles.

Bearing selections

Front bearing

Outside diameter	1.250 in (32mm)
Inside diameter	0.625 in (16mm)
Thickness	0.437 in (12mm)

Rear bearing (same as front)

Outside diameter	1.250 in (32mm)
Inside diameter	0.625 in (16mm)
Thickness	0.437 in (12mm)

There are only 8 parts to this spindle and two of them are purchased parts (the spacer is in two parts).

List of materials needed

Description	Diameter	Length
Housing	1.500 in (38mm)	4.500 in (115mm)
Spindle	1.000 in (25mm)	6.000 in (155mm)
Bearing spacers	0.750 in (20mm)	3.500 in (90mm)
Pulley	2.000 in (50mm)	0.750 in (20mm)
Nut*	0.625 × 18 tpi, 16 × 1.5mm	

* see Appendix 2 for UK equivalent

We will make the parts in the following order:

1. The housing.
2. The spindle.
3. Spacers.
4. Pulley.
5. Sizing the spacers.
6. Final assembly.

1. The housing

There are two ways to make the housing: with and without the threaded section that clamps the bearing outer race in place. I decided not to make the threaded

sections so we have to glue the outer races in place with an anaerobic adhesive such as Loctite. The major disadvantage of doing this is that the spindle can then never be taken apart for any reason. We will not apply the glue until everything is in place and we are sure every operation has been completed – it will be the last thing that we do. If we decide to do without the threads, we will not have to make the threaded clamping caps that fit in the threads. Without the caps is the quick way to build the spindle.

The two ends of this housing are identical except for depth – one end has to be 0.062 inches deeper than the bearing to allow some adjustment.

Start with the spindle housing. Hold the housing accurately in the 4-jaw and true it up. It should be true at both ends to ensure that the two bearing recesses are perfectly in line. Face the housing face, centre drill the face and then drill a 0.250 inch hole in the housing as far as your equipment will allow. The work will start to get hot as you proceed. Use a lot of coolant and lubricant as the hole gets deep. Drill this hole out to 0.500 inches in diameter as far as you can go. Bore this out to 1.000 inch in diameter halfway into the housing. The other side will be bored out to meet this.

Bore a recess to allow a bearing to fit in the recess and be flush with the outer lip of the recess. The bearing will be "Loctited" into the recess and so should have a clearance of about 0.001 inches all the way around for the adhesive to flow. This is an easy fit – the bearing should fall out with a little shaking.

Polish the outside of the housing. Chamfer all edges at 45 degrees. This completes one side.

Turn the housing around in the 4-jaw. Turn it to a length of 4.250 inches. Repeat the above drilling and boring operations and fit a bearing on this end just as you did on the other end except that on this end the bearing recess is 0.062 inches deeper than the bearing. Polish the rest of the housing and chamfer as before.

This completes the housing.

2. The spindle

Next we will make the spindle. The raw material for the spindle is a piece of free machining steel 1.000 inch in diameter and 6.000 inches long. All the work on the spindle is to be done between centres.

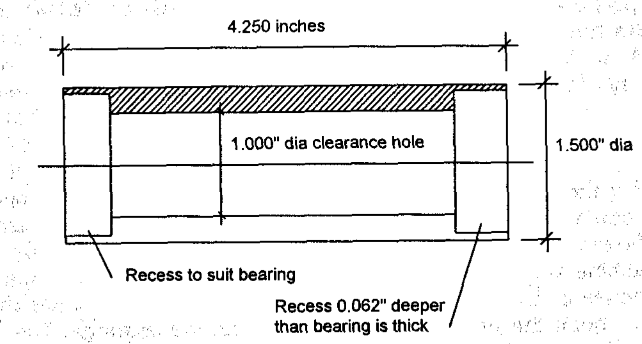


Figure 11.2 *Housing dimensions.*

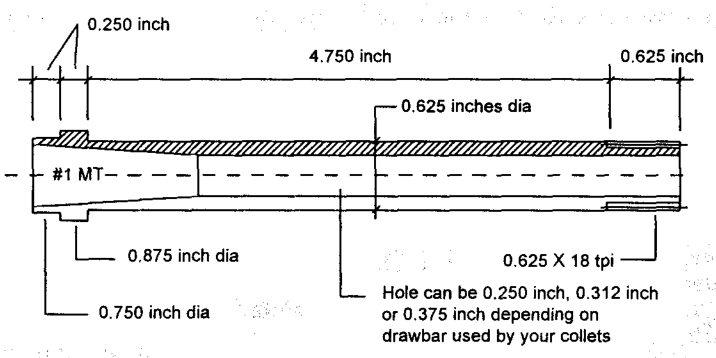


Figure 11.3 *Spindle dimensions.*

Use the 4-jaw, and face each end of the blank and place a centre on each end. Drill a 0.250 inch, 0.312 or a 0.375 inch diameter hole to the centre of the spindle from each side for the drawbar. The hole should match your drawbar.

The spindle geometry is suitable for allowing the work to be held by a dog while making the part. If you do not have a dog large enough, turn 0.625 inches of the spindle down at one end to fit in your dog.

First we want to make sure that the tailstock is set right to give an untapered cut. Make a finishing test cut along the length of the part and measure each end. Both diameters have to be identical i.e. within 0.001 inches or less of one another. If they are not, adjust the tailstock until they are. If there is to be a difference, the tail end should be the end that is smaller (so that bearings get tighter and not looser as they move up the shaft). Chapter 16 contains a discussion of tailstock and headstock alignment.

We will machine the pulley end first. Turn 5.375 inches of the shaft down to 0.625 inches. Check the fit of the bearings to this shaft, they should be a firm push-fit all the way on this shaft. You should not have to use force because you have to take the back bearing on and off a few times and eventually force will ruin the spindle and the bearing.

Cut the ⅝–18 (see Appendix 2 for UK equivalent) threads on the last 0.625 inches of the spindle. Check the threads for a good fit on the purchased nut. Chamfer the threads.

3. Spacers

Make the spacer as two parts for ease of fabrication and fitting. One part is 2.000 inches long and the other part is 1.125 inches long. Together, to start with, they should be about 0.100 inches longer than the finished dimension between the bearings. Making the spacers is a straightforward drill and ream operation. Use 0.750 inch diameter stock. Hold the work accurately in the 4-jaw. Drill and ream each spacer for a finished 0.625 inch hole. Carefully face and chamfer all edges on each side of each spacer so that they will bolt up true between the bearing. Again, the two spacers together have to be slightly longer than the space between the bearings. The length will be carefully reduced to fit between the bearings.

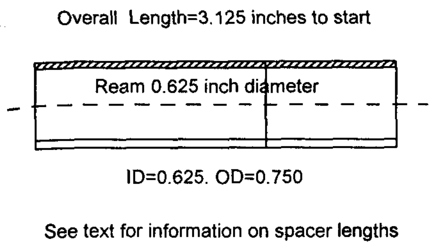


Figure 11.4 *Spacer dimensions.*

When making these spacers, the 4-jaw cannot be made too tight or the spacers will collapse under the pressure as the hole is drilled and reamed. The reamed hole itself needs to be slightly more than 0.625 inches in diameter so that the spacers slide on easily onto the spindle section between the bearings.

It is critical that the spacers be faced true so that they will fit to each other and the bearings as truly as you can make them fit. This will make the spacing between the bearings constant for any one length of spacers.

4. Pulley

The pulley should be made to suit the applications that you have in mind, the speed of the motor and the size of the motor pulley that you plan to use. I have drawn a 2.000 inch diameter pulley with a 0.625 inch diameter mounting hole. This would serve most purposes on a spindle this size. There is only one groove on this pulley for simplicity's sake. This will accept a "V" belt that is 0.375 inches wide at its widest (US size 3L). Make your pulley to suit the belting that you will be using.

Hold a piece of free machining steel 2.000 inches in diameter and 0.750 inches long in the 3-jaw. Face and centre the part. Drill to ½ inch in diameter and bore and then ream to 0.625 inches to fit on your spindle. It is often a good idea to take a light boring pass through a hole to true it up before reaming it particularly if your drills tend to wander or if the drilled hole has become off centre for any reason.

Turn a 1.125 inch diameter boss 0.125 inches long on the part. Chamfer

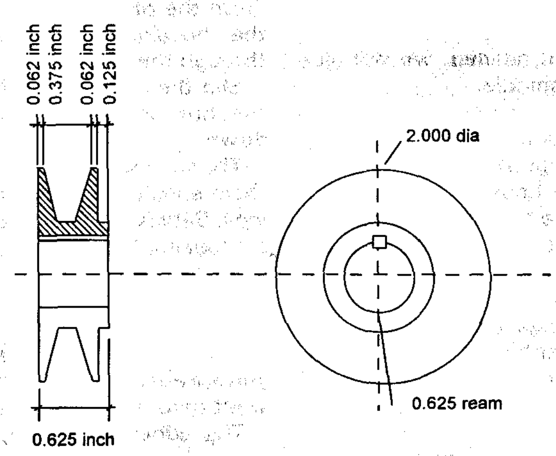


Figure 11.5 *Pulley dimensions.*

edges and polish to complete this side.

Reverse the part in the chuck and hold by the 0.125 inch long boss. Carefully face the pulley in anticipation of turning it in situ on the spindle. The part that is going to form the body of the pulley should be 0.500 inches thick, turn the rest of the material away. Chamfer all corners and polish. Do not cut the belt groove yet, we will do that later in situ to get a perfectly running pulley.

Mount the bearing spacers and the pulley on the spindle and tighten down with the nut. Mount the spindle between centres, true the outer periphery of the pulley and cut the groove for the belt. The top of the groove should be 0.375 inches wide and the included angle between the sides of the pulley should be 40 degrees. Take light cuts. All the work is done with a grooving or parting tool. First cut a groove 0.400 inches deep, then set the compound slide to a 20-degree angle and finish cutting one side of the pulley. Then set the compound to −20 degrees and cut the other side of the pulley. Finish the bottom of the groove flat. Use a double 45-degree tool to chamfer all edges. Polish all surfaces.

A keyway is not needed, we will glue the pulley to the spindle.

5. Sizing the spacers

The spindle bearings will have their outer races held in the housing with Loctite. The inner races are held with the spacers and the pulley nut in the back. Both the inner and outer races have to be the same distance apart for the best operation of the bearings and therefore the spindle. As presently constructed, the spacers are longer than they need to be and one bearing will stick out of the housing.

We need to determine exactly just how much we have to take off a spacer to get the fit just right. Bolt the spindle together now using the spindle, the two bearings and the two spacers. Put it next to the housing. The distance from the front of one bearing to the back of the other bearing should be the same as the spindle housing length. We will shorten one of the spacers by this amount to get the right fit.

Now assemble the parts inside the housing. The bearings should be flush with the housing faces.

6. Final assembly

Final means final and we do not intend to do it again. Before we start on the assembly, we have to be sure that everything is just exactly as we want it to be. Clean and polish all the parts. Check the seals on the bearings to make sure that they were not damaged in any way during the handling done in the fabrication and testing procedures.

First place one of the bearings on the spindle and slip the two spacers onto the spindle. Place the other bearing in the back of the housing (the deeper recess). From the other side place the spindle in the housing and thread the spindle through the second bearing.

Slip the pulley onto the spindle. Place the nut onto the spindle and tighten down.

The spindle should run true and free and there should be no backlash in the bearings. Satisfy yourself that this is what you are looking for, if not, now is the time to make the necessary adjustments.

Using Loctite

The adhesive should be applied only after you are absolutely sure that you will never want to take the spindle apart again.

The adhesive should be applied to a cleaned and degreased recess and race. Use the cleaning agent supplied by the adhesive manufacturer to clean the parts. Only the smallest amount of the adhesive needs to be applied, just enough to wet the outer race and recess.

First glue the front bearing into the shallower recess. Make sure it seats all the way in. Wipe excess adhesive off with a paper tissue. Position the housing on one end to let the front bearing set.

Push the spindle through the front bearing. Place the two spacers on the spindle and follow up by gluing the back bearing into its recess. Wipe off any excess adhesive carefully but leave enough for the pulley. Immediately place the pulley and the nut on the spindle and tighten down. Turn the spindle by hand to allow the back bearing to settle in. Set aside in a vertical position to allow the adhesive to set overnight.

The spindle can never be taken apart.

Cutting the No 1 MT

The No 1 MT is cut in the spindle with the spindle running in the spindle bearings so that it will be completely true to the bearings. We will rough bore the taper first and then finish it up with the taper cutting reamer.

There is a detailed description on cutting the No 2 MT for the basic spindle in Chapter 3. Read that and follow the instructions given to cut the No 1 MT in this spindle.

Making a drawbar

Make the drawbar out of a piece of ¼, 5⁄16 or ⅜ inch rod. Make the rod 0.750 inches longer than the distance from the back of an arbor to the back of the spindle. This should be measured from your spindle. Cut 0.750 inches of threads on each end to match the threads in the arbors. The threads need to be straight and it is worth the time to cut them on the lathe to make sure that they are. The pitch of the threads is to match the pitch on the arbors that you plan to use. It may be necessary to make a number of drawbars to suit your tooling needs.

0.375 inches of the drawbar goes into the arbor being held and 0.375 inches is available at the back for the washer and nut.

CHAPTER 12

Vertical spindle or gear cutting frame

You will be interested in this particular project if you have a serious interest in clock making.

Making this frame or spindle is a good exercise in making parts that fit as assemblies that fit into other assemblies. Each part has to be made accurately because each contributes to the accuracy of the overall assembly.

A vertical spindle as used in a small lathe is essentially a gear cutting frame. There have been complaints about these as regards the bearings that they were designed to use. It seemed that the bearings wore out rather faster than was considered tolerable for accurate work and one ended up with an odd last tooth on the clock wheel. I have addressed this specific concern in this design. The frame described here has the special attribute of being supported on sealed ball bearings top and bottom. The bearing positions are adjustable so that the gear cutters do not have to be of a fixed thickness. The frame can be held in the same way as lathe cutting tools are held on the compound slide. Since the cutting forces involved in cutting small clock gears are small, it can also be held in a quick change system. It can, of course, also be mounted on the carriage and the vertical slide if a few accessories are made up.

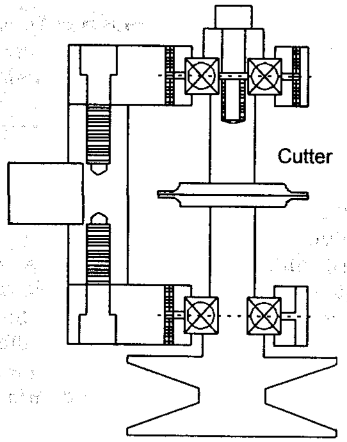


Figure 12.1 *Section across frame.*

The bearings

The selection of the bearings is the key to the design of this frame. Rather small bearings are to be used. We need a bearing with an internal diameter (ID) of 0.250 inches. These bearings will fit with a 0.500 inch by 1.000 inch bar with room to spare for the threaded adjusters, so that is what we will use.

Bearing specifications

External diameter	0.625 in (16mm)
Internal diameter	0.250 in (7mm)
Thickness	0.187 in (5mm)
Seals	Yes, both sides

These are common, inexpensive bearings. Specify a high-quality close fitting bearing, your distributor will know what you mean.

The most serious problem we will encounter is with the direction of rotation of the cutting wheel. We want to drive the wheel in such a way that the driving force on the pulley will always tighten (rather than loosen) the works. This is a prime consideration because retightening things in the middle of a large wheel cutting project cannot be tolerated if precision work is to result.

Since we do not want to get into the business of using left-hand threads and all the problems that go with that we need to do some planning. It is desirable that the cutting take place when the frame moves from right to left as you, the operator, face the lathe. See Figure 12.2. This is as seen from above the lathe.

This means that as seen from the top, the cutting wheel should be rotating counterclockwise (ccw). This in turn means that the pulley that drives the spindle has to be on the bottom! Not the end of the world, but highly inconvenient to say the least. Our belt drive arrangement will be difficult if we do not pay close attention up front. Mostly what this means is that we have to take some measurements on the lathe we are planning on using before we start.

The other alternative is to devise a mounting for the frame so that the cutting wheel can be on the far side (from the operator) of the wheel to be cut. That will reverse the direction of rotation of the wheel and the pulley can then be on top.

Making the frame parts

The frame is made from bar stock that is 1.250 inches wide and 0.500 inches thick. You will need about 10.000 inches of the material. As always I recommend free machining steel for all my projects – life is too short to use any "hard to use" materials except when absolutely neces-

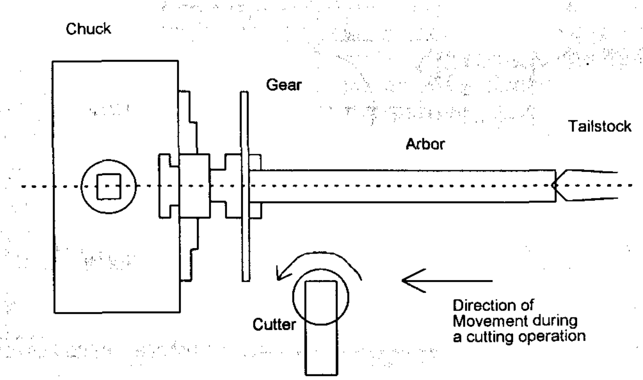


Figure 12.2 *Direction in which cutting should take place, looking down on the lathe from above.*

sary. You could use some drill rod (silver steel) to make the spindle itself so that it is good and stiff but you do not really need to. It's not all that long and slender in any case, and the loads imposed by cutting small brass gears are quite small.

Prepare 4 pieces of the bar as follows:

- 2 pieces 2.000 inches long for the top and bottom.
- 1 piece 1.500 inches long for the vertical back member.
- 1 piece 2.500 inches long for the tool holder tang. Make the tang last so that you can fit the mounting that you decide on for your particular application.

The first two pieces, the top and bottom are identical. Start by making the parts exactly 2.000 inches long. Make sure that the ends are at right angles to the face and sides of the part. File all imperfections so that all 6 sides of each part are flat and at right angles to one another.

Put marking blue on each part on one

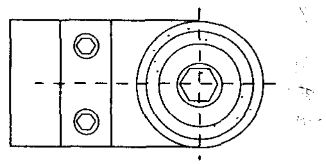


Figure 12.3 *Top: basic gear cutting frame on ball bearings.*

large face. Study the drawings.

The trick is going to be to make both parts identical. The most important thing is that the threaded hole that accepts the bearings be centred on one end of the parts and be exactly at right angles to the face of the part. This can be guaranteed by mounting the plates on a face plate and cutting the threads in the lathe.

The bearings that we are planning to use have an inside diameter of 0.250 inches, an outside diameter of 0.625 inches and a thickness of 0.190 inches. These will be held in threaded pieces that need to be 0.375 inches greater in diameter than the bearing OD with 24 tpi threads on the outside diameter. See

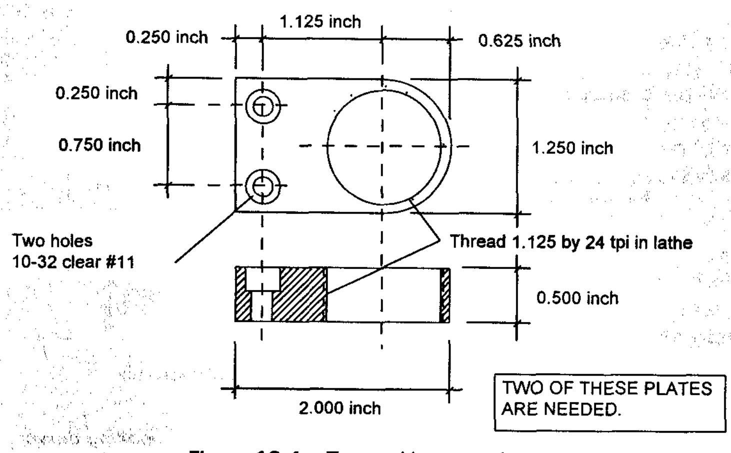


Figure 12.4 *Top and bottom plates.*

drawings. We need another 0.125 inches of material beyond these pieces to hold them. This gives us a bar width of 1.250 inches.

Mark and drill the two bolt down holes on one end of the bar. These are 10–32 (2BA) clear holes that are to be drilled ¼ inch in from the ends of the bar. Deburr and file the surface down after drilling.

Mark the centre of the face of the bar and mark the same distance (0.500 inches) in from one side. This will be the centre of the bearings. In the drill press drill a No 34 hole at this point and tap it 6–32 (4BA). Mount a centring button to this hole and fix it that this button is equidistant from all three sides. This can also be done by machining a disk 1.000 inch in diameter and 0.375 inches thick and using this to centre the part in the lathe (on the face plate).

It is easier to cut the threads inside this plate on a face plate because the face plate makes it easy to mount the part parallel to the cutting face in a lathe. Make a bolt down jig from a piece of ¾ inch sq bar stock. Drill and tap two holes to match the holes in the bar and bolt the frame bar down to this fixture, good and tight. Check to make sure that the parts fit together and that they sit flat on the

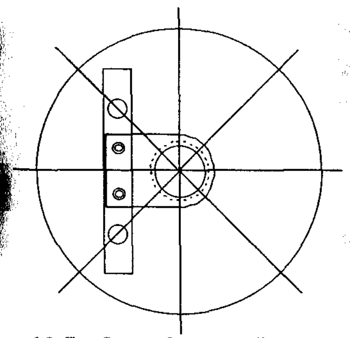


Figure 12.5 *Setup for threading top and bottom plates in lathe (on face plate).*

face plate and are parallel to the face plate.

Roughly estimate the centre location of the face plate and drill two holes in the bar fixture to allow you to mount it to the face plate. Centre the centre button at lathe centre and bolt the bar fixture tight to the face plate.

Remove the centring button and drill a centre drill in the part. Drill through ¼ inch. Open out to ½ inch with a drill and bore the hole out to about 0.750 inches. At this point check that the hole is actually centred on the three sides of the bar. If not, now is the time to make a correction by repositioning on the face plate. When everything is all right, open the hole out to 0.800 inches diameter. Thread the hole so that you have threads that are 0.875 by 24 tpi. These will have a theoretical internal diameter of 0.832 inches. The exact diameter is not critical, it is more important to get the top plate and the bottom plate as close to identical as possible.

Machine the other plate to be as identical to this plate as you possibly can.

Back of frame

The back of the frame is made of the same materials as the top and bottom. It is 1.500 inches long. Special attention needs to be given to making the ends of the part at right angles to the factory faces. This is much more critical than the length of the part. After you have machined the faces clamp the top and bottom to the back and check that the assembly is square and parallel. If necessary, adjust the faces with a file or by re-machining. The top and bottom plates need to be parallel and square so that the bearings will run properly in them. Lay the assembly on its side to make sure that it lies flat.

Clamp one end plate accurately to the

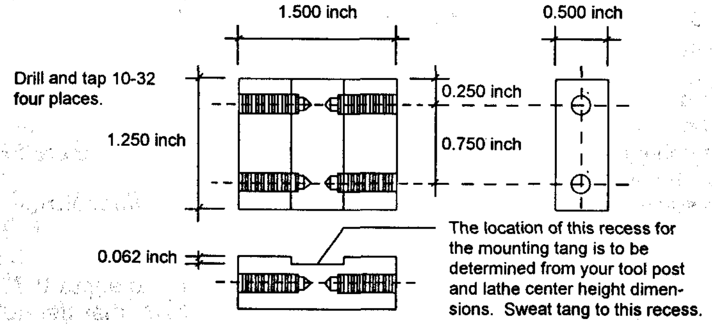


Figure 12.6 *Back plate.*

back plate and spot the holes through into the back. Drill and tap these holes 10–32 (2BA) at least ½ inch deep. Repeat on the other side.

Now using Loctite between the parts but not on the threads (and this takes some care so use very little adhesive) assemble the two ends onto the back and lay the assembly of a flat surface on its side. Make sure it lies flat. Make sure all components are vertical and tighten the screws down good and tight. Once the Loctite sets you will have an assembly that will not slip on the bolts.

Bearing support rings

The bearing support rings thread into the threads that were cut in the upper and lower plate just described. If the thread diameters are not identical in the above parts, you will have to make two different sets of bearing supports, one set for each of the plates.

Start with a piece of free machining steel 3.000 inches long and 1.062

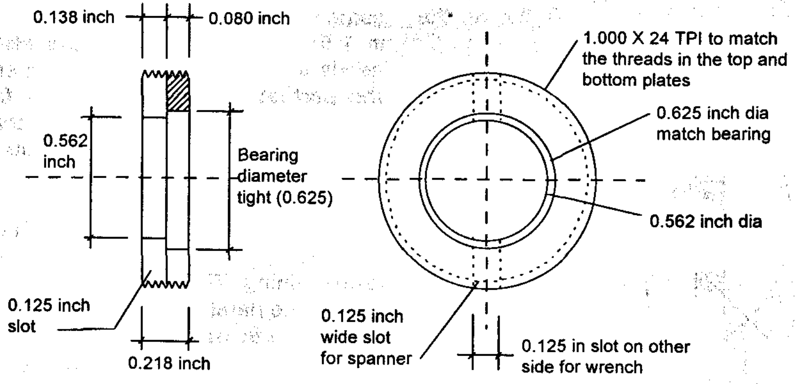


Figure 12.7 *Clamping rings – four rings are required.*

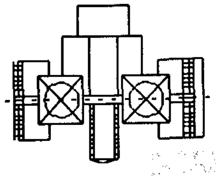


Figure 12.8 *How bearings are held in place. Threaded cups hold the outer races in place in the frame.*

inches in diameter. Hold in the 3-jaw chuck. Face the end and centre drill the piece. Drill into the part 1.500 inches deep with a 0.250 inch drill. Open this out with a 0.500 inch drill and bore this out to 0.562 inches.

The bearing seat has to be the diameter of the bearings and 0.080 inch deep. The bearing should be a push-fit into the recess bored and a little less than half the bearing (0.016 inch less) should go into the recess. This will leave 0.032 inches between the caps when tight on the bearing.

Thread 1.500 inches of the outside of the bar to 1.000 inch by 24 tpi. The threads are cut to be a snug fit on the larger of the two end plates that we made. When cutting fine thread and trying for snug fits, the following points need to be kept in mind:

- Keep the work clean and free of burrs.
- Keep the thread bottoms clean.
- Take very small cuts or you will have over-cut before you know it.
- Work at slow speeds.
- Use very sharp threading tools.
- Use a thread gauge to position the threading tool accurately.
- Do not forget to round off the thread crowns before you test your fits.

Once you have a nice fit on the threads, take a very fine finishing cut on the face of the part, chamfer the last threads on each end. Make a recess 0.080 inches deep and the diameter of the bearing in the end of the part. The bearing should be a snug fit in the recess. Chamfer all edges.

Part off a section 0.218 inches thick. Make one more part identical to this one.

Repeat the process for the other end plate and make two more threaded cups for it.

Next we need to cut wrench slots into these two sets of two parts. At the least we need an ⅛ inch slot across the back of the parts to allow us to tighten them into the threaded bearing hole – four or six would be better. The slots should be 0.125 inches wide and 0.109 inches deep. At this depth the slots will just barely miss the bearing recesses. Deburr hole, slots, threads and the recess all the way around.

Place a bearing between the two parts and thread the assembly into the threaded hole in the bar that fits these threads. Tighten down with a piece of ⅛ inch plate made into a special wrench just for this purpose. See drawing. The bearing should feel right at home in its housing. It can be moved up and down by threading the assembly up and down and then re-tightening it. At 24 tpi, each turn of the assembly moves the bearing 0.0417 inches or about 0.010 inches for every quarter turn. Fairly accurate adjustments can be achieved.

The spindle shaft

I will discuss two ways of building up the shaft (and describe one). One scheme has the pulley between the bearings and the other has the pulley above the bearings. I think the latter is preferable for most users because the belt is then

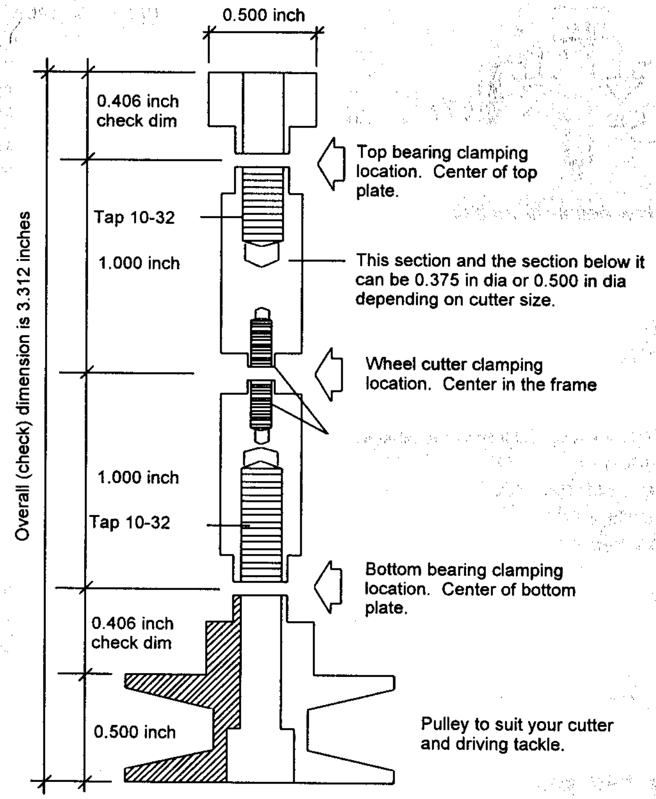


Figure 12.9 *Vertical section across spindle parts.*

easier to remove. Also the belt and pulley do not get in the way of the cutting operation as much as they do otherwise.

The basic design is of a shaft that is built in two sections with the cutter clamped between the two sections. Each section is then supported at its other end by one of the two ball bearings. The pulley can be placed on either half of the shaft or outboard of the bearings. The main problem is that the cutters used in clock making are rather small and thus all but the smallest pulleys will interfere with their ability to reach the wheel to be cut. Placing the pulley outside the frame allows us to use a larger pulley and to have more space to mounting and driving the spindle.

Let us take a bit more time to consider a pulley between the bearings. If we mount it on the upper half of the shaft, it will interfere with our ability to see what is going on. If we mount it on the lower half of the shaft, the swarf will fall down

onto it and the belt. Also consider that it is harder to drive a pulley that is mounted low near the lathe bed. In either case, we would have to use small belts to drive the cutter because the space available is so limited.

It is desirable that the distance between the bearings of the frame be as small as possible to give us a shaft that is as stiff as possible. This requirement also reduces the space available for the pulley, so even though every design I have seen in the literature places the pulley between the bearings, I am going to suggest that the better location is outboard of the bearings, on top of the frame and that is the way I will describe the construction.

Let us assume that the largest wheel to be cut with the spindle will be 9.000 inches in diameter (as in one of Mr. Wilding's elegant skeleton clocks and about the limit of what can be done on the Myford Super 7) and that the cutter we use will be a standard Thornton cutter 1.000 inch in diameter with a 7mm hole through the centre. We will design the mountings to clear the above dimensions.

There is also a problem with cutting extremely small wheels and pinions but I have found that those are best cut with a horizontal spindle like the basic spindle in Chapter 3.

All the work of making the spindle parts will be done in collets. I recommend that all spindle parts be made of silver steel (drill rod). This will give a little added stiffness and we need every bit that we can get on a small spindle. However, silver steel is hard to thread and it is not essential that it be used.

First take a 12.000 inch section of 0.500 inch silver steel and polish it so that all blemishes, rust and dents on it are removed. This will allow the parts to be held in the collets with greater accuracy.

Take a good look at the drawings. Start with the section of the spindle that goes under the cutter. Cut off a 0.500 inch piece of silver steel 1.000 inch long. Holding the part in a half inch collet, face the part and form a boss 0.090 inches long and 0.250 inches in diameter on the end. This should be a snug fit in the lower bearing and just a wee bit shorter than half the thickness of the bearing so that we can clamp it to the inner race. Next drill a centre in the end and then drill a No 11 hole ⅝ inch deep into the part. Carefully tap this 10–32 (2BA). About 0.375 inches of good threads are needed.

Turn the part around in the collet and face it. Place a very small centre on this end. Remove and measure the length – the theoretical finished length needs to be

1.000 inch – [half the bearing thickness] – [half the cutter thickness]

Confirm the length for your frame. Once the length is right, turn a stub down to 7mm in diameter and the thickness of the cutter minus 0.010 inches. Make sure that the step near the ½ inch diameter is absolutely clean so that the cutter will not hang up at this point. It must seat perfectly. Check the diameter with the cutter that you intend to use. The stub needs to fit inside the cutter and there should be no play – this is a critical fit. Centre drill and drill and tap 6–32 (4BA).

Carefully chamfer all edges and polish all surfaces. Wipe with oily cloth and set aside. This section is now done.

The upper section of the spindle is identical.

Take a 6–32 cap screw with a long threaded section and salvage the threaded section from it. A long set screw can also be used. Screw this into one of the spindle halves and place the cutter on the stub. Screw the other half of the spindle onto the screw. The cutter should be held perfectly.

Run the lathe. Both halves of the spindle and the cutter should now run true. If not, we need to find out what is wrong and fix it before we go any further.

Unscrew the two halves of the spindle and put the bottom half of the spindle and the cutter away for now.

Using similar screw and register techniques make the top bearing clamp.

Pulley

Make the pulley on a piece of free machining steel stock 1.250 inches in diameter and 1.000 inch long. Hold the part in the 3-jaw and take a cut to true the diameter. Face the part and centre drill it. Drill a 10–32 clear hole through the part. Turn the bearing register and a 0.500 inch diameter section to clear the frame. The pulley section will be ½ inch thick and will have a pulley groove to match the belting that you intend to use.

Turn the part around and hold it in the ½ inch collet. Face the part to make the belt section exactly ½ inch long. Machine the groove to the dimensions of your choice. Bore out the mouth of the hole in the pulley to accept the head of a 10–32 (2BA) socket head cap screw completely. Chamfer all edges and polish with emery papers.

Drill and ream a 3/16 inch cross hole at the centre in each half of the spindle shaft for a tommy bar. Chamfer both sides of each hole just slightly. Make two 3.000 inch long tommy bars out of 3/16 inch ground silver steel (drill rod).

Do a test assembly with all components and the upper and lower bearings to make sure that everything assembles up correctly. Nothing loose, nothing tight, Everything lines up and runs true, if not, fix it.

Final assembly

First do a dry run trial assembly to make sure that everything will work the way you think it is going to. This is your last chance to make adjustments.

Clean and prepare the parts for final assembly.

Mount the mounting tang to the back of the frame. Use Loctite on the threads and at the mating parts. Using Loctite on the mating parts gives you strength against twisting of the joint. This joint can be welded but there is a danger of warping.

Next mount the top and bottom plates to the back. Here again use Loctite on the threads and at the mating parts. Before you tighten the parts down, lay the assembly on its side on a flat surface to make sure that it lies flat.

Allow the adhesive in this frame assembly to set. Wipe away all excess adhesive and make absolutely sure that there is none in the threaded recesses for the bearings. Clean and lightly oil the recess threads. Loctite will set up in fairly oily parts, be careful.

Assemble the two halves of the spindle and the cutter. Place the two clamps that hold the lower bearing on the lower bearing and thread all three into the lower plate on the frame. Do not tighten anything.

Place the lower half of the upper clamp on the spindle and let it rest on the cutter. Place the lower boss of the spindle in the lower bearing and bolt the spindle to the lower bearing with the pulley.

Now thread the lower clam for the upper bearing into the upper plate until it is not quite flush with the bottom. Place the upper bearing from above and thread the upper clam onto it.

Place the bearing clamp on top of the assembly and put the cap screw down into the spindle. Do not tighten yet.

Everything is now in place.

Tighten the two clamps on the lower bearing and tighten the cap screw on the bottom of the spindle in the pulley. Everything on top needs to be loose at this time but the spindle will be constrained by the upper bearing. The bearing should be loose up and down. Make sure it is and then tighten the upper cap screw so that the spindle, upper bearing and pulley are one. Once this is done, there should be no radial play in the system but there might be some axial play.

The axial play is taken up by moving the lower clam of the upper bearing up until the play just disappears. Then tighten everything down with the upper clam.

In the final analysis, the spindle should run freely without either play or binding. When in use the bearings should not get hot. There should be no compromise as regards the proper and precise rotation of the cutter.

Notes on using the frame

The frame can be mounted either in a tool holder for a quick change system or bolted down with packings as would be done if one did not have a quick change system. It would also be possible to use a larger mounting tang with a hole in it so that the assembly could be bolted down on the tool-post stud itself.

The spindle can be run at between 2000 and 3000 rpm, for brass, with ease. Use a discarded washing machine or similar utility motor (for further information see *Electric Motors*, Workshop Practice Series No 16 and *Electric Motors in the Home Workshop*, Workshop Practice Series No 24, both by Jim Cox and published by Nexus Special Interests). The spindle needs no more than about ⅛ hp for most applications.

The cutter should be at exact lathe centre height for wheel cutting. The spindle should be perfectly vertical. The setup should be rigid. Lock all slides that are not to be moved.

Most gear cutting for wheel cutting should be done in one pass for each tooth.

CHAPTER 13

A spindle with tapered roller bearings

Introduction

This is the most sophisticated design in the book. It uses heavy duty tapered bearings and separate seals. It is also the most rugged of all the designs. I do not think you need to make a such a heavy duty spindle for your day-to-day amateur engineering needs.

This spindle could be made ½ inch (or more) longer and ¼ inch more in diameter to make it even more heavy duty. Increasing the length increases the distance between the bearings and thus increases the rigidity of the spindle as determined by the bearing span.

I should mention that this spindle is a little harder and more time consuming to make than any of the rest of the spindles in the book. I was not totally satisfied with the fact that the front bearing is so far back into the housing. This was the best compromise I could come up with and still stay within the 2.000 inch diameter spindle housing, and use automotive taper bearings (for ease of procurement).

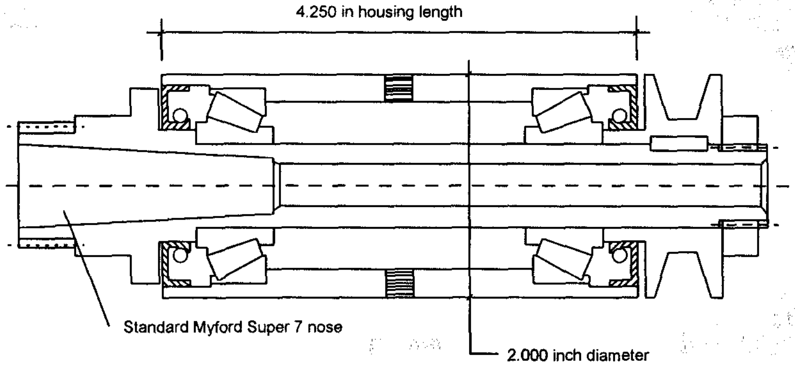
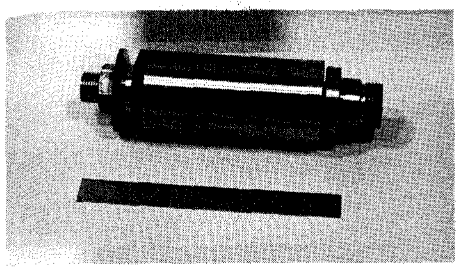


Figure 13.1 *Section across spindle with taper bearings. Note that the need for seals moves the front bearing farther inboard in this design.*



Two inch (50.8 mm) diameter spindle with tapered roller bearings. This is the smallest taper bearing spindle that can accommodate the spindle nose of the Myford S7.

Making this spindle housing 2.250 inches in diameter instead of the 2.000 inches shown will allow you to use the clam shell mounting plates that were made in Chapter 4 for mounting this spindle.

Using taper roller bearings makes this a substantial spindle and some amateur engineers will consider it to be overkill for the Myford Super 7B. There will be others who think I should have selected this as the basic design in the book. These are both valid observations and this spindle is included to define the heavy duty side of what might be made for the 7B. Those with larger lathes who want a substantial spindle can also use this design. Owners of larger lathes should increase the length of the spindle by one to one and a half inches depending on their needs.

Alternatively, the spindle can be built without the ability to mount chucks and face plates as shown above. Note that this moves the Morse taper in and decreases the amount of metal between the inside race of the front bearing and the Morse taper. This is not critical but would not be acceptable in an industrial spindle. Figure 13.2 is included only to show you what can be done. The spindle is not described in detail but can be built by following the instructions and changing the dimensions as needed.

Bearings selected

Quantity	2
Inside diameter	0.750 in (20mm)
Outside diameter	1.750 in (45mm)

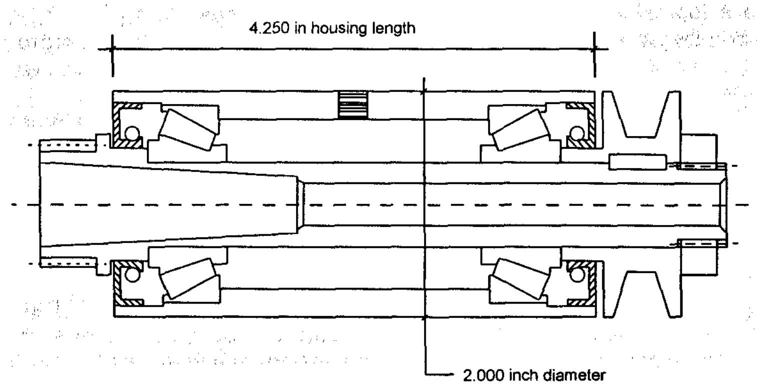


Figure 13.2 *Section across spindle with taper bearings. Building it without the chuck register shortens spindle.*

Thickness (overall) 0.625 in (16mm)
Seals Both sides

Seals selected
Quantity 2
Inside diameter 1.000 in (25mm), shaft size
Outside diameter 1.850 in (48mm)
Thickness (overall) 0.300 in (8mm)

Materials needed

Description	Diameter	Length
Spindle	1.750 in (44mm)	6.750 in (170mm)
Housing	2.000 in (50mm)	4.250 in (115mm)
Pulley	2.000 in (50mm)	1.125 in (30mm)
Nut*	0.750 × 16 tpi, 20 × 1.5mm	

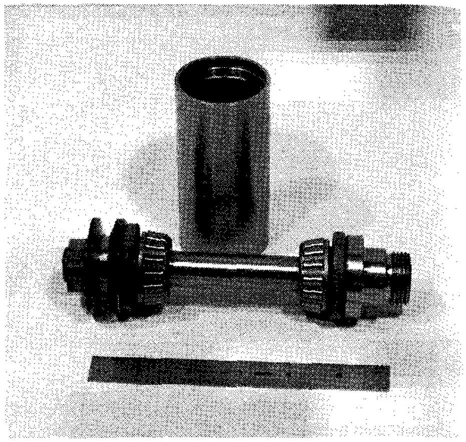
*See Appendix 2 for UK equivalent

First purchase the bearings and the seals. The seals selected should have the same or a slightly larger outside diameter than the bearings. Their inside or sealing diameter should be 0.250 inches larger than the ID of the bearings. We will make the parts to fit the bearings and the seals. Following a logical sequence, the parts will be fabricated in the following order:

1. Spindle.
2. Main housing.
3. Driving pulley.
4. Nut for driving pulley.
5. Final assembly.

1. Spindle
The sequence for machining the spindle is as follows:

- Centre the blank in the 4-jaw.
- Face and drill a large centre.
- Drill hole ¼ inch in diameter as far as it will go.



Internal spindle assembly of tapered bearing spindle showing relative bearing and seal placements on the shaft. A wide bearing placement is desirable for stiffness.

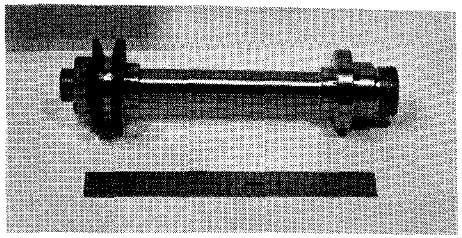
- Open this out to ½ inch in diameter as far as it will go.
- Support end with a ball bearing centre.
- Machine Myford S7 spindle nose on end.
- Reverse and re-centre using two face plates.
- Face and drill a large centre.
- Drill hole ⅜ inch in diameter to meet hole from other side.
- Work between centre and reversed face plate.
- Machine rest of spindle.

The spindle will be machined out of a piece of material 1.750 inches in diameter and 6.750 inches long. We will not machine the spindle No 2 MT at this time – that will be done as one of the last operations when we finish the spindle in situ in the bearings.

The initial work will be done between the 4-jaw and the tailstock centre. We can rough machine the spindle nose to shape by holding the part accurately between the 4-jaw and a ball bearing centre in the tailstock. A lot of material has to be removed from the spindle in this phase of the work just to get the nose roughly to size. Roughly to size means that we leave at least 0.050 inches on faces and 0.100 inches on diameters on each critical dimension for final finishing.

Remove the centre and mount your drilling tackle. We can drill the centre hole out to 0.500 inches, or as far as your drill will allow, in anticipation of boring it to its finished taper dimensions. The material might have shifted so face the end again to make sure that you have a true surface. Bore a slight 60-degree recess in the end of the hole to allow the spindle to continue to accept the centre accurately. Replace the centre.

Note
If using Myford chucks on these high-speed spindles it is well to remember that cast iron chuck bodies have a finite rotational speed before they burst.



Tapered bearing spindle and pulley showing the polished seal surfaces needed on the spindle shaft and the driving pulley. Make these diameters to suit the seals that you use.

Once the nose has been machined to rough dimensions, check your work carefully to make sure that the machined nose is actually suitable for making the finished spindle. If not, now is the time to start over before you have done a lot of finishing work.

Instructions for machining the spindle nose threads are given in Chapter 3 on the 2.250 inch diameter spindle.

Once you have the registers and threads right, mount the two face plates on the lathe spindle. Mount and centre spindle on the second face plate as

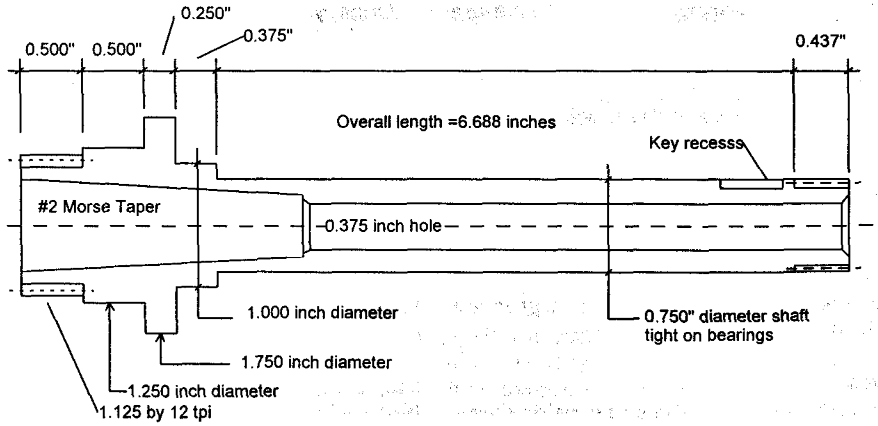


Figure 13.3 *Spindle dimensions.*

described in Chapter 3. Remember that the centring has to be perfect at this stage.

Now we have to polish, to a high mirror finish, the one inch diameter part of the front of the spindle that is going to be under the oil seal. If we do not get this bright, we will shorten the life of the seal. Surfaces can be brought to a high finish by applying successive grades of emery paper to them with a drop of oil. Start with 220 grit, then 400 grit and finally 600 grit and even 1200 grit. Spin the work at 1000 rpm and clean up between grades of paper so that no large grains remain to spoil the work as it progresses to finer and finer finishes.

Now work between a face plate and the ball bearing centre as we did with the basic spindle. Face and centre the other end of the spindle. Drill a ⅜ inch hole through it to meet the hole from the other side. Make sure that the centre is perfect after the drilling (fix it if it is not) and bring the tailstock centre up to the part.

Again rough machine the outline of the spindle first.

We will start the finish work by machining the seats for the front seal, then for the bearing inner races. We are aiming for a firm to tight push-fit for the bearing inner races. This is the hardest part of making this spindle. The portion of the shaft between the bearings can be turned down just a bit to allow the front bearing to slide over to its seating after it has been slid over the back seating.

First we have to machine the back of the register flange and the back of the seat for the front seal. Once the flange and seal seat are right we can proceed with the rest of the spindle.

Caution

Both bearings have the same inside diameter. Do not try to cut both the front and back bearing seat at one time because if there is any taper in your tailstock setup, you will get one seating looser than the other, the danger being that you will over-cut one seat.

First prepare the seating for the back bearing, then prepare the seating for the front bearing. The space between the two seats does not need to be a tight fit but should not be too loose because we do not want to remove any more material than we have to. The pulley has to be a tight fit because it forms an oil seal in this design. This means that the front bearing has to pass over almost the entire spindle to get to its seat. Remember – the seating has to be tight at each bearing but can be loose in between bearings. This means you have to know where the bearings actually fit in the finished spindle.

Once you are happy with the seating of the bearings, it is time to cut the threads for the nut that holds the pulley and inner races in place. These threads should be cut to match the purchased nut. The threads are to extend 0.125 inches under the pulley (this 0.125 inches includes the recess to clearing the threading tool).

Once you have a nice set of threads cut, chamfer on all edges, and clean up the work.

This completes all the work on the outside of the spindle except for cutting the keyway. The No 2 MT still has to be cut.

2. Main housing

The blank for the main housing is a piece of free machining steel 2.000 inches in diameter and 4.375 inches long. This is to be finished to 4.250 inches long. If hollow bar with a 1.000 inch hole in it can be obtained this will save a lot of work. If not, we will have to make the bar hollow (not a trivial matter on a small lathe).

The two ends of the housing are identi-

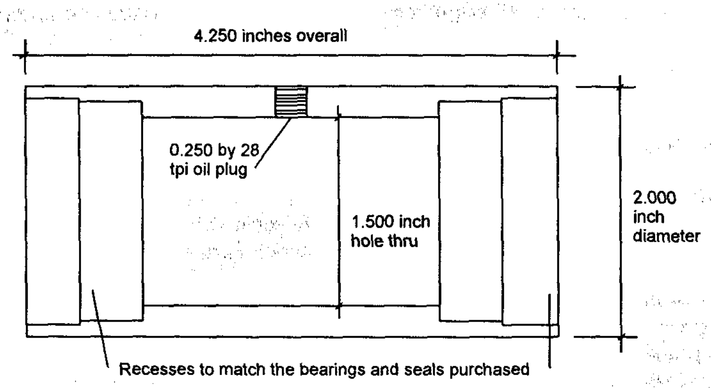


Figure 13.4 *Housing details.*

cal – each end holds the outer race of one bearing and one seal. Once the races are fitted they do not need to be removed. However, if you get them halfway in and jam them in there, it is a mess because they will be very hard to get them out. We need to work hard to keep that from happening.

I will describe the work needed to be done for one side and then the same effort is to be repeated on the other side after the part has been turned around in the 4-jaw and sized to a 4.250 inch length.

Hold the housing blank in the 4-jaw and centre it to run true at both ends. Face the end and drill a centre in it.

Pass a file over the housing to clean up all the bumps and blemishes. Polish with emery cloth – this should give you a nice finish. If the finish is not to your satisfaction, consider taking a very slight cut with a round nosed turning tool to clean up the bar to suit, but avoid doing this if you can. (Keep in mind that we need to hold this in the clams so we cannot take too much off.) Then polish it up. We want an accurate, polished surface to work with so that we can centre the spindle accurately when the need arises.

The bearings and the seals may not be the same size: it is best to bore the seats for the seals first and then bore for the bearings because there is a possibility that we will disturb the bearing bore while we are making the seal seating. By getting the seal work done and out of the way we can then bore for the bearings and be assured that we will not disturb our work. The rule is to always do the most critical part last, even though that is the worst time to make a mistake.

I am not giving specific dimensions for these recesses because the chances are that the bearing and seals will not be the exact size that I have specified, so make the recesses to suit. If the seal and the bearing have the same OD, the recess has to be sized for the bearing and the seal will conform to the recess. Use a carriage stop to make sure that you do not overbore the seal and/or bearing recesses.

Before you remove the housing from

the chuck, always chamfer all edges and polish up.

Once you are happy with one side of the housing, turn the housing over, turn the length to exactly 4.250 inches and make the recess on the other side.

3. Driving pulley

The blank for the driving pulley is a piece of free machining steel 2.000 inches in diameter and 1.000 inch long. As always it is the same material as used to make the housing.

Hold the blank in the 4-jaw and centre accurately. Face the blank and drill a 0.500 inch hole through the blank. Bore this out to 0.750 inches to be a tight fit on the spindle. Remember: the pulley has to be a tight fit because it forms an oil seal in this design.

Turn the shoulder on the pulley for the seal. This is the same size as was turned on the front side on the spindle. Chamfer all edges on this side and polish. The seal seat has to be protected at all times, any blips on this surface will ruin the seal in a hurry. Do not use this surface to hold the pulley in a chuck or in any other device, under any circumstances without protecting it.

Instructions for turning the pulley and cutting the keyway are given in Chapter 3. Please refer to those instructions to finish the pulley.

Like the taper, the drive pulley is best machined in the spindle bearings – please refer to the instructions in Chapter 3.

4. Nut for driving pulley

This nut is the same as the nut for the basic spindle in Chapter 3.

See the detailed instructions for modifying the nut in Chapter 3. This nut has to have a set screw placed along one face for a locking device. The reason for this is that we need a very fine adjustment on the nut to allow us to set the bearing clearances to the right setting and this is the easier way to do this. The set screw should be a very short 8–32 socket head set screw. Make a short brass pad (0.060 inches long) to go under the set screw so that it does not mar the threads when the set screw is tightened home.

Test assembly

The purpose of the test assembly is to determine that everything will actually fit together as planned.

Assemble up the spindle and make sure that the seals seal and clear the rotating surfaces properly.

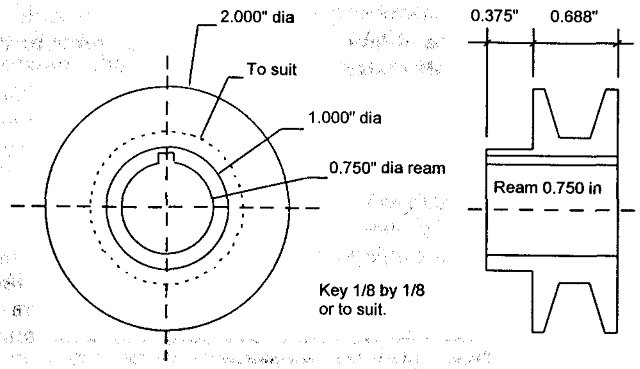


Figure 13.5 *Driving pulley dimensions.*

5. Final assembly

Final assembly takes place once we are sure that we will not want to take the spindle apart again, before the Morse taper is reamed and the pulley groove is turned. Since this taper is machined in the bearings to be absolutely true to the bearings, it is best if this assembly is never disturbed after this operation.

Clean and grease everything.

It is likely that the bearing outer races are already in place (before final assembly). This is OK because it is not worth the trouble to take them back out. Clean all parts and grease them lightly with a semi-liquid lithium grease – a grease works better than an oil. A sticky grease like that used in front axle bearings of a car is a good choice.

Since both ends of the spindle housing are identical, it does not matter which side the spindle is introduced from. Place one greased bearing inner race in the spindle, place a seal over it and seat it in the housing. Place the spindle in the housing from this side and the other greased bearing inner race on the spindle from the other side and press it home. Place the second seal in place. Place the pulley on the spindle and press it home. Place the nut on the spindle and take the nut up by hand.

Now slowly tighten the nut onto the pulley as you rotate the spindle by hand. A point will come when it will no longer be possible the rotate the nut by hand. At this point place a ½ inch rod in a collet and place it in the spindle nose. Tighten the collet down. Place the half inch rod in the 3-jaw in the lathe and bring the tailstock with a centre in it to support the other end of spindle. Lock the lathe spindle. You can now place a wrench on the pulley nut and take up the nut some more. Not much force is required on the wrench. Keep tightening the nut as long as the spindle does not get stiff. Once it gets stiff tap the spindle back and forth with a plastic mallet all the way round from both sides to make sure that everything is seated as far as it will go. Tighten the nut some more and repeat the tapping. Once everything has seated firmly loosen the nut just enough to remove the tightness. The slightest pre-load on the bearings is desirable. Keep in mind that the seals create drag on the spindle. Set the lock nut set screw.

Machining the Morse taper and the pulley groove

See the detailed instructions given in Chapter 3 on the basic spindle. Follow those instructions. The pulley groove should be made to match the belting you will be using to drive the spindle.

CHAPTER 14

Driving the spindles

Introduction

The two major concerns in driving a spindle are making sure that adequate power can be delivered to the spindle at the right speed. On these small spindles it will seldom be necessary to deliver much more than 0.25 horse power or about 200 watts to the spindle. This can be done with a standard, appliance type, fractional hp belt that is ⅜ inch wide for the larger spindles. On the smaller spindles, less power needs to be transmitted but at higher speeds up to 0.125 horse power or about 100 watts can be transmitted with a 5mm or 7mm round polyurethane belt. (You need to understand that to transmit the same amount of power a smaller belt can be used at a higher speed.) A polyurethane belt called Bondaband is available from N.S. & A. Hemingway, 30 Links View, Half Acre, Rochdale, Lancs., OL11 4DD. **Do not try to use PVC belting as this will stretch far too much.**

Spindles may be driven from overhead gear or from motors mounted right on the carriage of the lathe. I prefer that they mount to the carriage so that they can move with the spindle being powered.

Note
To repeat the statement in Chapter 13, if using Myford chucks on these high-speed spindles do remember that cast iron chuck bodies have a finite rotational speed before they burst.

The drives needed by these small spindles may be divided into two basic categories: (1) normal milling drive and (2) high-speed grinding drive.

Normal milling drive

For most of our purposes, we can run the milling spindles at between 1400 and 1800 rpm. To do this we will be using motors that run at 1750 rpm (1450 rpm in UK). The cuts taken will be light and in most cases we will be using nothing more than ⅜ inch and ½ inch end mills for milling.

A drive that will serve well for this application is best made from a recycled ¼ hp appliance motor of the type one may find on a small residential furnace, on a washing machine or on a clothes dryer. These motors are relatively easy to mount if you find one that already has a base mounting base on it. Motors without a base are best used for some other application because we do not want to

take the time to make a compact base for the motor. If some other compact motor can be found, it too can be used. DC motors should not be used.

We will avoid the need for belt adjustment by letting the weight of the motor tighten the drive belt. This means we have to mount the motor on a swivelling base.

It is important that the motor mount we design be easy to put into use. If the spindle is mounted to the vertical slide, and for most milling applications it will be, then it would be best if the motor was mounted on the carriage also so that the motor and spindle can move together as the assembly is used. The major advantage of doing this is not during cutting but rather when you move the spindle away from the chuck to inspect your work, then everything moves away as one unit and you do not have to worry about the motor belt coming loose.

The weight of the motor maintains the tension in the belt. The belt tension can be adjusted by adjusting the moment that the weight of the motor applies to tension the belt. The pivot point for the motor is attached at/to the cross slide so that it moves with the entire assembly. In this arrangement the vertical slide can be moved up and down without adversely affecting the belt tension.

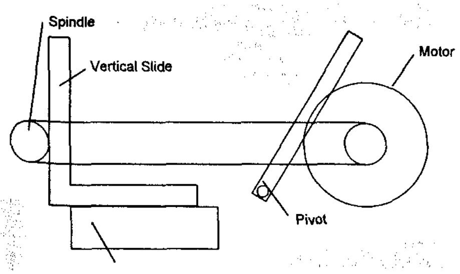


Figure 14.1 *Schematic of motor mounting arrangement.*

Usually, but not always, the spindle will be located between you and the lathe axis. This being the case it is preferable to have a motor that can be reversed with ease. On most motors the reversal is effected by reversing the starting windings. Usually a plate on the motor will give you information on how to go about doing this. It is well worth the effort to mount a double pole-double throw switch in the starting windings so that you can reverse the motor whenever you want to with ease.

The pulley on the motor can, in general, be the same size as the pulley on the spindle (for most purposes). If an adjustment needs to be made in the spindle speed, it is easier to make it by changing the size of the motor pulley and, if necessary, the belt.

When using milling cutters, beginners should remember that the major enemy of all cutting tools is heat. We do not want the cutting tool to get hot. We can keep it cooler if we use slow speeds and coolant at all times. Slower speeds mean slower feeds. Take your time.

All this means that there is no good reason for us to run the milling spindle at high speed and that we can use a 1:1 drive from the motor for most of our milling applications. Tiny mills will need a higher speed.

I made the motor drive for my cartridge spindle using the following raw materials:

- ¾ by ¾ by ⅛ inch angle iron (or ⅝ by ⅝ will also work)
- ½ inch rod
- ¼ hp motor
- ¼ inch fasteners
- Some scraps from the scrap bin

First we need to attach a couple of pieces of angle iron to the base of the

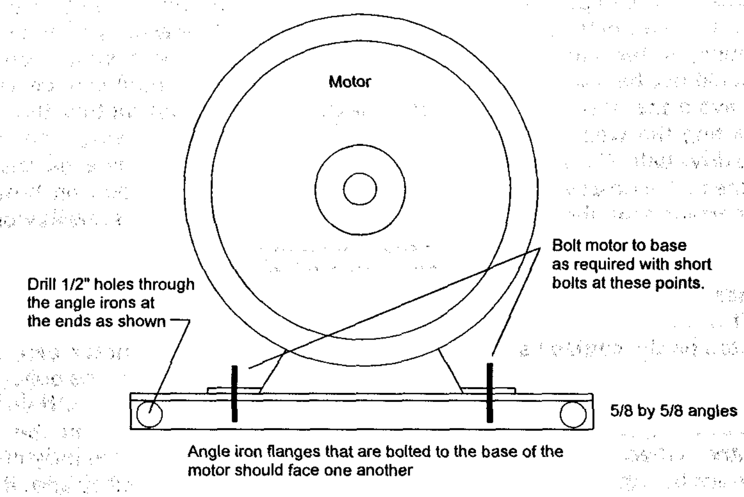


Figure 14.2 *A simple motor mounting.*

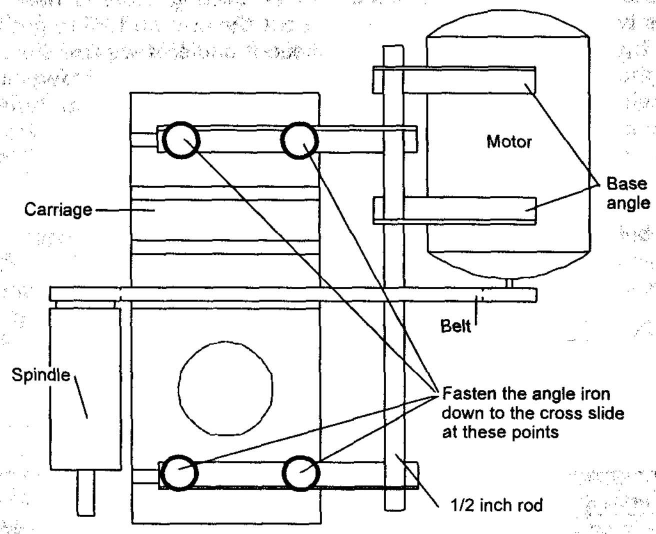


Figure 14.3 *Motor mounting arrangement as seen from above. The spindle can also be mounted facing the other way. The motor can be flipped end for end.*

motor so that we can drill holes for the pivot shaft in them. These angles should be about two inches longer than the diameter of your motor. See Figure 14.2 for details. The mounting is not critical – we are trying to create a way to pivot the motor easily.

Next we need to have a way to support the pivot shaft on the cross slide. This can be done by mounting two angle irons to the cross slide as shown in the figure.

High-speed grinding drive

The high-speed application for the spindles is light grinding. In grinding, the cut you can take is dependent on two things: the size of the motor you have and how much coolant can you get to the surface being ground. In our case the answer to these questions is "Not very big and not very much". This means we can only grind off a little at time, small feeds will have to be used at all times. This in turn means that we do not need a powerful drive system.

When designing a high-speed drive unit we would be well advised to use a high-speed motor. Since we will not be using DC motors, it means that a 3500 rpm (2900 rpm in UK) AC motor will most likely be used. We will want the surface speed of the grinding operation to be between 4000 and 6000 feet per minute. On a 4.000 inch diameter grinding wheel this means about 5000 rpm. We have to check the maximum speed of the wheel we use/buy to make sure that we can spin it at this speed safely. Smaller wheels need to spin faster and you need to understand that the small Dremel Moto wheels cannot really be spun as fast as they need to be for optimum cutting. This does not mean that we cannot use them – we just have to be more cautious about how we do it.

A high-speed grinding drive is best accomplished with an overhead drive arrangement. The reason for this is that the motor pulley gets quite large as the speed of the spindle increase. Any pulley over 6.000 inches in diameter is difficult to handle at close quarters on a small lathe.

The overhead drive system can be supported either from the roof joists if they are not too far up (basement joists are just about right) or from the lathe itself. A number of designs have been discussed in *Model Engineer* from time to time and most of these can be used with the spindles discussed in this book without difficulty.

The problem with overhead drives is that they are quite time consuming to create, considering that they do not get used very often. On the other hand if you are going to be cutting a lot of clock gears, it might be well worth your while to build an overhead drive.

Tool-post grinder drives

We have two tool-post grinder spindles that we have to address: the OD grinder spindle and the ID grinder spindle. These have spindle housings that are the same size so one arrangement can serve both spindles although the ID spindle has to be driven at a higher speed.

The grinding wheel centre should be mounted at the same height as the lathe spindle centre. (There will be times when you will want to mount these to the vertical slide. That is not being addressed here.)

These relationships are shown schematically in Figure 14.4.

First we will create a mounting for the spindle and then add the motor and drive.

Figure 14.5 shows the periphery of a 4 inch wheel mounted on the OD grinder. The grinding wheel must extend past the mounting to allow long shafts to be

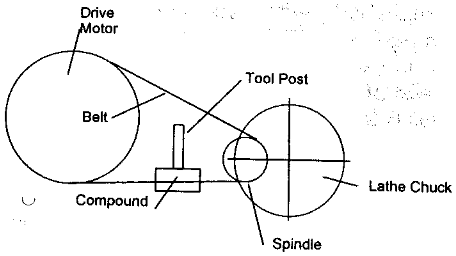


Figure 14.4 *Tool-post grinder schematic relationships.*

ground. This requirement does not apply to the quill mounted wheels on the ID grinding spindle. Since we know that a 4 inch chuck will clear the top of the cross slide, we know that a 4 inch grinding wheel mounted at centre height will clear the cross slide also. It also means that this is about the largest wheel that we can mount on the OD grinder spindle unless we can fix it that the wheel is past the cross slide, then a larger wheel could be used. However, large wheels mean large motors and we want to avoid that on our small lathes.

The plate that mounts to the top of the compound slide has to be large enough to allow the side plates to clear the compound slide on your particular lathe. The plate does not have to be able to rotate on the compound because the entire compound can be rotated on the cross slide.

The motor for the tool-post grinder arrangement has to be mounted in such a way as to meet the following basic requirements:

- Move with the spindle.
- Not be in the way of the work.
- Not be in the way of the operator.
- Belt drive must clear the work.
- Allow for easy belt adjustment.

As we did with the cross slide mounted drive, we can use a half inch rod that passes through the plates for the compound mounting to be the support for the motor. A new belt of a suitable size will have to be obtained for the new centre-to-centre distances between the two pulleys.

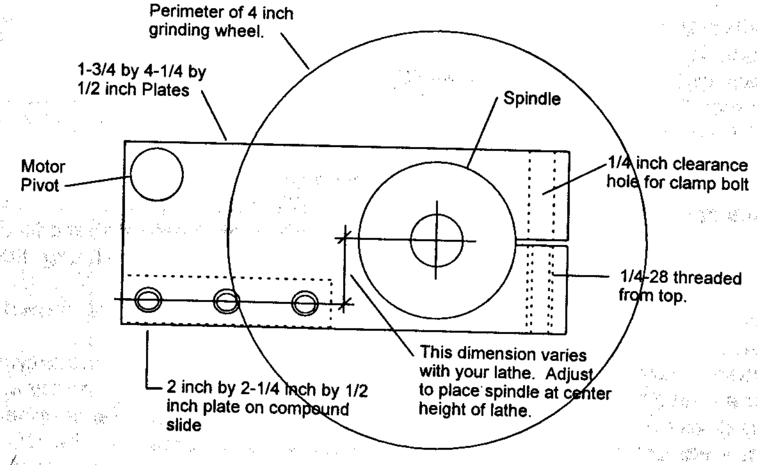


Figure 14.5 *Spindle clamping plates – elevation.*

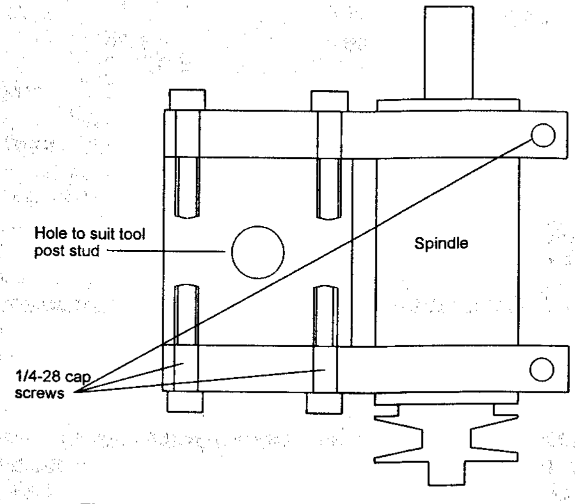


Figure 14.6 *Top view of spindle mounting.*

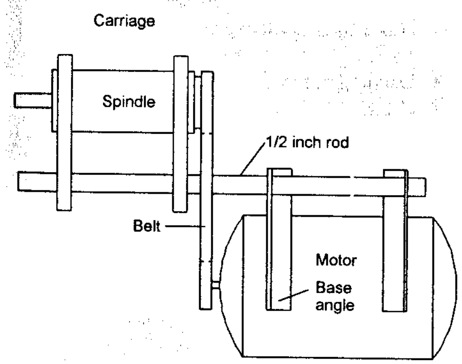


Figure 14.7 *Top view of the tool-post mounted spindle. The motor can be offset to either side as can the spindle.*

The biggest advantage of a shaft mounted motor is that it is easily moved back and forth and can be flipped over end for end in a few minutes if it is in the way of the work. The arrangement is also easy to make and adjust.

Caution

Safety is always priority number one.

We have not given any consideration to safely as regards the exposed belt drives in the above discussions. Depending on how you intend to use your setup, you should always make the necessary arrangements to ensure that you have a safe operation.

CHAPTER 15

Notes on using the spindles

I imagine that the general feeling is that if you can make a spindle, you know how to use it, however, this is not necessarily true and certainly was not so in my case. There is a considerable learning curve that can be minimised with a little guidance.

The first time spindle user can use the following notes as guidance for using the various spindles described herein. It took me a while to learn how to use spindles when I first starting using them and these notes reflect the experience I have gained.

The most important thing to keep in mind is that the smaller the part that you are making, the more critical the setup is. By critical I mean that each and every aspect of the set up becomes very important. The system is now much less forgiving.

It helps to keep a shop log. Start a shop log and use it – it is a very useful resource. Never write anything down anywhere except in your shop log. Sketches, ideas, notes, dimensions, phone numbers, birthdays, promises, lists of things to be done and what you did and how you did it. Everything goes in the log. It takes me about a year to fill a log book and I use one ruled at 5 divisions to the inch in two directions. It makes nice 0.200 inch square graph paper.

The following aspects of spindle use are discussed:

- Cutting gears for clock making.
- Making a dividing plate for a dividing head.
- Drilling cross holes.
- Cutting a keyway.
- Cutting a slot in a screw head.
- Drilling very small holes.
- OD grinding.
- ID grinding.

Let us discuss these one at a time to clarify the needs and procedures:

Gear cutting

Read the entire section before proceeding. We are not going to discuss how to set up a dividing arrangement, just how to cut the teeth. We are discussing tiny brass clock gears as compared to larger work.

Suppose that we are cutting a clock gear that has an outside diameter of 0.300 inches and 20 teeth. The specifications for this gear might be as follows:

Outside diameter	0.500 in
Number of teeth	20
Material	Brass
Width of gear	0.250 in
Hole through gear	0.125 in
Module	as needed
Type of tooth form	as needed

The gear outline is first formed accurately on a piece of 0.500 inch brass held in a 3-jaw chuck or, better yet, in a collet. Form both sides of the gear to finished dimensions – you cannot machine it after the teeth are cut. The teeth will be too weak and will just bend over no matter how sharp the tool. Do not drill and ream the inside hole just yet, we need the stiffness on the shaft at this time. Instead turn a true point on the end of the shaft to indicate the exact centre of the gear.

Coat the gear blank completely with marking blue. This will make it much easier for you to see what you are doing as you cut the gears.

Mounting the spindle

Remove the compound from the cross slide and plug the hole it was in.

We are now ready to mount the spindle on the vertical slide. The spindle has to be exactly at right angles to the lathe axis and exactly parallel to the lathe bed and thus the cross slide bed. Understand in your mind that moving the spindle up and down and in and out on the cross slide will not change any of these aspects of its relationship to the gear teeth to be cut.

The spindle is made parallel to the turning face by bringing the vertical slide on which it is mounted up to a face plate and securing it while it is up against the face plate. Then mount the spindle on the vertical slide.

The spindle is made parallel to the lathe shears by using a square between the shears and the face of the spindle housing as the spindle is mounted onto the vertical slide.

Cutting the teeth

It is better to start by making a gear with a few teeth (16 to 24) because you have to cut all the teeth before you can really see what you did, therefore fewer teeth make for a less painful experience. It is also easier to cut teeth that are easier to divide so that you do not have to worry about getting the divisions right. Pick a number that turns the dividing handle a full number of turns so you do not have to mess with the dividing head arms. Twenty is a good choice but it will, of course, depend on the actual gear that you are cutting.

Mount the cutter in the arbor and the arbor in the spindle. Lower the cutter axis to the height of the lathe spindle, now move the carriage towards the part that you had machined as the gear blank and centre the gear cutter exactly on the centre of the point you formed. Use a magnifying glass to make sure that you are at the exact centre. Lock the cross slide by tightening one of the screws that adjusts the gibs. The cross slide is not to be moved again until we are done with the gear cutting.

Next raise the spindle up with the vertical slide so that the cutter clears the outside diameter of the gear. Tighten the gibs on the vertical slide so that the movement is a bit stiff. We want to fix it such that the spindle will not drop down

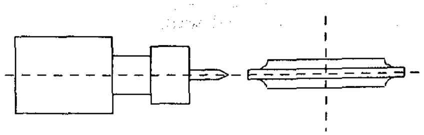


Figure 15.1 *Aligning the cutter with the gear blank (top view).*

by gravity as we lower it. Back the handle up to tighten up against the nut. Turn the spindle ON and very slowly lower the spindle and cross slide until the cutter just grazes the top of the gear. Back the handle up to take up the slack and make a note of the reading.

Taking a cut across the gear, make a conservative estimate of how deep the teeth have to be cut. This can be done with a pair of calipers and a magnifying glass. Be conservative and write this value down too. Lower the spindle by this amount plus 0.050 inches and then back it up the 0.050 inches. This takes up the backlash. Tighten down the gib on the vertical slide and make a cut. Turn the gear by one tooth position and make another cut. You will remember that we were not going to discuss how this was to be done (dividing head on spindle etc.).

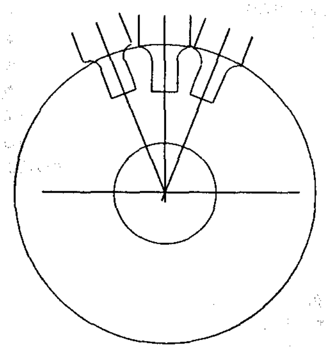


Figure 15.2 *Showing how cutter depth affects the land.*

Now with a magnifying glass take a look at how much uncut material is left on top of the tooth just formed. Consider this the land. We want it so that the marking blue just barely disappears when we cut two, identical, adjacent teeth. So half the land we are now seeing belongs to each tooth (cut). The spindle has to be lowered enough to remove half the material at the land, the other half will be removed when we cut the last tooth again.

Loosen the gib and do not allow the spindle to drop. If you want to lower the spindle 0.005 inches, lower it say 0.055 inches and then back it back up 0.050 inches. This is the only way to eliminate backlash in an operation like this. Write down the dial reading – this is the reading we will work from the next time. Retighten the gib and take a cut.

Move the gear over to cut the next tooth and take another cut. If the land now remaining on the outside is half of what it was at the last tooth, you are at the right depth. Tighten all gibs down and cut the rest of the teeth. The land should just barely disappear when the next tooth is cut.

Never go back to deepen a tooth. Keep moving forward and pick the last few shallow teeth after all the other teeth have been cut.

Do not remove the gear blank from the chuck until all the teeth have been cut and the hole has been drilled and reamed. Machine the front but do not touch the teeth. Then part the gear off a wee bit longer than the teeth to make sure that the teeth are not touched. Rub the excess off on a piece of 400 grit emery paper laid on a flat surface.

You may get a good gear if you follow these instructions, but be willing to do it over if you have to. It is surprising how much you learn from cutting your first gear. I made four before I was happy with one.

Drilling and reaming the hole is the last thing that is done before parting off. When you form the gear outline, leave as much material as possible to make the setup as stiff as possible. Cut away material from behind the gear so that the

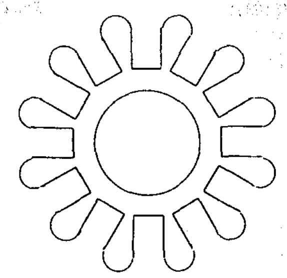


Figure 15.3 *A theoretical 12-tooth gear to show tooth form (exaggerated).*

cutter does not have to cut any more than it has to on the gear itself. Cutting extra material wears away your expensive gear cutter. However, there will be times when you will have to leave extra material to have a stiff setup.

What we are aiming for is a procedure that we can follow that will yield a good gear every time. Once we get that down pat, we will write it down and follow it religiously. A written down procedure that works with your equipment and your skills is the target.

Gears made from plates have to be mounted to an accurately turned arbor and nut and provided with adequate backing plates on both sides to allow them to be cut. The backing should come as close to the bottom of the teeth as possible.

If you need to cut a rack, it is best done with the cutter in the lathe spindle and the rack mounted on an angle plate on the vertical slide. The teeth have to be spaced very carefully and every precaution has to be taken to avoid backlash errors. Large racks need to be cut on the carriage with packing as needed because a large cutter will not clear the vertical slide properly.

Making a dividing plate for a dividing head

There are times when we are called upon to make a special plate for a dividing head or in order to do a special job. The holes can be drilled by the lathe spindle or by the auxiliary spindle. It is usually easier to hold the part in the lathe spindle. This is so because it is easier to turn up the form needed in the lathe and then to machine it in place, without moving it, when doing precision work. This means we have to set up the dividing gear on the back of the lathe head.

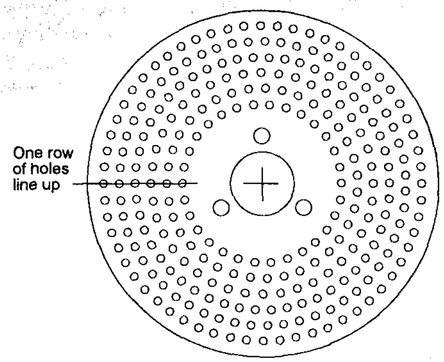


Figure 15.4 *Dividing plate.*

If the opportunity arises and if you can afford it, get yourself an extra chuck or two, and get in the habit of leaving work in a chuck if you need to remove it from the lathe. In this connection beginners are advised that a 4-jaw is more useful than a 3-jaw chuck by being more versatile (a major benefit).

If only one row of holes has to be drilled in the plate, it is not important to have the spindle at the same height as the lathe nose. If more then one row has to be drilled, the rows have to be spaced evenly and there will be a point where one hole from each row lines up on a radial line. In order to do this right the spindle and the lathe nose have to be at the same height.

It is easier to drill all the holes with the appropriate centre drill. The centre drill will locate the holes more accurately. The depth of the hole drilled should be such that it is about 0.010 inches in diameter greater than the holes to be drilled for the locating pin. So, if we are to use a 3/32 (0.093) pin, the centre drill should go in deep enough to make a 0.103 inch recess. When this is drilled out to 0.093 inches, a slight chamfer will remain. This will help to guide the locating pin. (This also means that the holes have to be a minimum of about 0.125 inches apart.)

Once all the centre holes have been drilled, the work can be moved to a drill press and finished there if that is preferred. Deburr all your work.

Note: if the dividing can be done on the George Thomas dividing head, the drill is best held in the lathe spindle. In that case we would not be discussing this here! (I strongly recommend that you consider making the George Thomas dividing head. You will enjoy making it and you will use it almost every time you are in your shop.)

Drilling cross holes

When drilling a cross hole in a shaft, the shaft, is held in the lathe spindle, and the drills are held on the vertical slide in the spindle. The important thing is to get the spindle at the exact lathe nose height so that the hole will go right through the centre of the shaft. Since this is an often-needed setup, the best thing to do is to make up a spacer that will allow you to mount the spindle *on the cross slide* so that it is exactly at lathe centre height, with relative ease. Then the only remaining concern will be to get the spindle exactly parallel to the motion of the cross slide. This is important to ensure that the drilling takes place along the axis of the spindle. Otherwise the drill will wander and eventually break.

When drilling a hole that is not at right angles to the shaft being drilled, it is sometimes necessary to mill a small flat on the shaft with an end cutting mill to create a flat that we can drill straight into. This can be done with the drilling spindle.

Incidentally, it is also well worth your while to have a length of rod that is exactly the length of the distance from the bottom of the spigot on the lathe spindle to the top of the lathe bed. This rod is used to set the height of the spindle quickly to lathe spindle height when the spindle is mounted *on a vertical slide*. Both spigots are the same size and measuring to the spigot lets us ignore whatever may be in the spindle.

Height spacers

On my lathe, the lathe spindle centre is 2.125 inches above the top of the cross slide table. This has to be measured on every lathe because every lathe can be slightly different in this dimension. Write the exact dimension down in your shop log on page 1.

The spindle itself is held in two 2.500 inch wide plates that have been cut in half. When held in this clam, the spindle is 1.250 inches above the surface that it is mounted on. This means that we need spacers or risers that are 0.875 inches thick to place under the 2.500 inch by 4.000 inch plates. The easiest way to make these spacers is to make them out of ¾ inch round stock. Make 4 cylinders 0.875 inches long with a 17/64 hole through each one. Chamfer the edges. You will also need longer mounting studs for the T nuts. Make them to suit.

Cutting a keyway on a shaft

Cutting a keyway in a shaft is done in two basic ways depending on the type of key to be accommodated. Usually either a square key or a half moon key will be used. For the model engineer, the square key is the preferred key. Of course the key does not have to be square – it's just that square keys are easier to use. For almost every application that the model engineer is interested in the key can be made from brass or soft iron. Brass is easier to work with and more than strong enough for the work we are interested in – all you need for a key is a scrap of plate.

Half the key goes into the shaft and half the key goes into the pulley or whatever is mounted to the shaft. We measure from the theoretical OD of the shaft. The key depth can be over-cut in either or both directions but it is better not to. The key width should be a snug fit. If there is a set screw, it should be positioned at the key slot. When cutting a set screw hole and a keyway, cut and tap the set screw hole after you cut the keyway, that way you do not have to line up the keyway with anything when you cut it.

It is easier to get the slot width right with a Woodruff key cutter than it is with an end mill – an end mill can tend to cut oversize. Here I am making the assumption that the model engineer never needs to cut a key slot over ⅛ inch wide.

Once the spindle is set up, move it over to touch the nearside of the shaft to be slotted. Then raise the VSS up and move it into the shaft, half the shaft diameter plus half the cutter diameter. Tighten down the gibs and make your cuts. The use of cutting oils will be helpful. Check your work with the key that is going to be used in the slot.

Clean and deburr before sliding the pulley back onto the key and shaft.

Cutting the keyway in the pulley is described in detail in Chapter 3 on the cartridge spindle.

Cutting a slot in a screw head

After making a perfect screw, we often resort to cutting the slot in it with a hacksaw and spoiling the whole effect. No more. Now that we have a spindle, we can cut perfect screw slots ever time.

The trick is in holding the screw so that the spindle can be used to cut the slot. The easiest way to hold the screw is the lathe chuck. A way has to be found for holding the chuck steady while the cut is made. This can be done by locking the spindle by engaging the back gear and then pulling the lathe spindle over to one side with a weight applied to the chuck.

An alternative method is to hold the lathe chuck steady with an expanding mandrel with an arm that you can tie down to the table the lathe is on. A drawing that shows how to make such as mandrel and arm is provided in Chapter 16.

Mount the cutter to be used on a half-inch mandrel and mount in the spindle.

The spindle is best mounted on the vertical slide. Lower or raise the spindle to lathe centre height. Lock the carriage to the lead screw with the half nut and disconnect the system from the gearbox. Cut into the screw by moving the carriage – you can control the depth of the cut by watching the divisions on the lead screw handle. Slots should be about 1.25 times as deep as they are wide.

Drilling very small holes

Here are few tricks to keep in mind when drilling small holes:

- Make sure that you have a sharp centre drill that leaves a true centre.
- Drill slowly, i.e. with a slow feed rate.

- Use a sharp drill.
- Use a high speed.
- Use a cutting fluid.
- Withdraw the drill frequently to clean and lubricate the drill.
- It is very hard to drill deep, small, holes. (This is best done by electrical discharge machining (EDM) by someone else.)

Drilling holes under 0.020 inches in diameter requires considerable skill if the work is to be done right. These holes should be avoided by the beginner. If they must be drilled in any number, the material they are to be drilled into must be selected carefully.

Grinding

Setting up

As a rule of thumb, it is best if no grinding is done on the lathe. That said, those of us who do not have separate grinding facilities need to use the lathe for grinding the occasional part, so we need a procedure to minimise the damage to the lathe.

Before undertaking any grinding, make sure that the lathe is as protected as you can make it. Strangely enough this means you have to clean the lathe before you start. Doing so makes it easier to clean up afterwards.

First set up your grinding operation but do not grind anything yet.

Before you start grinding, get some old newspapers and some Scotch tape and cover everything on the lathe and around the setup with the paper.

After you get done, do a thorough cleaning up job on the lathe with particular attention to the ways. Wipe every smidgen of dust off every surface and re-oil every surface profusely with a thin oil (5W or 10W is good) to wash away every last piece of grit. Heavy oils and greases would tend to trap the grit.

With small grinding spindles, only a very small amount of material can be taken off by grinding, therefore all parts should be made as close to size as possible with only the slightest amount of material left to be removed by grinding.

We have one other problem that has to be kept in mind – we have to keep the threads on our grinding arbors in mind as we grind so that we do not loosen the threads and have the wheel come loose as we grind. This means we have to grind in a such a direction that the load tightens the arbors onto the spindles and the wheels onto the arbors.

Almost all grinding will be done with the spindle at lathe centre height.

OD grinding

Grinding on the outside diameter of the part is the most common grinding operation undertaken with a tool-post mounted grinder on a lathe.

When very light cuts are to be taken, feeding the wheel into the work becomes a problem. This can be alleviated by feeding in with the compound set at 5.739 degrees. At this angle, moving the compound along the lathe axis by 0.0010 inches moves it across the axis 0.0001 inches. This is the easiest way to move the wheel by 0.0001 inches.

Movements at other angles can be achieved by mounting the compound at 5.739 degrees to the angle being ground. This means that the axial positioning has to be done with the thread cutting screw and its handle. Grinding at an angle to the lathe axis is a difficult proposition if accuracy is paramount (which it is or we would not be grinding).

ID grinding

When considering an internal grinding operation, we are talking about taking very small amounts of material off. Internal grinding often leaves the material removed in the part hollow being ground. We have to take the time to shut down to remove this material every so often.

Small grinding wheels do not last very long, just a few passes and they are ready to be replaced.

Internal grinding is a high-speed operation for the spindle. Spindle speeds of between 4,000 and 30,000 rpm are desirable. A certain amount of care has to be exercised at these speeds. Things must be secure and well balanced at all high speeds.

The wheels and arbors used are, of necessity, small and must be used with care. Small wheels do not last long and it may be necessary to replace a wheel a time or two before the job is done.

Take extremely light cuts and work with great care to avoid bending the ⅛ inch arbors on which the wheels are mounted.

It is usually not advisable to dress a wheel used for internal grinding though this can be done in the home shop with mixed results. It is best to consider these wheels to be throwaway items.

CHAPTER 16

Notes and ancillary information

The purpose of these notes is to support the spindles that are to be built.

As usual these notes are intended for beginners.

The following items are covered:

1. Making a set of centring buttons.
2. Aligning a lathe headstock and tailstock.
3. Cutting large threads in two passes.
4. Centring a part in a 4-jaw chuck.
5. A mandrel for locking the spindle and a plate for simple divisions.
6. Dremel Moto spindle nose dimensions.

Making a set of centring buttons*

It is essential to have at least one centring button in your tool collection. It is desirable to have a set of one longer one and four shorter ones. If we are about to make one, we might as well go ahead and make a set of five with a stand to go with them.

It is preferable that the buttons be of an even diameter dimension. All the buttons should have exactly the same diameter – either 0.400 inches or 0.500 inches are the diameters of choice. We will make them with a diameter for 0.500 inches because we probably do not have a 0.400 inch collet for the lathe. Making them thus allows you to subtract either 0.400 or 0.500 from the measured dimension to get the centre-to-centre dimension of the two locations that the buttons occupy.

The buttons do not have to be hardened, but hardening them will make a better, more longer lasting tool for your collection.

I am going to describe buttons that are slightly larger than those usually seen as these will be easier for a beginner to make.

Start out with some ⅝ inch diameter stock. I picked this because it is the size of the base on the buttons. Use either silver steel (if you are going to harden them) or mild steel.

Take a close look at the drawings.

Buttons

Make the four short buttons first, one at a time. Make them with the base to the lathe chuck. Place the ⅝ inch bar in the 4-jaw and centre. Face the bar and centre drill it. Drill a ¼ inch hole 1¼ inch deep into the bar. Turn the bar down to exactly 0.500 inches in diameter for a length of 0.500 inches. Just barely bore the hole to clean it up. Very lightly chamfer the face edge. Polish all finished surfaces with emery paper (200, then 400, then 600 grit with a drop of oil). Leave a 0.070 inch base flange and part off the piece. Make three more pieces at this size and one more that is ⅛ inch longer on the 0.500 inch diameter part.

Set up your collet for ½ inch work. Place one of the buttons in the collet with the base end out and face the base to give a finished dimension of 0.063 inches. With a boring tool open the ¼ inch hole out to 0.375 inches in diameter and 0.437 inches deep. Very lightly chamfer all edges. Do this to all five pieces and keep in mind that one unit is longer.

*Known as toolmakers' buttons in the UK.

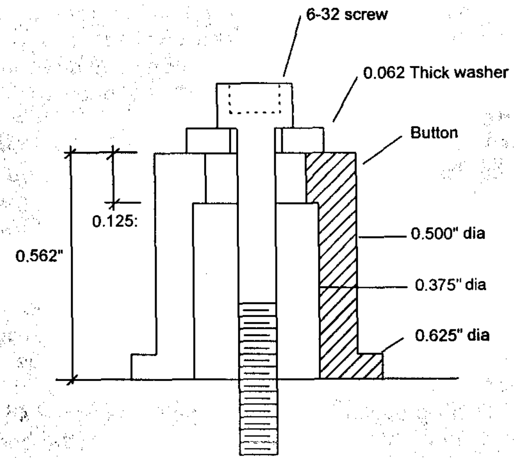


Figure 16.1 *Machinist's button.*

Washers

We need five washers for the top of the buttons. Each has to be 0.450 inches in diameter and 0.063 (1/16) inches thick. Thicker washers may be made if you prefer. These are best made of scraps. Drill 6–32 clearance holes (No 28) in 5 pieces of 1/16 thick brass (or steel if you like) and clean them up with a file. Screw them down on to a 0.375 inch mandrel with a 6–32 tapped hole in it, held in a 0.375 inch collet. Turn the outside diameter down to 0.450 inches. Lightly chamfer all edges.

Screws

Purchase these as socket head cap screws if you can. They look so nice. If not, five 6–32 (approximately 4BA) screws would be ideal (smaller sizes are harder to work with) so we will make our hold down screws 6–32 (approximately 4BA). We need 4 screws ¾ inch long and one screw ⅞ inch long. We need ⅜ inch of threads on each screw. Make them out of ¼ inch mild steel stock. Cut the threads with a die held in the tailstock to get the threads straight. Part off the heads slightly over 3/16 inch thick. Turn around in the chuck and carefully face the screw heads to 3/16 inch high. Chamfer edges. Cut the screw head slots by holding the screws in your tool holder set up at the lathe centre height and use a 0.032 inch wide saw to cut the slot. Screw slots are to be 3/32 inches deep. Remove all burrs. Carefully chamfer all edges.

Base

A base is not essential but is a great device for keeping your buttons, washers and screws together. Make the base from ¼ inch brass (or mild steel). Brass will make the thread cutting easier. The base is going to be ¼ inch thick by ¾ inch wide by 2¾ inches long. The five 6–32 threaded holes are ¾ inch from centre to centre and 0.438 inches from each end. Make sure the threads are exactly at right angles to the base. File to size. Chamfer all top edges with a smooth file and polish with emery paper. Lightly oil. Mount the buttons on the base and they are ready for your first project.

2. Aligning a lathe headstock and tailstock

Aligning the headstock of the lathe to the tailstock is more complicated than it seems at first sight. I will describe the ideal setup and you can decide what you want to do on your machine.

As a rule it is considered desirable to have the bed of the lathe absolutely level. This is done to take the twist out of the lathe bed. On a small lathe this is not very important because a short bed is not likely to twist very far, but on a 40 foot bed this might be a big problem. A bed is usually levelled with an accurate spirit level, often referred to as machinist's levels. A level can be calibrated by placing it on a level surface (or a surface that has been levelled). It should indicate a level condition in all directions.

Next we need to make sure that the head of the lathe is exactly parallel with the lathe bed. This means that a straight, preferably ground rod held in the chuck will be completely parallel to the lathe bed at all points on its surface. This can be checked by traversing a dial indicator mounted on the lathe carriage back and forth from one end of the bar to the other. We are assuming that the chuck or collets used hold true.

The same should be true of the tailstock – its barrel should travel exactly parallel to the lathe bed.

The lathe spindle and the lathe tailstock quill should be at the same height above the bed. This may not actually be the case but is often assumed to be because there is no easy way to fix this problem. It is a matter of scraping the bottom of the headstock or the tailstock and as this often does more harm than good it is left alone. (The factory usually provides matched units but an old lathe might have the headstock from one lathe and the tailstock from another and this can cause a misalignment).

The only adjustment we normally have available to us is the ability to move the tailstock at right angles to the longitudinal axis of the lathe. For this reason, most amateurs concentrate on this adjustment. However, it is worth your while to know exactly how your lathe is set up.

The cross slide should move at right angles to the lathe bed and exactly so. If there is to be a deviation, it should cut the part being faced slightly concave. This will allow parts to sit one on another without wobbling and machined shoulders to seat tight.

Study the following diagrams. These show three ways that a lathe might cut. Here we are talking about taking a cut with the longitudinal automatic feed and not with the manual compound feed. When making these cuts, try to position the tool close to centre height. It is not critical but the closer to centre height you get the better. If you miss centre height, the hyperbolic cut you would get is very slight and most amateurs will not even be able to measure it.

If you can get the lathe to cut perfectly parallel as shown in Figure 16.2a, you have the perfect condition. This is what we are striving for, but if you are unable to attain this condition perfectly do not worry unduly.

If you must be left with a taper, then a taper that gets fatter as you go towards the headstock is the preferred condition (Figure 16.2b). This means that the bearings will get tighter as you push them onto the shaft that has been turned. This is tolerable.

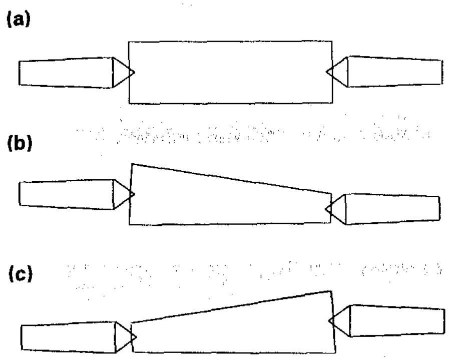


Figure 16.2 *(a) This is the ideal condition – perfectly parallel cuts; (b) If you must have a taper this is the acceptable type of taper; (c) Under no circumstances do you want a taper like this – it is totally unacceptable.*

Under no circumstances do you want your lathe to cut a taper like the one shown in Figure 16.2c – you will have trouble getting the bearing and other parts on to the part being turned and then they will get loose right away. This is totally unacceptable.

3. Cutting large threads in two or more passes

If you are cutting fewer than 16 threads, you may want to consider cutting the threads in two passes. This is done to reduce the cutting forces on the tool by reducing the length of the flank that the cutting tool has to cut.

Let us assume that we are going to cut 8 threads per inch for a large screw. For ease of discussion let us assume that these threads have a 60 degree form. The pitch of these threads is 0.125 inches which means that the thread flank is 0.125 inches wide. On the last pass, the thread and tool meet along a full 0.125 inches. This is hard to cut and a very sharp tool taking very small cuts would have to be used.

A better method is to divide the work up between two or, better yet, three passes. The first pass cuts only a third of the full depth of the thread, then the tool is moved over one third of a thread and the next third of the threads is cut. This cut ends two thirds of the way into the thread when the flank starts to meet the first third of the work.

Move the tool over again and make the third set of passes. These will end at the full depth of the thread and will again meet the flank cut previously. It is now usually necessary to take a finishing cut to finish the threads.

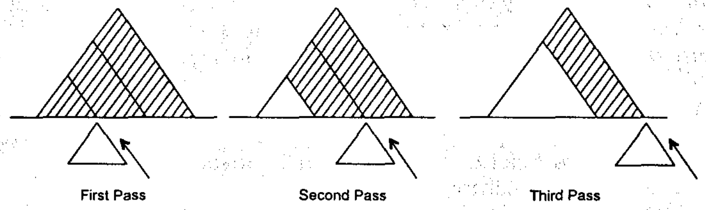


Figure 16.3 Taking the three sets of passes to cut coarse threads.

4. Centring a part in a 4-jaw chuck

The 4-jaw chuck is probably the most versatile part holding in the arsenal of most amateur engineers. As such, the mastering of its proper use is a long-term undertaking. This most basic skill to be mastered is the centring of a part in the 4-jaw chuck so that the part is centred along its entire length.

It is often important that the part being made be centred in the chuck as accurately as possible. Older 3-jaw chucks are notoriously inaccurate holders so the 4-jaw chuck is used when parts must be held accurately. However, just centring the part at the chuck is often not enough to get the job done right. We have to make sure that it is centred along its entire length. On a small lathe like the Myford S7 the small opening through the spindle means that much of the work we do will be outside the chuck or between centres. This makes centring the outside end of the work even more important so that an accurate centre can be drilled in it.

The first thing we do is go over the part with a large smooth file to take out all the bumps and scratches that are proud of the surface. This will make the part easier to centre by eliminating all the bumps on the surface of the part that tend to make the dial indicator needle jump.

Approach the work slowly. Do not tighten anything down too tight too early. Rough centre the part in the chuck by eye. You should be able to get within about 1/16 of an inch of being on centre with a little practice.

Mount a dial indicator at lathe centre height and make it approach the work from the side you are standing on. Find the highest point on the shaft and loosen the jaw on the side opposite it and tighten the jaw at the dial indicator – but not too tight just yet. Work between these two jaws until the part is centred between them, then shift to the other two jaws and centre the part between them. At the end of this exercise, the part will be within about 0.010 inches of being centred.

Now rotate the part slowly by hand and stop at each jaw. Make a note of the four readings. Turn the dial on the indicator or use the cross slide so that the zero point on the dial indicator is halfway between the high point and the low point. Now the zero point gives you a rough indication of where you are trying to move the part to as you manipulate the jaws.

If the part is high, tighten the jaw at the dial indicator a little more snug. If the part is loose, just barely loosen the jaw. As you go around the part the part will start to get closer and closer to centre.

Once you get within about 0.002 inches of centre, you can start tightening down on the jaws selectively to bring the part to the exact centre. If the part is sticking out of the jaws less than an inch or two, the part is centred and you can proceed with the turning.

Note
Do not strike the part when the dial indicator is in contact with the part or you are likely damage the indicator. Move the indicator back off the part with the cross slide and then make the adjustment.

If the part is sticking out more than a couple of inches, the outer end of the part should be centred also. This is done by moving back and forth between the two ends of the part and making adjustments to the outside end with a light mallet. The idea is not so much to centre the outside of the part as it is to keep it parallel to the part near the jaws. In that way, as the jaws are centred, the outsides will move with them and the part will become centred as a whole. By the time you get down to tightening the jaws, the part should be completely parallel. The final tightening will centre everything.

There is a certain amount of experience and getting to know your chuck in these centring procedures. Once you get a feel for how your chuck responds to your touch, centring goes pretty fast.

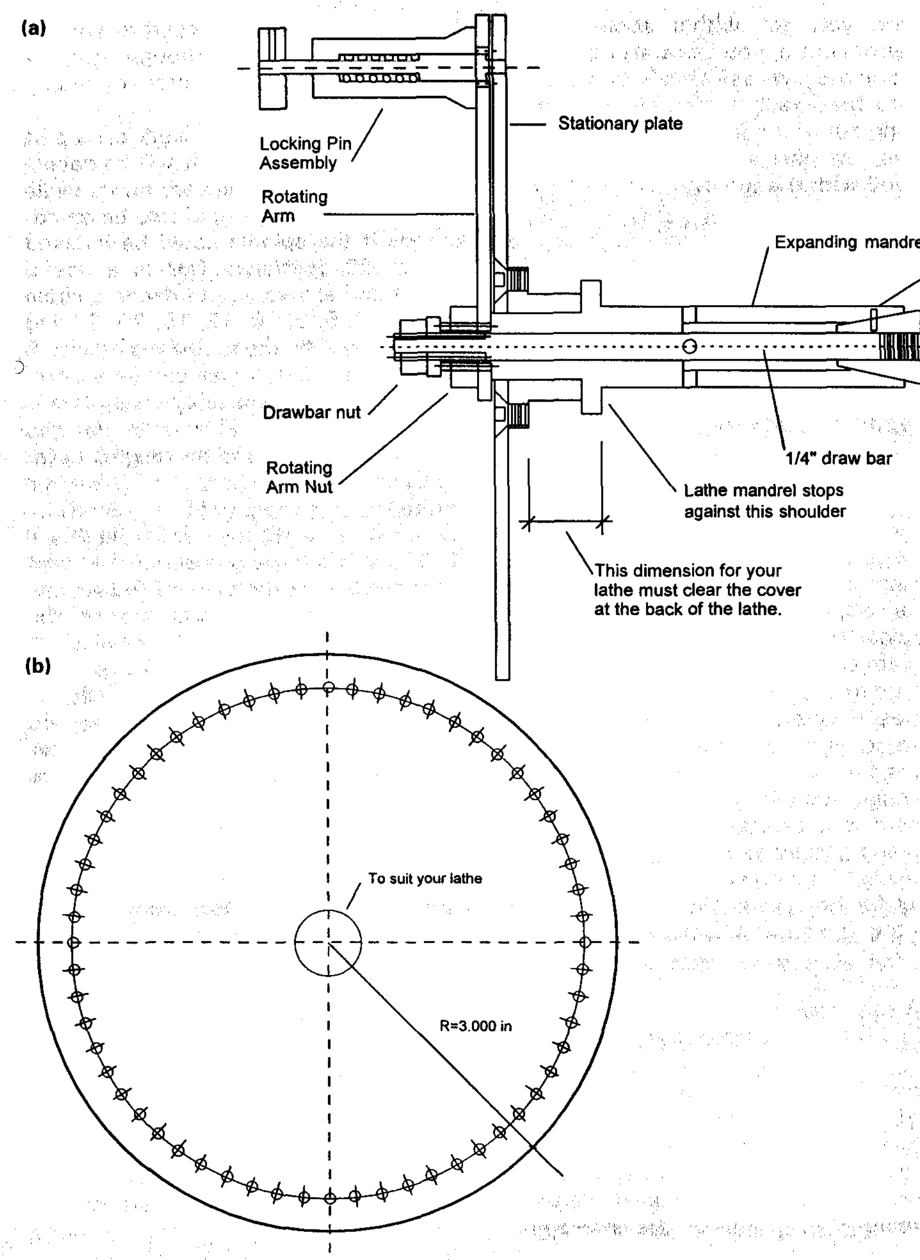
5. A mandrel for locking the spindle and a plate for simple divisions

In this discussion we will discount the possibility that you already own a dividing head and have a way of attaching it to the lathe spindle for division purposes. This is for beginners and is a simple way to provide 60 divisions on the lathe spindle rotation. It will be accurate enough for most applications though not, of course, as accurate as a proper dividing head.

If you are going to do work on a part held in the lathe spindle, it will be necessary to hold the spindle very firmly while you do the work. It would also be an advantage if the spindle could be indexed through 60 divisions. This is a useful number and allows you to divide a circle into 2, 3, 4, 5, 6, 10, 12, 15, 20, 30 and 60 divisions. The most obvious omission is 8 divisions. Sixty holes can be accommodated quite comfortably on a plate 6 inches in diameter. This is by far the most flexible and useful dividing plate for you to have in your shop.

Note the following:

1. There is a large gearbox cover that extends past the back of the spindle on most lathes to accommodate the change gears. The indexing assembly has to extend past this so that the cover will not interfere with the hold down arm. You will need to check the dimensions for your particular lathe and adjust the length of the expanding shaft that extends into the lathe mandrel accordingly.
2. The length of the hold down arm has to be adjusted to suit the lathe mounting and table in your shop. It should be designed to go down at 45 degrees as shown to minimise the effects of up and down and sideways movement between the lathe and the table. The best compromise is 45 degrees unless you know that your lathe moves in some other direction with more ease, then the arm should be positioned such that the movement of the lathe does not move the relative position of the plate to the lathe.



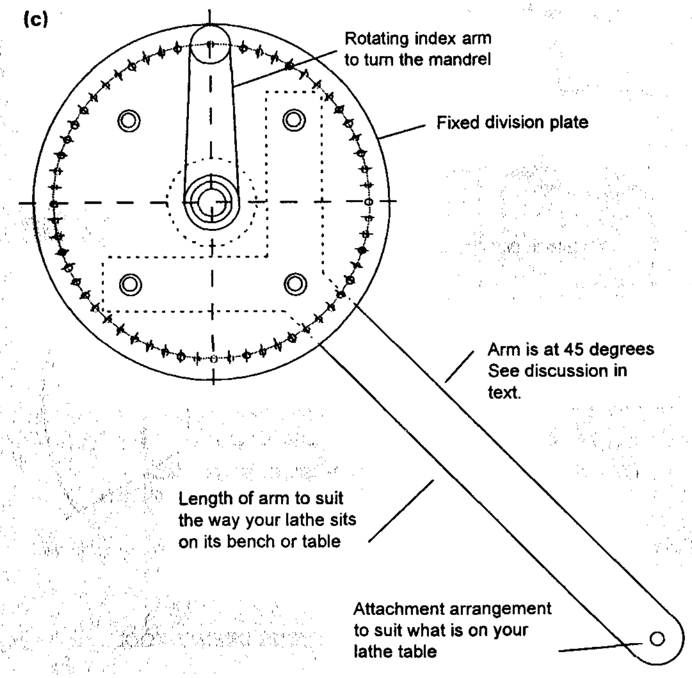


Figure 16.4 *(a) Section across the simple indexing assembly; (b) Indexing plate with 60 divisions – only 12 divisions would still be very useful; (c) Back elevation of indexing assembly.*

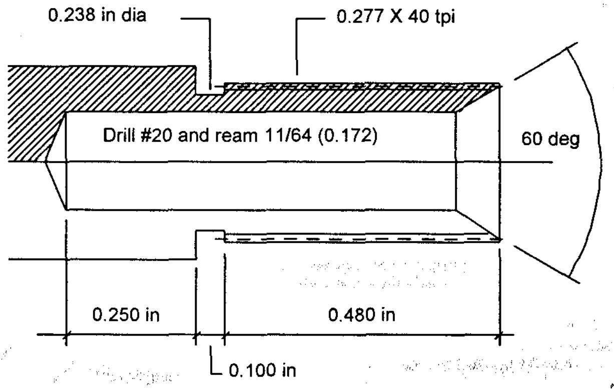
The spindle of the attachment expands in the lathe spindle and becomes a part of it. The division plate is a close fit on the spindle but is free to turn on the spindle body. The division plate is attached to the lathe base (or mounting table) by a stiff bar – this bar keeps the plate from rotating, i.e. once installed the plate does not rotate. The spindle rotates in the plate and the indexing arm is attached to the spindle. A pin on the arm can be dropped into any of the 60 holes in the dividing plate to perform the division needed. All parts should be made to fit closely so that there is minimal play in the system.

The plate is made from 0.125 inch sheet steel to give it the stiffness and body that you will need to attach the holding arm. On the face plate, bore a 1 inch hole at the centre. Use the plate arbor to spot the three holes that hold the plate to the arbor. Attach the arbor and machine the outside of the plate in the 4-jaw chuck after accurately centring the arbor. The 60 holes in the plate have to be drilled with the aid of a dividing head of some sort. I suggest that this be done by spotting the holes with the dividing head and then drilling them in a drill press.

6. Dremel Moto spindle nose dimensions

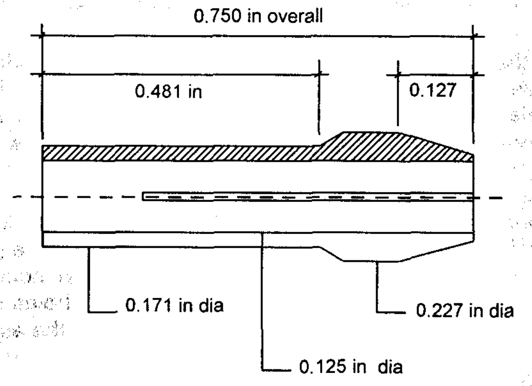
The Dremel Moto Tool collets and collet closer are used on a number of the spindles. The measurements given here are taken from an actual closer and its collets. You should check your specific tooling to make sure that it is identical to the information given here. It is unlikely that metric tooling will be to these dimensions.

(a)



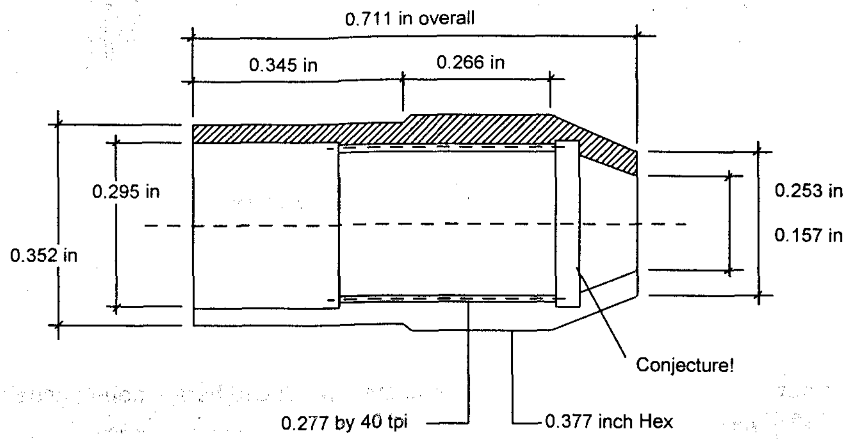
CONFIRM THESE DIMENSIONS ON YOUR DREMEL TOOL

(b)



CONFIRM THESE DIMENSIONS ON YOUR DREMEL TOOL

(c)



CONFIRM THESE DIMENSIONS ON YOUR DREMEL TOOL

Figure 16.5 *(a) Dremel Moto spindle dimensions; (b) Dremel Moto collets; (c) Dremel Moto collet closer.*

APPENDIX 1

SI drawings

Please note that only dimensioned drawings are reproduced here – non-dimensioned drawings appear in the relevant chapter.

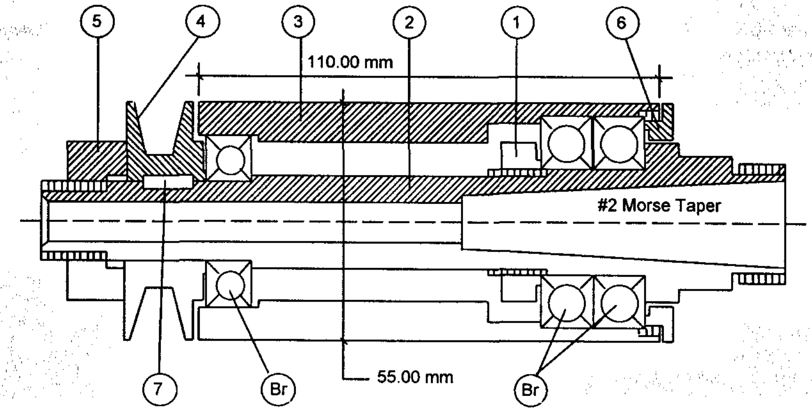


Figure 3.1 *Cross section of a cartridge spindle. Note: besides the bearings there are only 7 parts to be made.*

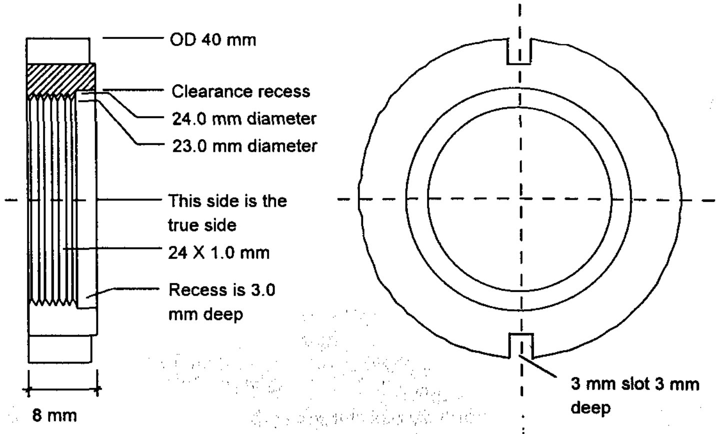


Figure 3.4 *Front bearings, inner race and clamping nut.*

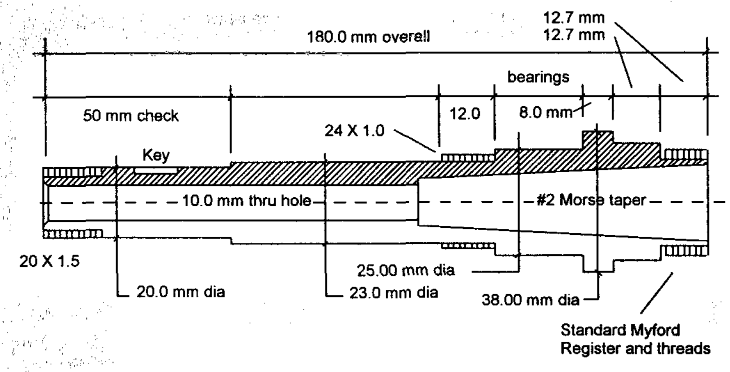


Figure 3.7 *Section along the spindle.*

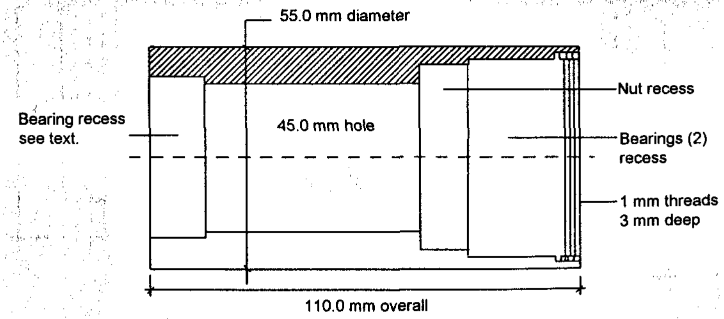


Figure 3.11 *Spindle housing.*

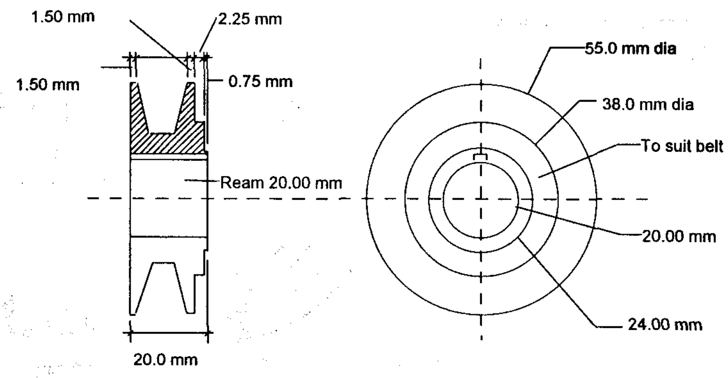


Figure 3.20 *Section across the pulley/pulley dimensions.*

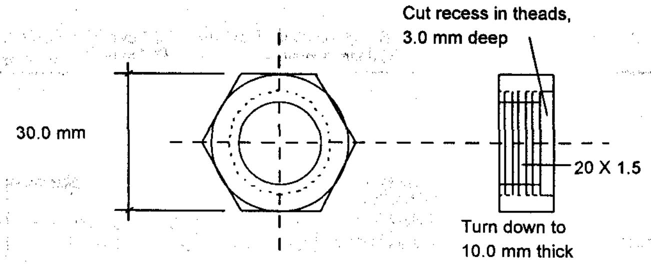


Figure 3.21 *Modification of a commercial 20 × 1.5 nut.*

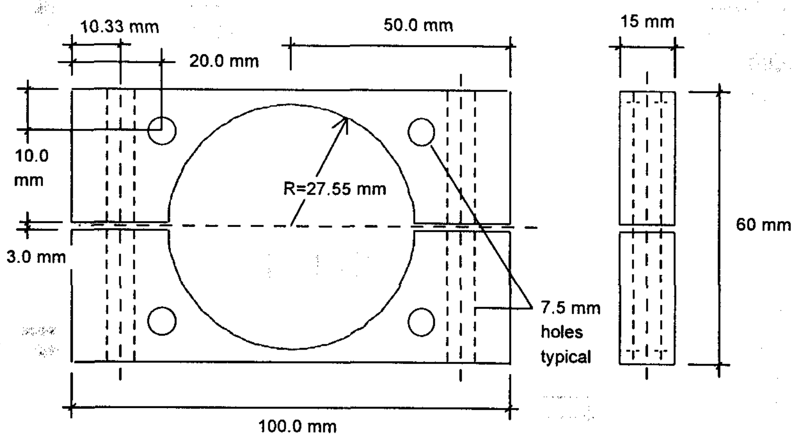


Figure 4.1 *Clamp plate dimensions.*

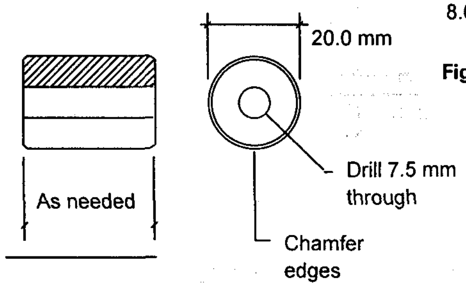


Figure 4.4 *Optional spacers for plates.*

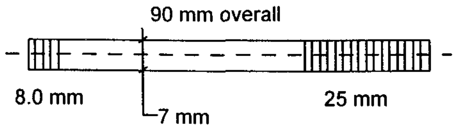


Figure 4.5 *Studs for mounting spindle.*

Figure 4.6 *"T" nuts for mounting spindle.*

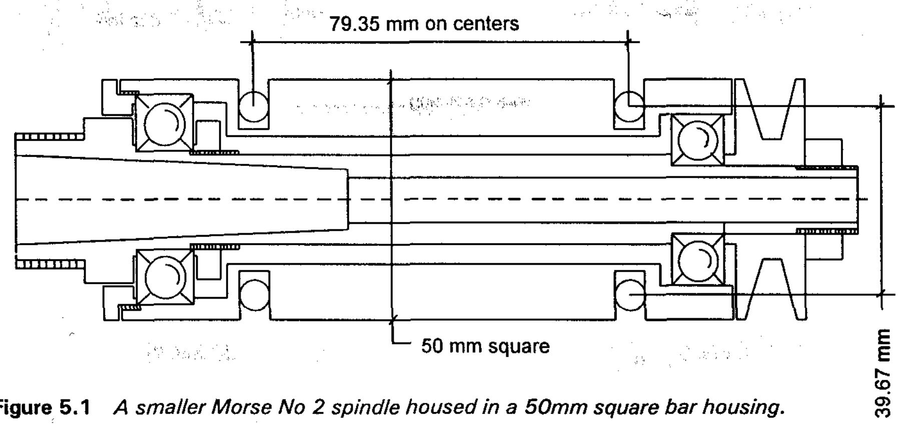


Figure 5.1 *A smaller Morse No 2 spindle housed in a 50mm square bar housing.*

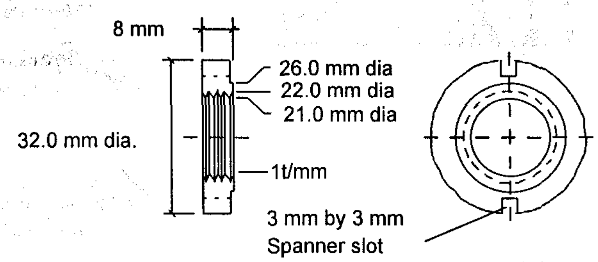


Figure 5.3 *Front bearing, inner race clamping nut.*

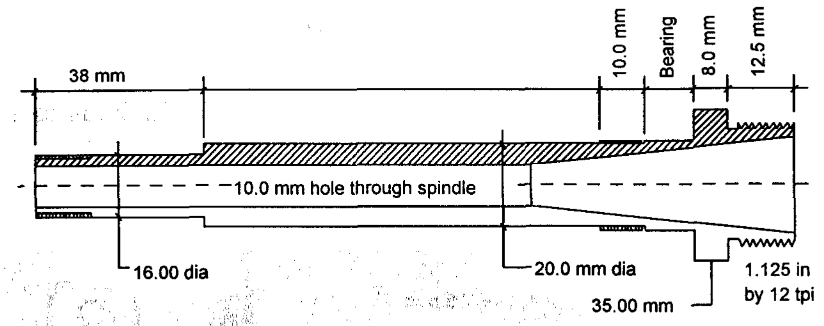
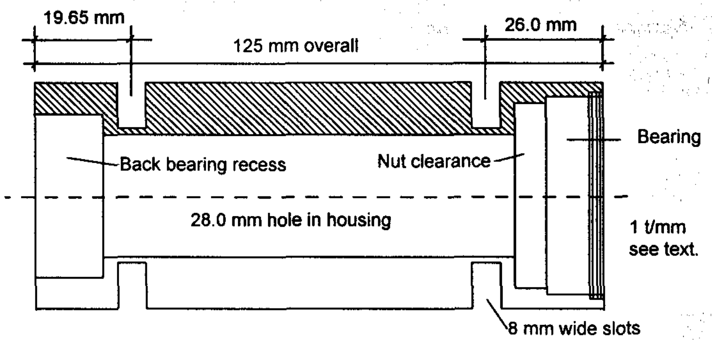


Figure 5.5 *Spindle dimensions.*



This housing is to be made of 50 mm by 50 mm bar stock.

Figure 5.8 *Details of housing.*

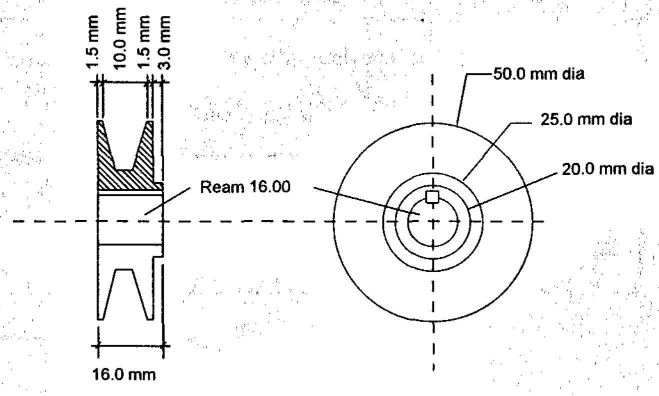


Figure 5.9 *Driving pulley.*

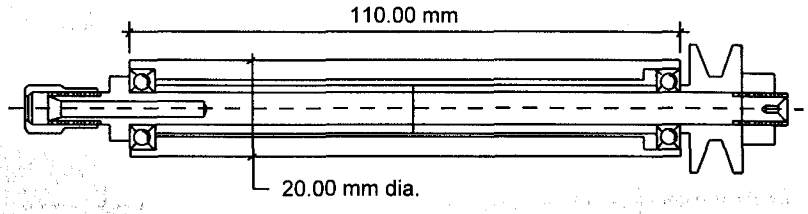


Figure 6.1 *Section across the micro spindle.*

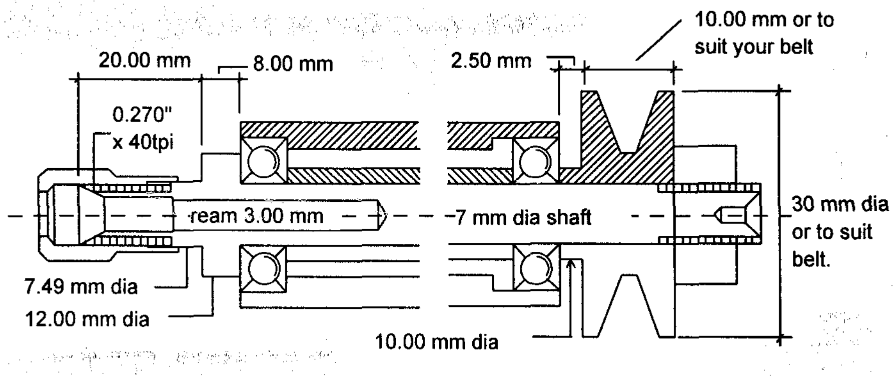


Figure 6.2 *Spindle nose details.*

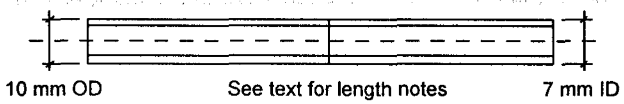
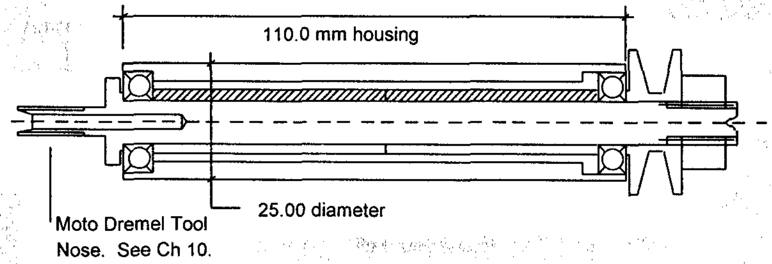


Figure 6.3 *Spacer dimensions.*



Bearing are to be glued into the housing (Loc-Tite)

Figure 7.1 *25mm diameter spindle with Motor Dremel Tool nose.*

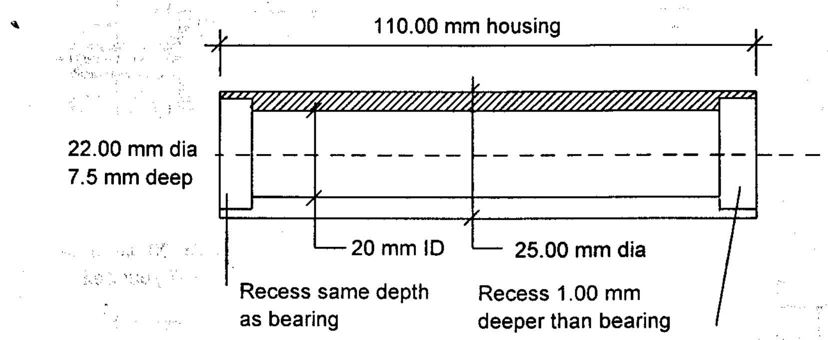


Figure 7.2 *Spindle housing dimensions.*

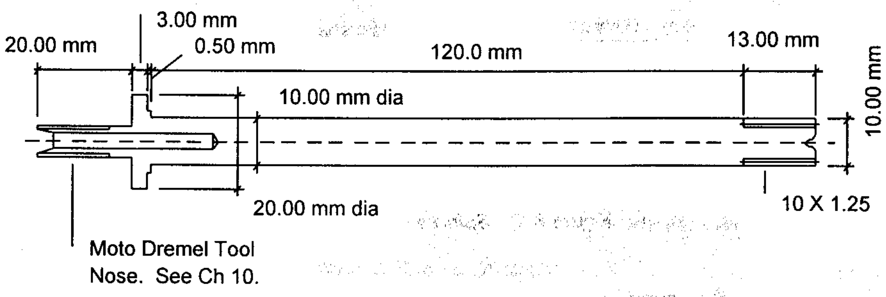


Figure 7.3 *Spindle dimensions.*

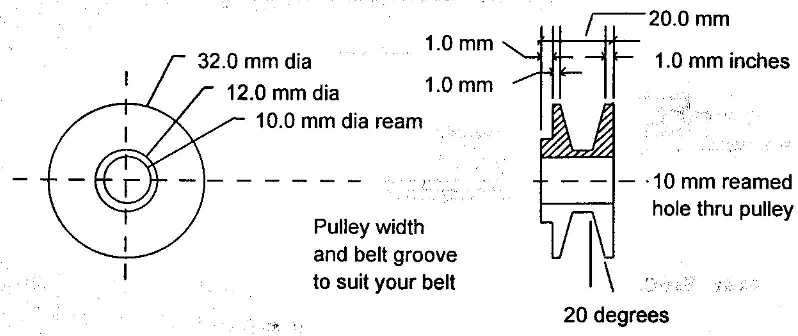


Figure 7.4 *Pulley dimensions.*

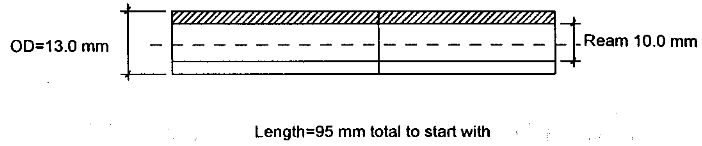


Figure 7.5 *Spacer dimensions (see discussion in Chapter 6).*

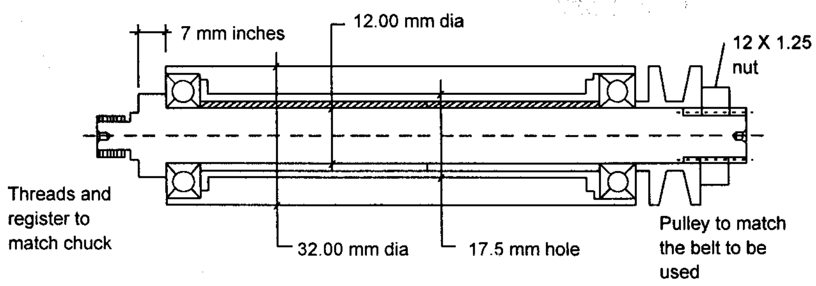


Figure 8.1 *32 mm diameter spindle with Jacobs 1B chuck threads (it can also be made with the Moto Dremel Tool nose on it).*

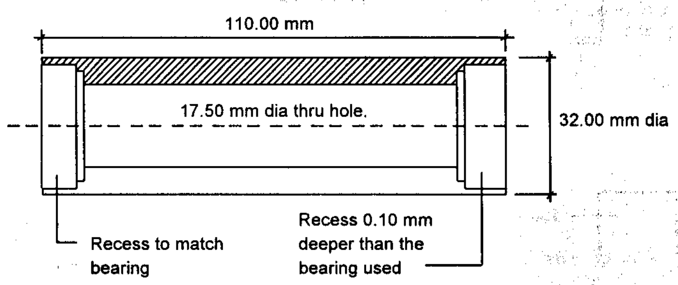


Figure 8.2 *Spindle housing dimensions.*

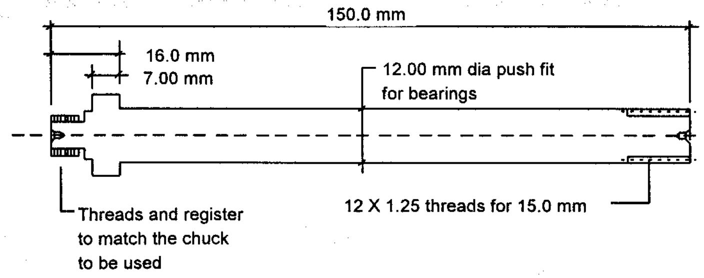


Figure 8.3 *Spindle dimensions.*

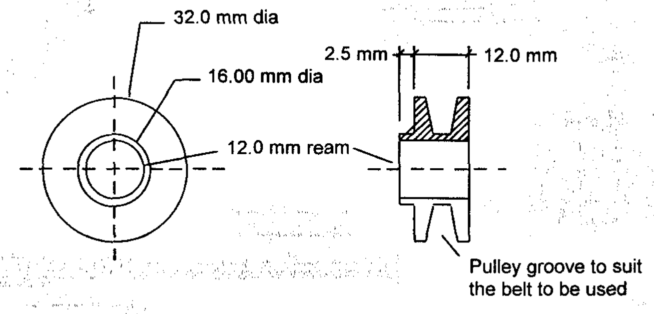


Figure 8.4 *Pulley dimensions.*

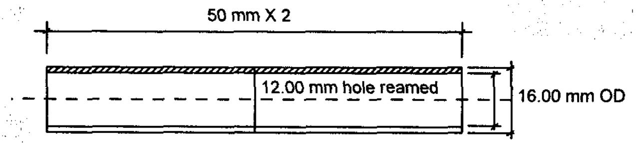


Figure 8.5 *Spacer dimensions.*

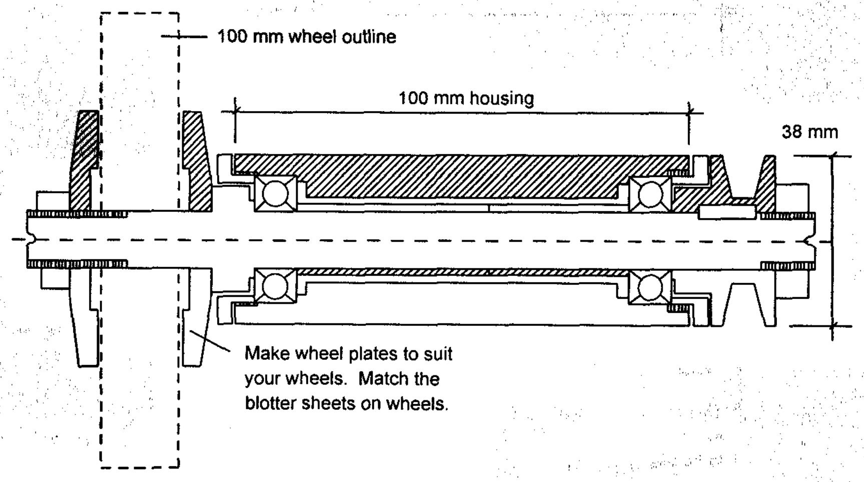


Figure 9.1 *The external grinding spindle for approximately 100mm diameter wheels.*

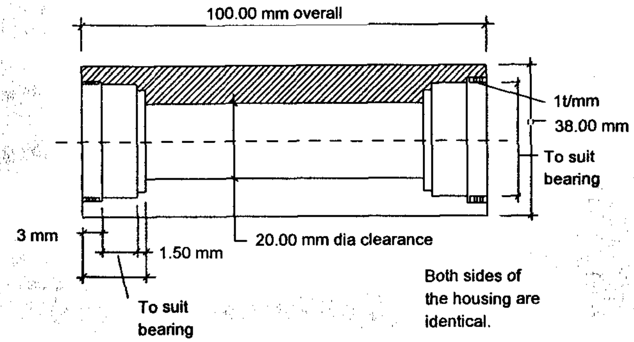


Figure 9.2 *Outer housing dimensions – the ends are identical.*

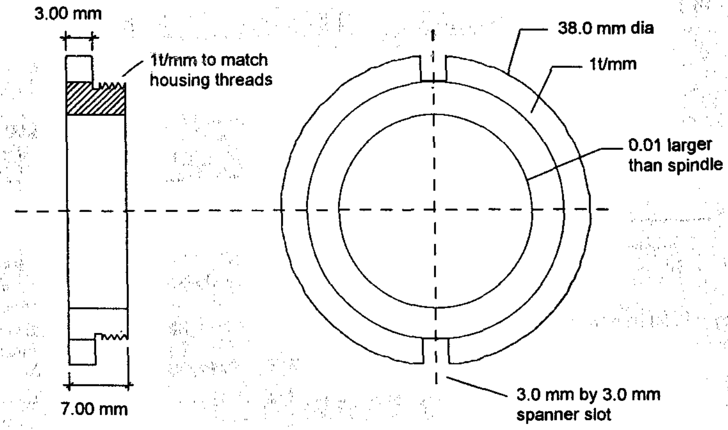


Figure 9.4 *Bearing cap dimensions - two are needed.*

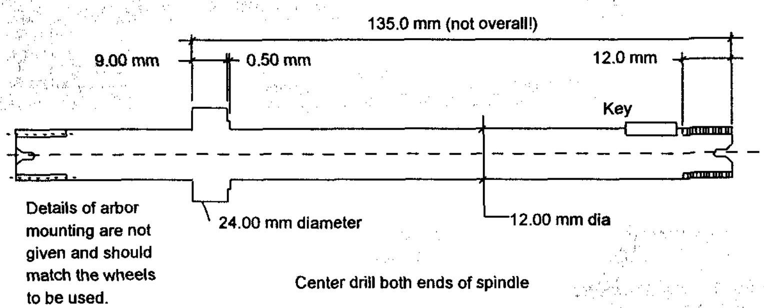


Figure 9.5 *Spindle dimensions.*

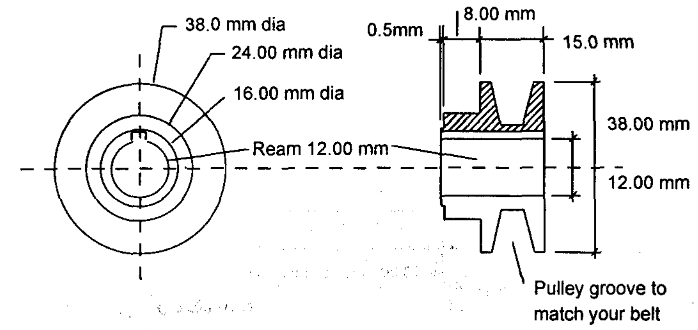


Figure 9.7 *Pulley dimensions.*

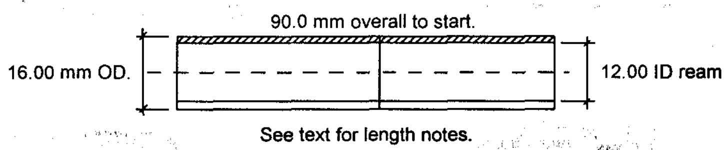
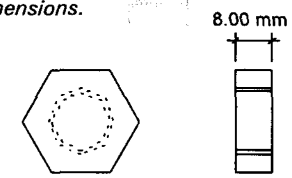


Figure 9.6 *Bearing spacer dimensions.*

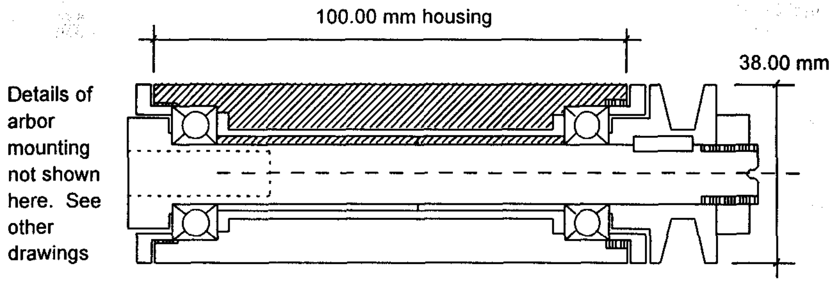
Key is 3.00 mm by 3.00 mm brass stock. Round as shown

Figure 9.9 *Key dimensions. File to fit keyway by hand.*



Standard 12 X 1.25 nut

Figure 9.8 *Pulley nut dimensions.*



The spindle and drive are identical to the OD grinder parts

Figure 10.1 *Cross section of ID grinding spindle. The parts of the spindle shown above are identical to the OD grinding spindle.*

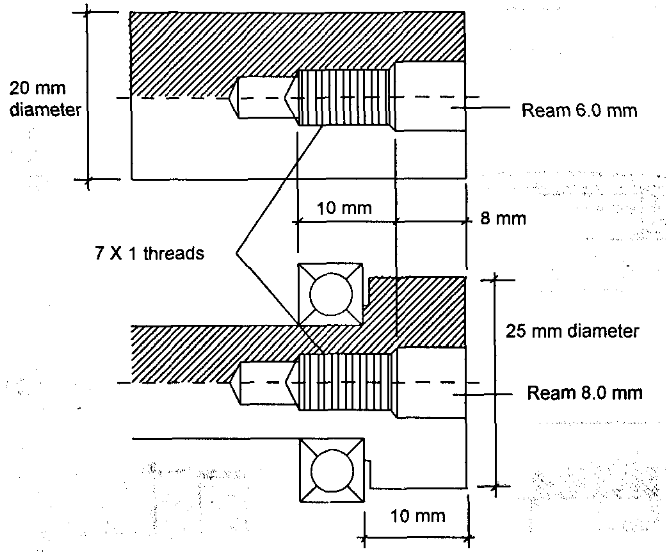


Figure 10.2 *Spindle nose details and quill mounting recess.*
and Figure 10.3 *Cross section of two quill holding fixtures.*

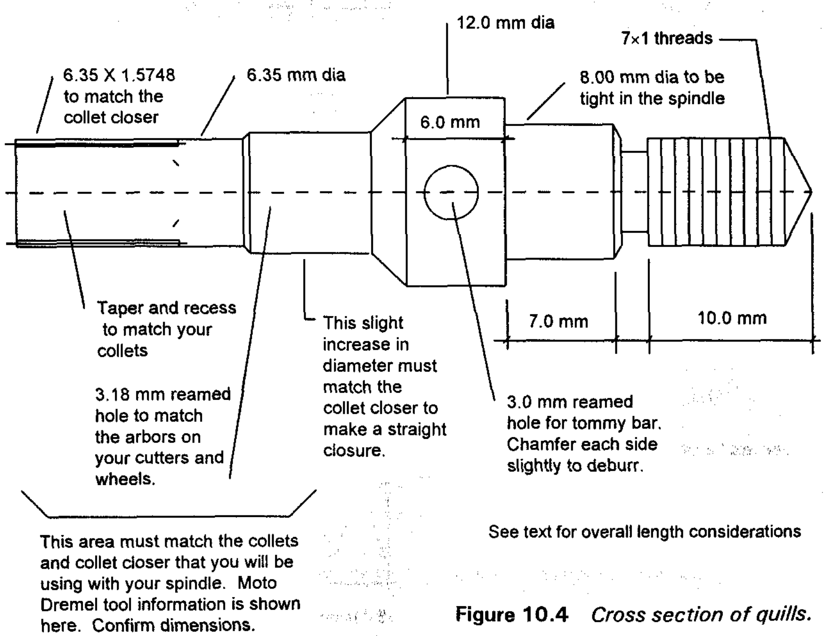


Figure 10.4 *Cross section of quills.*

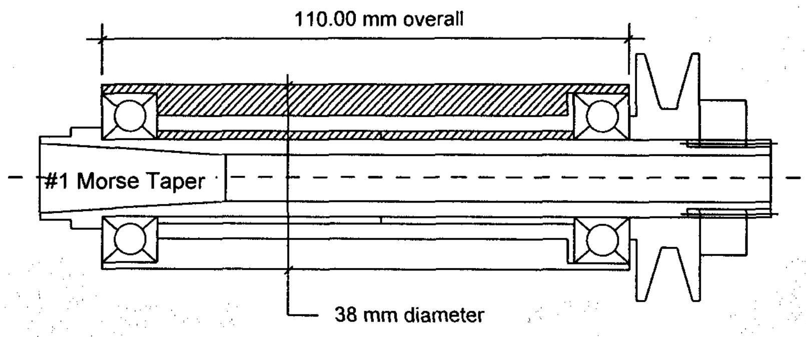


Figure 11.1 *Cross section across spindle.*

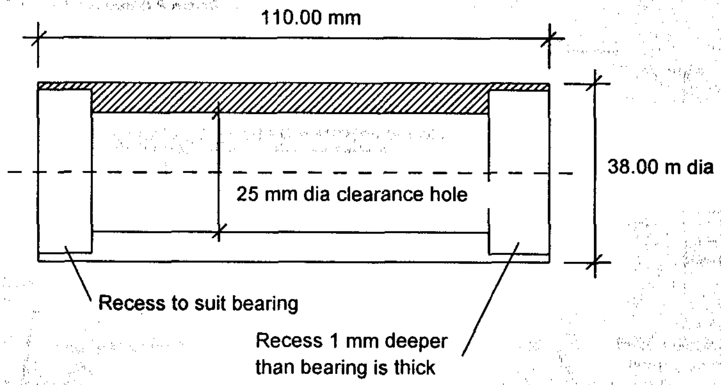


Figure 11.2 *Housing dimensions.*

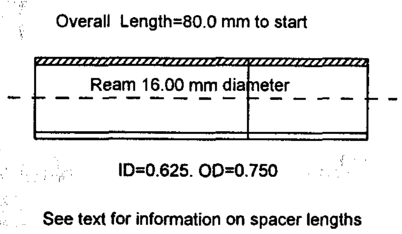


Figure 11.4 *Spacer dimensions.*

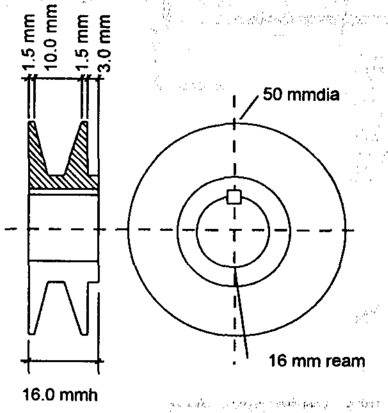


Figure 11.5 *Pulley dimensions.*

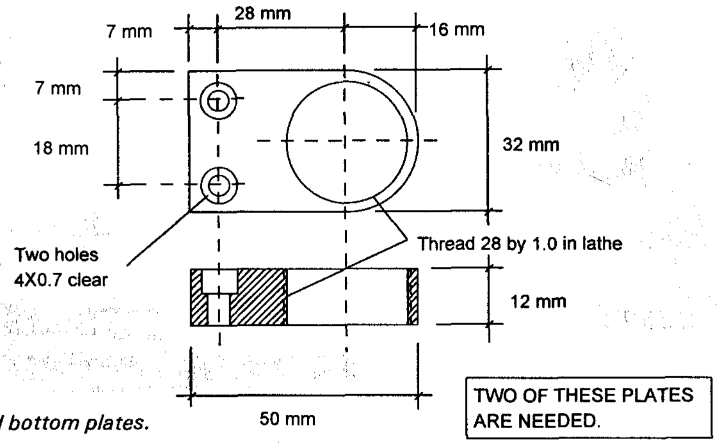


Figure 12.4 *Top and bottom plates.*

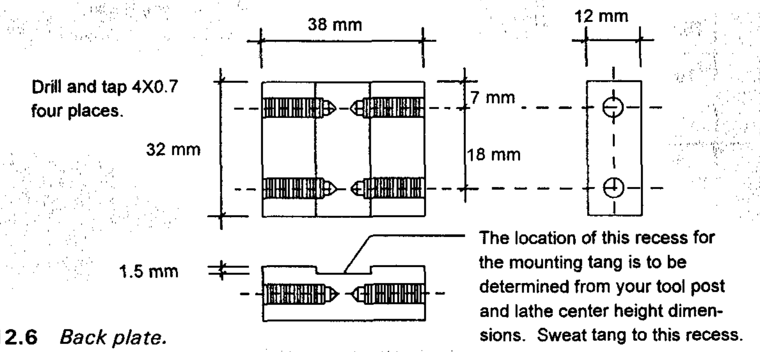
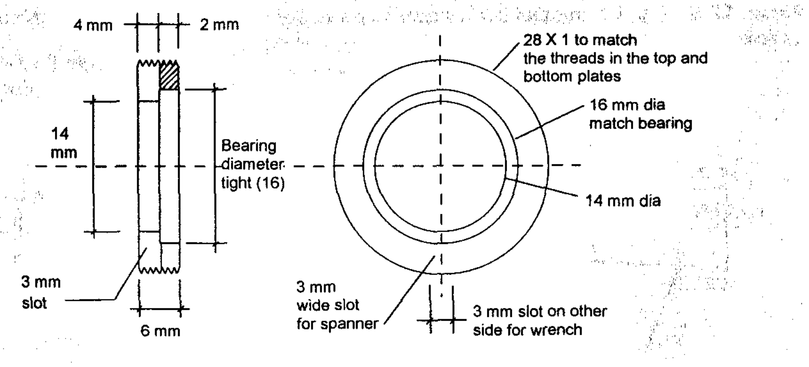


Figure 12.6 *Back plate.*



Dimensions given are for 16 mm OD by 8 mm ID by 8 mm in. thick bearings

Figure 12.7 *Clamping rings – four are required (make them from the same stick).*

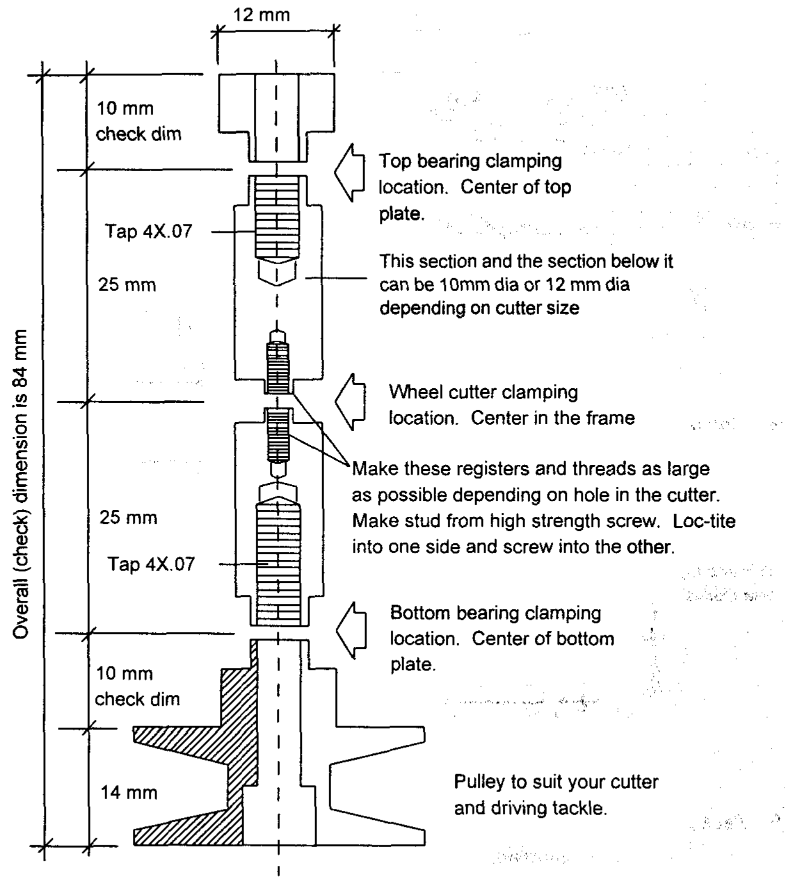


Figure 12.9 *Vertical section across spindle parts (replace the two centre sections for different cutters).*

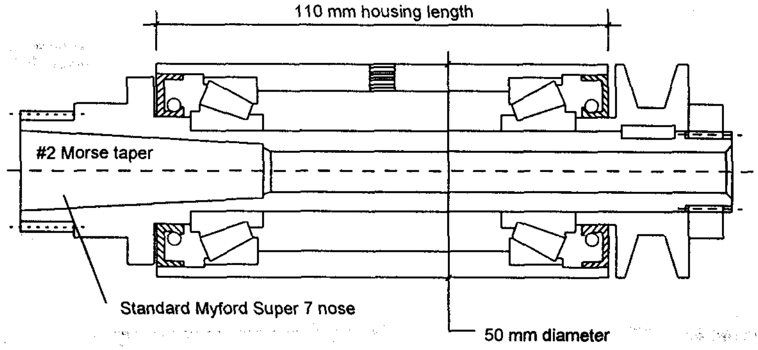


Figure 13.1 *Section across spindle with taper bearings. Note that the need for seals moves the front bearing farther inboard in this design.*

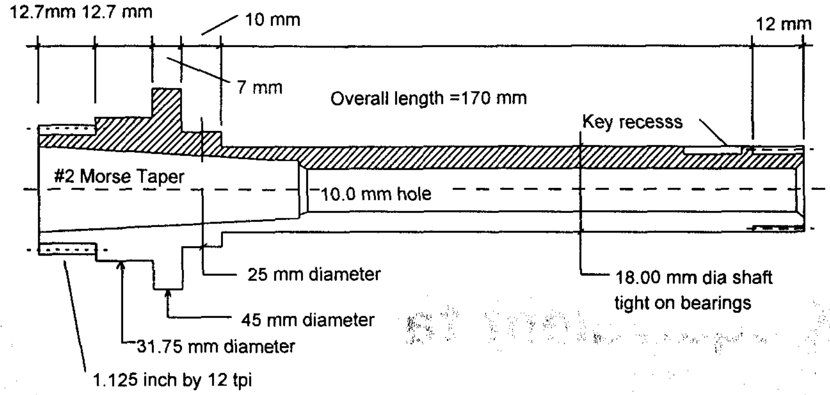


Figure 13.3 *Spindle dimensions.*

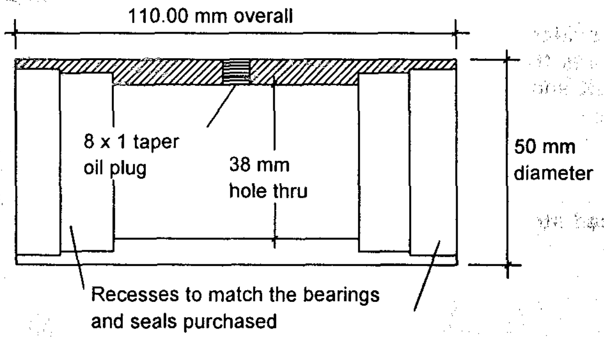


Figure 13.4 *Housing details.*

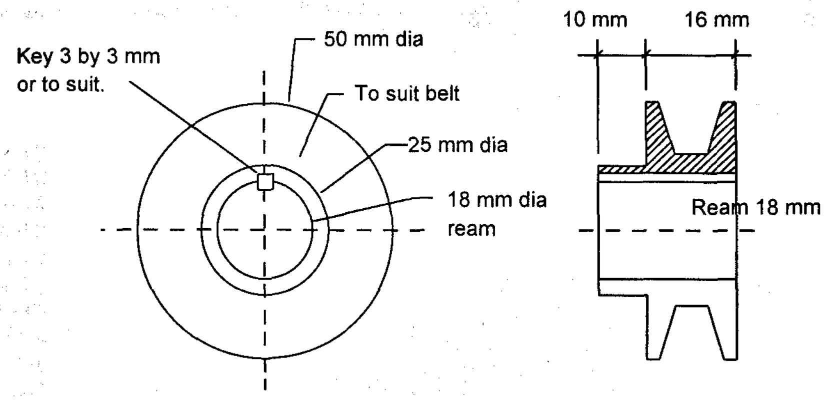


Figure 13.5 *Driving pulley dimensions.*

APPENDIX 2

UK equivalent tables

This table is provided as a reference for the builder. It lists the main US threads and indicates UK and metric equivalents for the US threads suggested in this book. In most applications, thread sizes are not critical and if the threads will fit the space you have, the selection will be adequate. Thread strength is not a critical consideration in the spindles presented. Fine threads are easier to cut (in a lathe) than their coarse equivalents – this is especially true for larger thread sizes. It is not as important a consideration on small screws because their threads are already fairly small and are best cut with a thread die in any case.

Suggested American size		Suggested British size		Suggested metric size	
Thread	Tap drill	BA thread	Tap drill	Metric thread	Tap drill (mm)
Unified National Fine thread standard (UNF)					
0-80	3/64				
1-72	53				
2-64	50				
3-56	45				
4-48	42				
5-44	37				
6-40	33				
8-36	29				
10-32	21	2	22	5 × 0.8	4.50
12-28	14				
1/4-28	3	1/4 BSF	3	6 × 1	5.0
5/16-24	I	5/16 BSF	H	8 × 1	7.0
3/8-24	Q	3/8-20 Wh	P	10 × 1.25	8.70
7/16-20	25/64 in.	7/16 BSF	W	12 × 1.25	10.80
1/2-20	29/64 in.	1/2 BSF	7/16 in.	12 × 1.25	10.80
9/16-18	33/64				
5/8-18	37/64				
3/4-16	11/16 in.	3/4 BSF	41/64 in.	18 × 1.5	16.50
1/8-14	13/16				
1-12	59/64				
1 1/8-12	1-3/64				
1 1/4-12	1-11/64				
1 3/8-12	1-19/64				
1 1/2-12	1-27/64				
Unified National Coarse thread standard (UNC)					
1-64	53				
2-56	50				
3-48	47				
4-40	43	**6**	**43**	3 × 0.5	2.65
5-40	38	**5**	**37**	3 × 0.5	2.65
6-32	36	**4**	**31**	3.5 × 0.6	3.10
8-32	29				
10-24	25				
12-24	16				
1/4-20	7				
5/16-18	F				
3/8-16	5/16				
7/16-14	U				
1/2-13	27/64				
9/16-12	31/64				
5/8-11	17/32				
3/4-10	21/32				
7/8-9	49/64				
1-8	7/8				
1 1/8-7	63/64				
1 1/4-7	1-7/64				
1 3/8-6	1-7/32				
1 1/2-6	1-11/32				

Index