CHAPTER 1

Lathe

INTRODUCTION

In previous chapters, we have seen that with the help of forging and casting processes, we can manufacture machine parts of different shapes and sizes. However, parts so manufactured have poor geometry and size control (*i.e.,* tolerance on dimensions) and their surface finish is not very good. Hence, in most cases, castings and forgings undergo machining before these parts can be assembled with other parts to form a complete machine like cycle or motor car etc.

In machining, we use a machine tool like lathe or shaper and a cutting tool made of a much harder material than the material of the part to be machined. Material removed from the part is achieved by the relative movement between the cutting tool and the part. The cutting tool is given a sharp cutting edge and it is forced to penetrate inside the work piece surface to a small depth. The relative motion between the tool and work piece results in a thin strip of material being sheared off from the work piece reducing the thickness of the work piece. This process has to be repeated several times before the entire surface of the work piece can be covered and reduced in depth. The thin strip of the material sheared from the work piece is called 'chip'. It must be understood that chips are produced by shearing action and not by cutting. Subtantial amount of power is required for machining. The function of the machine tool is to provide this power and the required motion of work piece relative to the tool.

In some cases of machining, motion is given to the work piece and tool remains stationary. In some other cases, the work piece is stationary and the machine tool provides motion to the cutting tool. In yet other cases, motion is given both to tool as well as the work piece.

Cutting tools are made of material which can be hardened by suitable heat treatment. During machining, lot of heat is generated and the temperature of the cutting edge of the tool may reach 650–700°C. The tool must maintain its hardness even at such elevated temperatures. This property of retaining its hardness at elevated temperatures is called 'red hardness'. Cutting tools develop the property of red-hardness due to addition of tungsten and molybdenum to high carbon steel. These days, cutting tools are made of high speed steel, or tungsten carbide. Tools made of ceramic materials (like Al_2O_3, SiC), and polycrystalline diamonds are also used for special applications.

Cutting speed: Readers must understand the concept of "cutting speed". Cutting speed means the linear speed at which cutting takes place. If the tool is stationary, the speed at which the work material approaches the cutting edge of tool is the cutting speed. It is measured in metres per minute.

The optimum cutting speed depends upon the tool material, the material to be cut and whether a cutting fluid is being used or not. The purpose of using cutting fluid is to remove heat from the cutting area and to lubricate the tool face so that the friction between chip and tool surface reduces. Use of cutting fluid makes cutting process more efficient. Similarly, cutting at recommended cutting speed results in improved tool life and performance.

Recommended cutting speed for machining cast iron and mild steel with high speed tools is 35 metres per minute. However, if tungsten carbide tools are used, cutting speeds of 65–70 metres per minute may be used. For non-ferrous material, much higher cutting speeds are permissible.

CENTRE LATHE

A centre lathe is also called an engine lathe or simply a lathe. It is one of the commonest and oldest machine tools. It is also one of the most versatile and widely used machines. Its main function is production of cylindrical profiles.

A centre lathe is shown in Fig. 1.1.

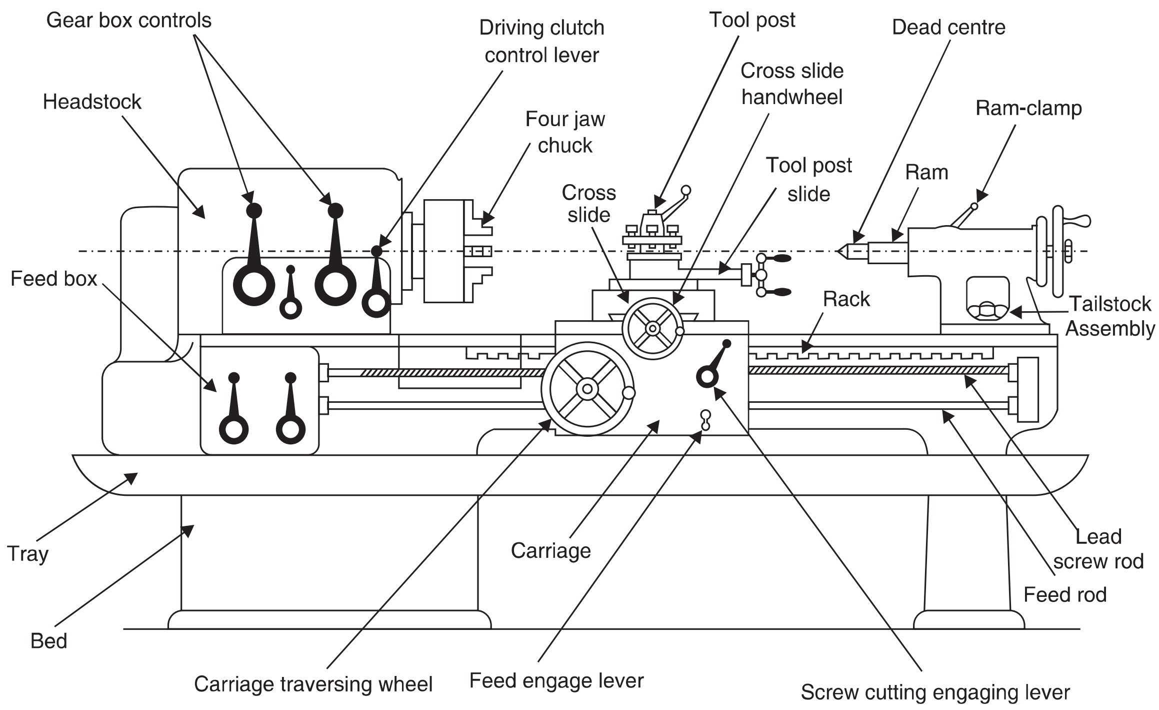

Fig. 1.1 Centre lathe

The main parts of a centre lathe are:

1. **Machine bed,** usually made of cast iron. It holds or supports all other parts of the lathe. The top of the machine bed is flat and is machined to form guide ways on which the carriage slides along the length of the lathe.

2. **Headstock:** It is fixed at the extreme left hand of the bed and contains shafts and gears immersed in lubricating oil. The driving shaft inside is driven by an electric motor. The driven shaft, which is in the form of a hollow spindle can be driven at various r.p.m. by changing gears, projects out of the headstock, A chuck (either three jaw or four jaw), is screwed on this spindle. The work piece can be held in the jaws of the chuck. When the spindle rotates, the chuck as well as the work piece held also rotate about the longitudinal axis of the spindle.

3. **Tailstock:** A tailstock is provided at the right hand end of the bed. It can slide along the guide ways provided on the bed and may be brought nearer to the headstock, if so desired. It can then be clamped or fixed on the bed in that position.

The tailstock has a spindle in the upper part of the tailstock, the axis of which coincides with the axis of the headstock spindle, both being at the same height above the bed. This spindle can be moved forwards or backwards by rotating a hand wheel. The front portion of tailstock spindle carries a 'dead' or 'live' centre. When a long work piece is held in the chuck at the headstock end, it is supported at the tailstock end by moving forward the tailstock spindle. Of course, there has to be a small conical hole in the centre of the work piece, in which the tailstock centre may be inserted to provide support. If the centre (being carried in its own bearings) rotates along with the work piece, it is called a live centre. However, if the tailstock centre remains stationary and work piece alone rotates, the centre is called 'dead centre' and the conical tip of centre has to be lubricated with grease to reduce the friction between the tailstock centre and the work piece.

A typical tailstock is shown in Fig. 1.2.

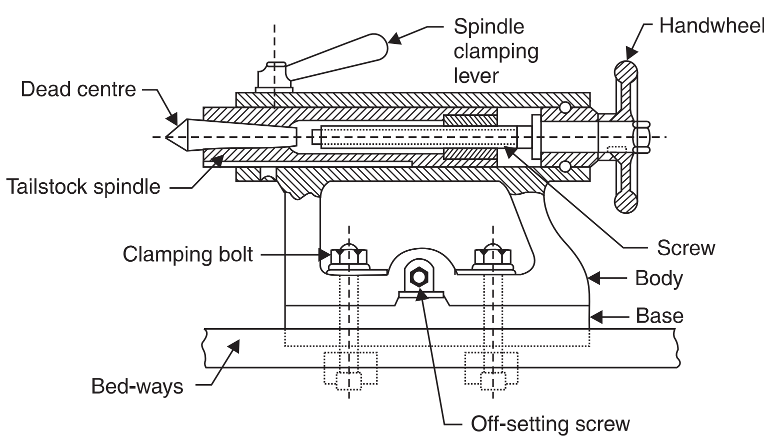

Fig. 1.2 Tailstock

4. **Carriage:** A carriage is shown in Fig. 1.3. The carriage can slide along the length of the machine bed from the tailstock end to the head stock end. This movement is controlled by manually operating the hand traversing wheel. It can also be imparted this traversing motion at different speeds automatically by engaging into the feed rod or feed shaft.

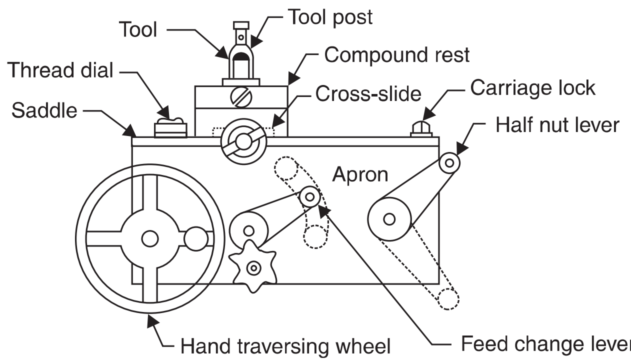

Fig. 1.3 Carriage

The carriage carries a cross slide, which can independently move in a crosswise direction at right angles to the bed. The cross slide can also be moved either manually through a smaller hand wheel or through an automatic device. Mounted upon the cross slide is another small slide, called the compound rest (or tool post slide) which can be rotated in a horizontal plane. Its normal position at 0° rotation is parallel to bed. Its angle of rotation can be read off on a protractor. This compound rest is used during taper turning to set the tool for angular cuts. The compound rest can be moved only manually. The cutting tool is clamped in the tool post which is mounted on top of the compound rest.

The gears, clutches and other mechanism required for giving movement to the carriage and cross slide etc. is hidden from view by means of an apron (thin steel plate) screwed upon the front face of the carriage. Half hidden in the front are two long shafts, (the screwed one is called the lead screw shaft/rod and the plain one is called feed shaft/rod) extending from the headstock to the tailstock end. These two shafts can be engaged one at a time to give longitudinal movement to the carriage. Lead screw is only used during the screw cutting operation. Feed shaft is used in other operations like turning.

Size of a lathe is specified by the distance between headstock chuck to tailstock centre. This is the length of the longest job which can be accommodated or machined on the lathe. In addition the swing of the lathe (*i.e.,* the vertical distance between chuck centre and the lathe bed) is specified as this is the radius of the largest work piece which can be turned on the machine.

CUTTING TOOLS USED ON THE LATHE

In a centre lathe, the work piece is held and fastened in a chuck. If a component is manufactured out of a round bar, the bar passes through the hollow spindle of the headstock, and the required length of bar is pulled out and then clamped in the jaws of the chuck, free end of the bar projecting towards the tailstock end. Mostly the movement of tool is from right to left. This is known as right hand working. Sometimes, it becomes necessary to do some work while moving tools from left to right, *i.e.,* left hand working. The tools for right hand lathe operations are quite different than tools for left hand working. In fact they are mirror images of each other.

Many different kind of operations are carried out on lathes such as

(*i*) Turning

(*ii*) Facing

(*iii*) Taper turning

(*iv*) Profile turning or form turning

(*v*) Parting

(*vi*) Boring

(*vii*) Threading

(*viii*) Knurling.

The tools used for these operations all different. Some of the right hand tools are shown in Fig. 1.4.

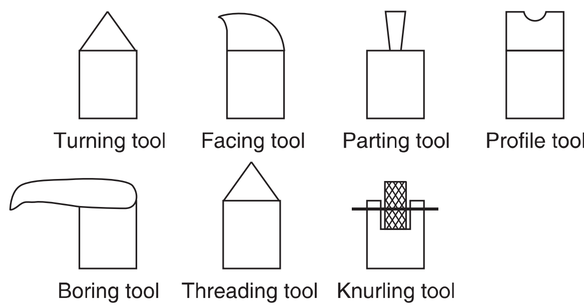

Fig. 1.4 Right hand lathe tools

HOLDING THE WORK PIECE IN THE CHUCK AND CENTERING

All jobs have to be securely clamped in the chuck and centred before any of the above listed operations can be performed on a lathe. 3-jaws chuck is a self centering device and is used for clamping round bars etc. A four jaws chuck is for clamping irregularly shaped jobs. In 4-jaws chuck each jaw moves in radially independent of other jaws. Centering means that the centre line of the work piece should nearly coincide with centre line of machine spindle. It is not enough to hold the job centrally in the chuck, the portion of work piece projecting out of chuck should also be centrally placed. Collet chuck, face plates etc. are some other holding devices for the work piece.

Turning: In this operation, the work piece is rotated at a suitable r.p.m., so that metal cutting may take place at the recommended cutting speed. If '*d*' is the diameter of work piece and *N* the r.p.m., the cutting speed can be calculated as π.d.N. A cutting tool is clamped in the tool post taking care that the tip of the tool is at the same height as the centre of job. In the turning operation, the job rotates and the cutting tool is inserted in the surface of work piece by moving the cross slide, starting at the right hand end of the work piece. The depth of cut of 1–1.5 mm may be taken and then the tool is steadily moved from right to left by sliding the carriage on the machine bed. The operation of turning is shown in Fig. 1.5.

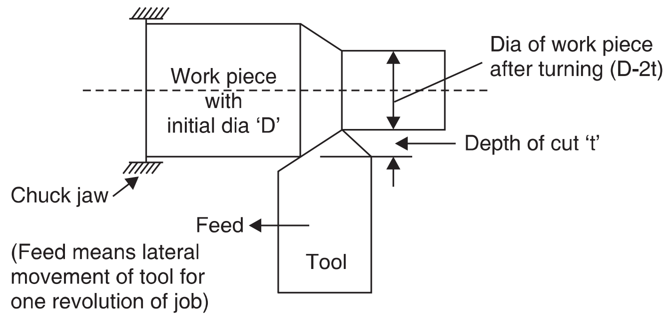

Fig. 1.5 Turning operation

Feed is given to the tool. Feed is measured in mm/rev of work piece. Since work piece r.p.m. is N, feed per minute will be $N \times$ feed/revolution (mm).

Obviously, it may not be possible to achieve the desired reduction of diameter in one pass of the tool, the tool will have to be brought back to the right side, again advanced by 1–1.5 mm by moving the cross slide and then traversed again from right to left side. This process will have to be repeated several times until the desired diameter is reached.

In the process of turning, a cylindrical shape is generated as a result of the combined movement of the work piece and the tool.

Facing: In this operation, the work piece is rotated as before, but the tool is moved across by cross slide. The carriage remains fixed in one position. The result is production of a flat circular section at one end of the cylinder. All lengths can be measured taking this surface as datum during further machining operations.

TAPER TURNING

Taper turning means production of a conical surface by gradual reduction in diameter as we proceed along the length of the cylinder. A conical surface will be produced, if the cutting tool moves along a line which is inclined to the longitudinal axis of the work piece instead of moving parallel to it. A taper is defined by the half angle (α) of the cone as shown in Fig. 1.6.

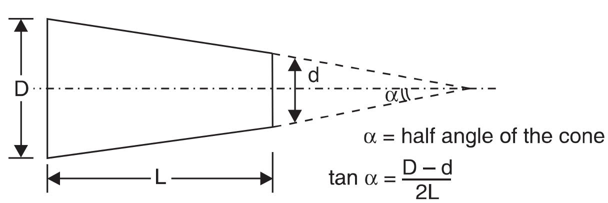

Fig. 1.6 Taper turning calculation

Following methods are used for taper turning on lathe:

1. By swivelling the compound rest.
2. By offsetting tailstock.
3. By using a taper turning attachment.
4. By using a form tool.

Taper turning by swivelling compound rest

In this method the compound rest is swivelled *i.e.,* rotated in a horizontal plane by half cone angle (α). The work piece is rotated as usual, but instead of using the carriage to traverse the tool, the tool is moved forward by the compound rest slide handwheel. Since the compound rest has been swivelled to an inclined position with respect to the longitudinal axis of lathe, the tool moves at an angle to the longitudinal axis of lathe generating a conical surface accurately.

By setting over the tailstock centre:

In this method, the tailstock centre is shifted in a direction at right angles to the longitudinal axis of the machine. The tailstock base guide ways have some clearance and it can be shifted laterally by a limited amount on the machine bed. The calculation of the taper angle can be understood from Fig. 1.7.

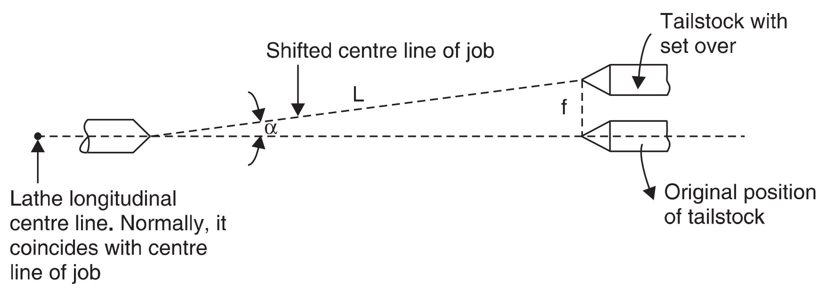

Fig. 1.7 Offsetting tailstock

If length of job is L and set over of tailstock is 'f' then half taper angle, $\alpha = \sin^{-1} \frac{f}{L}$. It will be appreciated that in this case tool will traverse parallel to machine centre line but the work piece has taken an inclined position with respect to the longitudinal centre line machine. This method can only be used, if taper angle is small. Since the set over cannot be accurately measured, this method is not accurate, but in this case, work pieces with long length can be tackled, which is not possible with compound rest method.

By using taper turning attachment

This method allows accurate production of a wide range of tapers. A taper turning attachment is used on the backside of the cross slide. In this case the cross slide moves a certain distance for a given amount of longitudinal traverse by the carriage. That is the tool gets a simultaneous movement in two perpendicular axes. The angle of taper cut will depend upon the ratio of movement of tool in the two axes.

Taper turning by form tool

In this case, tapers of only very short length are cut. The front profile of the form tool is such that when the tool is pushed against the work piece, the taper is produced. This method is illustrated in Fig. 1.8.

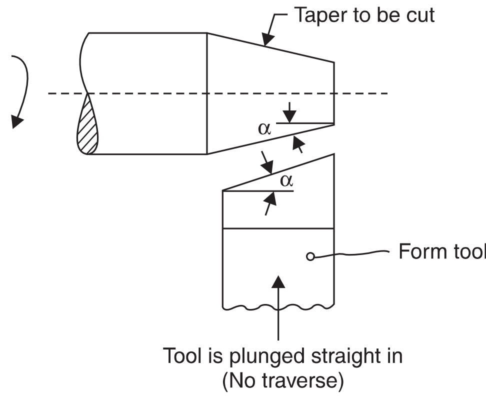

Fig. 1.8 Taper by form tool

PROFILE OR FORM TURNING

The basic principle of this lathe operation has become clear from the example of taper turning with the help of a form tool. Various other forms like a specified radius, semicircular shape etc. can be generated in a similar manner with a suitably shaped form tool and taking a plunge cut (*i.e.,* only cross slide will be used while carriage will remain locked in position).

Form tools should have a short profile, otherwise the work piece and the tool tend to vibrate and chatter.

Parting off: This operation is performed with a parting tool. This also requires a plunge cut. Gradually the diameter of work piece at the tool contact surface will reduce and will become smaller and smaller as the tool is fed in. Ultimately as the tip of tool will reach the centre line of job, the job will be parted in two pieces, the left hand piece will remain clamped in the chuck, while the right hand piece of requisite length will separate out.

Boring: Boring means enlarging an existing hole. For initial drilling of a hole on the lathe machine, tailstock centre is removed and in the tailstock spindle a drill is inserted. The tailstock is brought closer to the work piece, which is held in the chuck and rotated. Now using the handwheel of the tailstock, the drill is advanced.

The advancing drill comes in contact with end face of the work piece and drills a hole through it. After the hole has been drilled to required depth, the drill is withdrawn. This hole can then be enlarged in diameter by using a boring tool.

The operation of boring is shown in Fig. 1.9. It is a delicate operation. The diameter of the boring tool or boring bar fitted with a tool bit has to be smaller than the hole in the work piece. The boring operation is really an internal turning operation but not being able to see the actual cutting, makes the operation tricky and delicate.

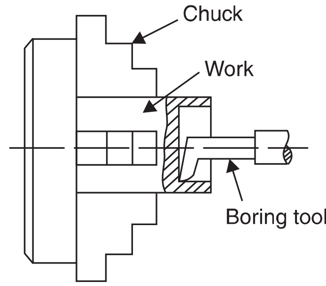

Fig. 1.9 Boring

Threading: Threading is an operation of cutting threads or helical grooves on the external cylindrical surface of the job. In this process, the carriage is connected to the lead screw. The pitch of threads to be cut equals $\frac{\text{r.p.m. of lead screw}}{\text{r.p.m. of workpiece}} \times$ Pitch of lead screw. Thus there should be an arrangement to change the ratio of r.p.m. of work piece and the r.p.m. of lead screw. This is done by a system of gears, which give the required ratio.

Threads have a standard profile. The cutting tool profile should match with this profile. Now the threads can be cut in the usual manner by traversing the tool by engaging the clutch between carriage and lead screw. Such screw cutting lathes are provided, with reversible motors. The r.p.m. of spindle is kept very low for thread cutting.

Knurling: For providing better grip, some work pieces are provided with a shallow diamond shaped pattern on its circumference. Knurling rollers, which have a similar pattern cut on their surface are hardened. When a work piece surface is required to be knurled, the work piece is held in a chuck and rotated and the knurling roller is clamped in the tool post and by moving the cross slide, the roller is pressed into the surface of the work piece. As the roller and work piece surface rotate together, the pattern is etched into the surface of the work piece.

Conclusion: There are many accessories and fittings, which, if provided greatly improve the performance and range of work which can be carried out on a lathe.

QUESTIONS

1. Make a sketch of a centre lathe and label its main parts.
2. List the various operations which may be performed on a centre lathe.
3. Describe at least three methods of taper-turning on a centre lathe.
4. Sketch some tools commonly used on a lathe.