MODULE-2
MACHINING PROCESS

LESSON CONTENTS:

Introduction, Types of motions in machining, turning and Boring, Shaping, Planning and Slotting, Thread cutting, Drilling and reaming, Milling, Broaching, Gear cutting and Grinding, Machining parameters and related quantities.

OBJECTIVES:

- To Study the Various Machining Process on various machine tools.
- To study the machining parameters and related quantities.

2.0 Machining Process:

Cutting processes remove material from the surface of a workpiece by producing chips. Some of the more common cutting processes, illustrated in Figure are as follows:

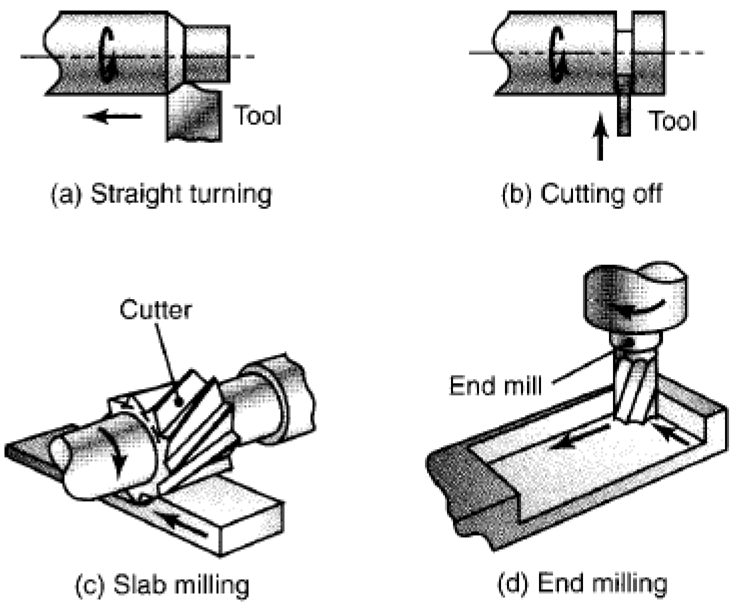


Fig: Various machining process

- Turning, in which the workpiece is rotated and a cutting tool removes a layer of material as the tool moves to the left.
- Cutting off, in which the cutting tool moves radially inward and separates the right piece from the bulk of the blank.
- Slab milling, in which a rotating cutting tool removes a layer of material from the

surface of the workpiece.

- End milling, in which a rotating cutter travels along a certain depth in the workpiece and produces a cavity.

2.1 Types of motions in Machining:

For obtaining the required shape on the workpiece, it is necessary that the cutting edge of the cutting tool should move in a particular manner with respect to the workpiece. The relative movement between the workpiece and cutting edge can be obtained either by the motion of the workpiece, the cutting tool, or by a combination of the motions of the workpiece and cutting tool.

These motions which are essential to impart the required shape to the workpiece are known as working motions. Working motions can further be classified as:

1. Drive motion or primary cutting motion

2. Feed motion

Working motions in machine tools are generally of two types: ***Rotary & Translatory***. Working motions of some important groups of machine tools are shown in figure:

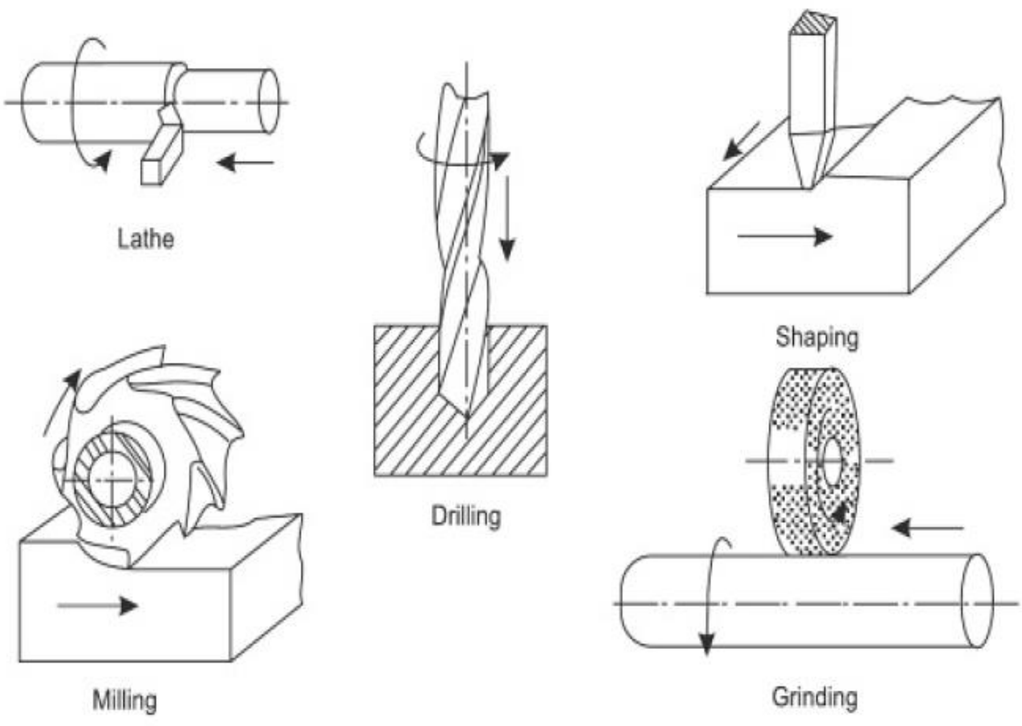


Fig: various machining process with the various relative motions

1. For lathes and boring machines:
    a. Drive motion - Rotary motion of workpiece
    b. Feed motion – translatory motion of cutting tool in the axial or radial directions
2. For Drilling machines:
    a. Drive motion - rotary motion of drill
    b. Feed motion - translatoey motion of drill
3. For milling machines:
    a. Drive motion – rotary motion of the cutter
    b. Feed motion – translatory motion of the workpiece
4. For shaping, planning and slotting machines:
    a. Drive motion – Reciprocating motion of the cutting tool
    b. Feed motion – intermittent translation motion of workpiece
5. For Grinding Machines:
    a. Drive motion – Rotary motion of the grinding wheel
    b. Feed motion – Rotory as well as translatory motion of the workpiece

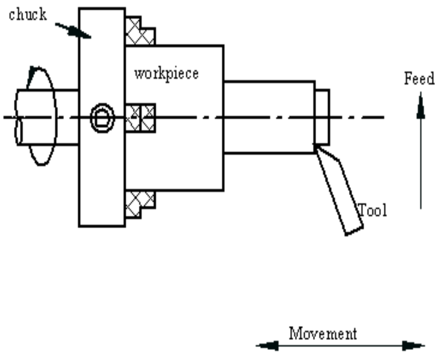
2.2 Lathe operations/ Turning operations:

The operations that can be performed on a lathe are

1. **By holding the job between centers or between chuck and dead center**
    a) Turning – plain, step, taper, etc
    b) Facing
    c) Chamfering
    d) Knurling
    e) Thread cutting
    f) Polishing
    g) Spinning
2. **By holding the job by a chuck alone**
    a) Turning and Facing of short length work piece.
    b) Drilling
    c) Reaming
    d) Boring
    e) Thread cutting, internal/external.
3. **By using special attachments.**
    a) Grinding
    b) Milling

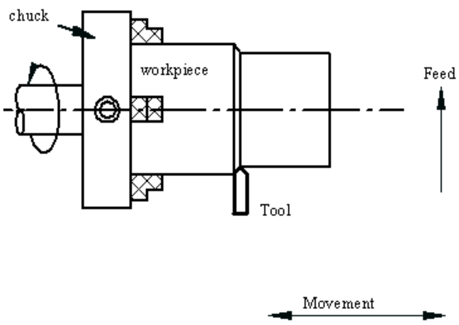
2.2.1 Facing

Is the operation of machining the ends of a piece of the work to produce a flat surface square with the axis. This is used to cut the work to the required length. The operation involves feeding the tool perpendicular to the axis of rotation of the work piece. A regular cutting tool may be used for facing a large work piece. The cutting edge should be set at the same height as the centre of the work piece. A properly ground facing tool is mounted in a tool holder in the tool post to accomplish facing operation.



2.2.2 Plain Turning

The process of metal removal from the cylindrical jobs is called straight or plain turning. Cross-slide and the carriage are used to perform turning operation and make the operation faster and economical. Plain turning operations are generally performed in two steps-rough and finish turning. Rough turning is usually done for rolled, cast or forged parts to remove the uneven or sandy or rough surface on the jobs. A roughing tool does roughing and used for excess stock removal. For finishing a tool with slightly round cutting edge is used. The depth of cut rate is at the range of 0.2 to 1 mm and the feed rate between 0.1 to 0.3 mm.

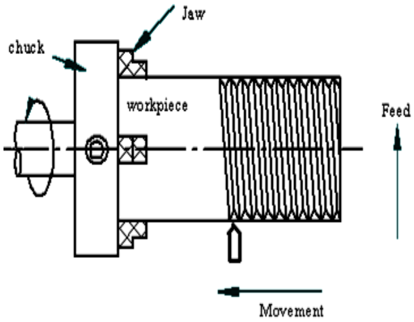


2.2.3 Step Turning

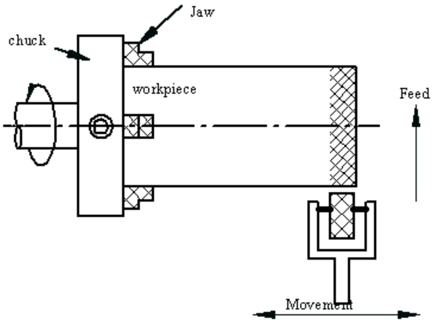
A step turning operation is performed using a step cutting tool, after the turning operation. The work is held in between the centers or with the chuck the tool is held at a height equal is the axis of the work. The depth to obtain the step on the cylinder is provided by cross slide movement and the carriage movement. These operations are performed manually/ automatically.

2.2.4 Thread Cutting:

A thread is a helical ridge formed on the cylindrical rod surface. By employing V-Shaped cutting tool it is possible to accomplish threads on the work piece. When the tool is moved longitudinally with linear uniform motion while the work piece is rotating with uniform speed. An appropriate gear ratio is maintained between the spindle on which the work piece is mounted and the lead screw has the ability to enable the tool to move longitudinally at the appropriate linear speed, the screw thread of the required pitch can be cut.



2.2.5 Knurling:



Knurling is an operation performed on the lathe to generate serrated surface on the work piece. This is used to produce a rough surface for griping like the barrel of the micrometer or screw gauge. This is done by a special tool called knurling tool which has a set of hardened roller with the desired serrations.

During knurling operation, the hardened rollers of the tool are pressed against the slowly rotating work pieces such that the impression of tool serrations are formed on the work pieces' surface. Usually, there are three different pattern of knurling produced as per requirements and is as shown.

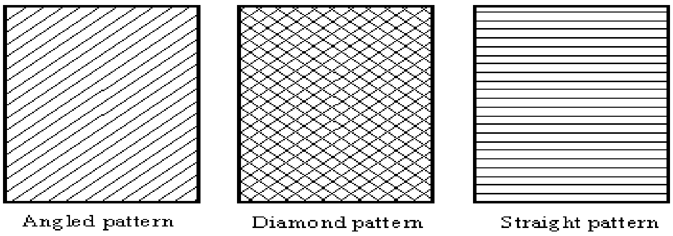
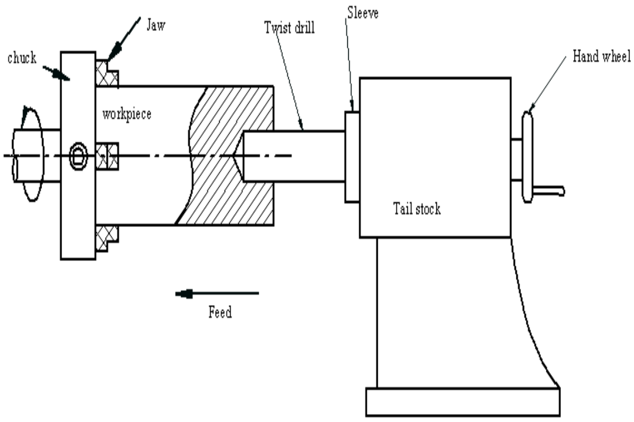


Fig: Patterns of Knurling

2.2.6 Drilling

Drilling is a metal cutting process carried out by a rotating cutting tool to make circular holes in solid materials. The tool which makes the hole is called a drill bit or twist drill. In operation the drill bit is fed against the revolving work piece by rotating the hand wheel of the tail stock as shown in fig. drilling on lathe is limited to



produce hole through the axis of the work piece only. So drilling operation is best to perform on drilling machine.

2.2.7 Taper Turning

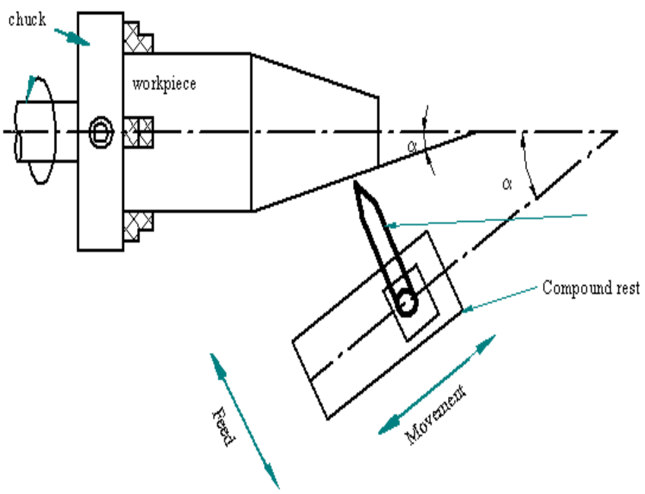
Taper turning is an operation to produce conical surface on the work piece. This can be machined by either work piece inclined to the axis of the lathe or tool moving inclined to the axis of the lathe.

There are many methods for taper turning

a) By swiveling the compound rest.
b) By offsetting the tail stock.
c) By taper turning attachment.
d) By using form tool.

a) **Taper Turning by Swiveling the compound Tool Rest**

$$\tan\alpha = \frac{(D-d)}{2l}$$

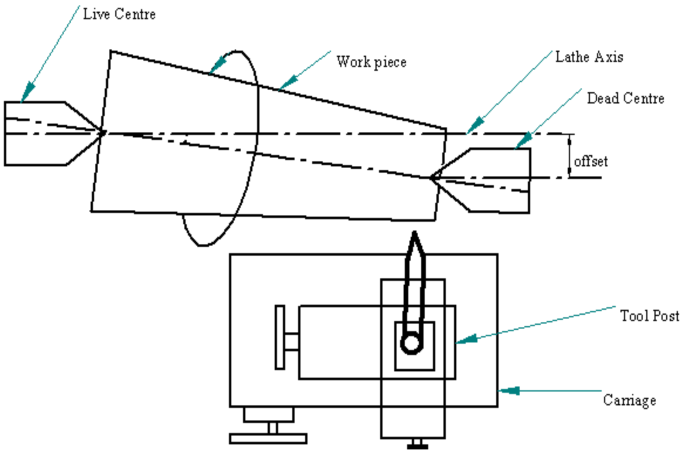


The work pieces which requires steep taper for short lengths the taper turning was done by swiveling the compound rest method. In this method the compound tool rest is swiveled to the required taper angle and then locked in the angular position. The carriage is also locked at that position. For taper turning the compound rest is moved linearly at an angle so that the cutting tool produces the tapered surface on the work piece. This method is limited to short taper lengths due to the limited movement of the compound tool rest.

The taper angle is calculated by,

Where, D= bigger diameter of the taper (mm)
d= smaller diameter of the taper (mm)
L= Length of the taper (mm)

b) **Taper Turning by Offsetting the Tailstock (or Tailstock set over method)**



$$\textbf{offset} = \frac{(\mathbf{D}-\mathbf{d})\mathbf{L}}{\mathbf{2}\boldsymbol{l}}$$

In this method the work piece is inclined with respect to the lathe axis and tool movement is in line with the lathe axis to produce the required taper. Here the tail stock body is shifted by small distance (offset) laterally. This makes the work piece is shifted at one end and hence there will be an inclination with respect to the lathe axis. The tool is moved parallel to the lathe axis and fed against the revolving work piece which produces the required taper.

The offset is calculated by,

Where, D= bigger diameter of the taper (mm)
d= smaller diameter of the taper (mm)
L= Length of the taper (mm)
l= Total length of the work piece

This method is used to produce only external taper and suitable for small taper on long work pieces.

c) **Taper Turning by Taper Turning Attachment**

A taper tuning attachment is used to cut both internal and external tapers. The taper turning attachment is as shown in fig, consists of a bracket which will be connected to the rear side of the lathe bed. A guide bar which can be swiveled in the horizontal plane and locked in position is mounted over the bracket. A guide block pivoted to a draw-link will slide in the longitudinal slot in the guide bar. The draw-link is connected firmly to the cross slide. The tool is mounted on the tool post slide. The cross slide is allowed to move freely on its ways by loosening the cross feed screw and the engaging nut.

2.3 Boring Operations:

In machining, boring is the process of enlarging a hole that has already been drilled (or cast) by means of a single-point cutting tool. Boring is used to achieve greater accuracy of the diameter of a hole, and can be used to cut a tapered hole. Boring can be viewed as the internal-diameter counterpart to turning, which cuts external diameters.

Boring operations may be carried out on various machine tools, such as lathe, milling or boring machine itself.

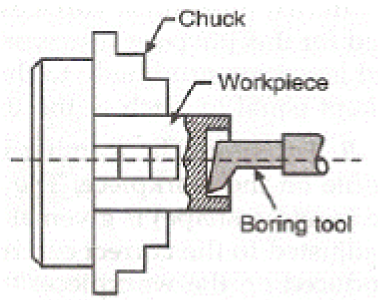


Fig: Boring operation

In boring operations, the single point cutting tool is set to the diameter of the hole to be turn and fed against the rotary workpiece. The diameter of the hole to be bore can be increased or decreased by moving the cutting tool in and out of the tool holder.

2.4 Shaping operations:

The shaper machine tool makes use of a single-point cutting tool that traverses the work and feeds over at the end of each stroke. The types of surfaces it is best able to produce are shown in figure.

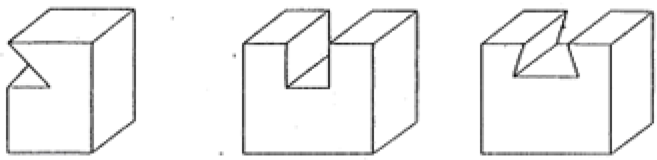


Fig: Grooves machined on Shaper

Contour work may also be done by coordinating the tool hand feed to a layout line, or by duplicating attachment places on the machine. Thus, contours can be formed with inexpensive single point cutting tools for short runs where the cost of from tools for milling work is prohibitive.

The different operations, which a shaper can perform, are as follows:

1. Machining horizontal surface
2. Machining vertical surface
3. Machining angular surface
4. Slot cutting
5. Key ways cutting
6. Machining irregular surface
7. Machining splines and cutting gears

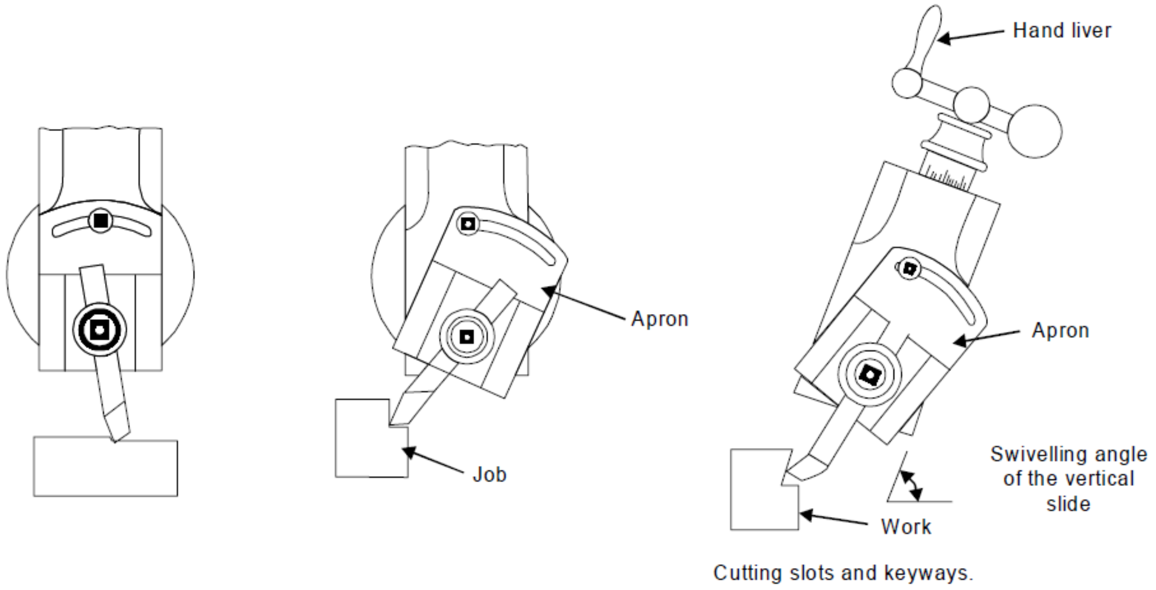


Fig: (a) machining horizontal Surfaces (b) vertical Surfaces (c) angular surfaces

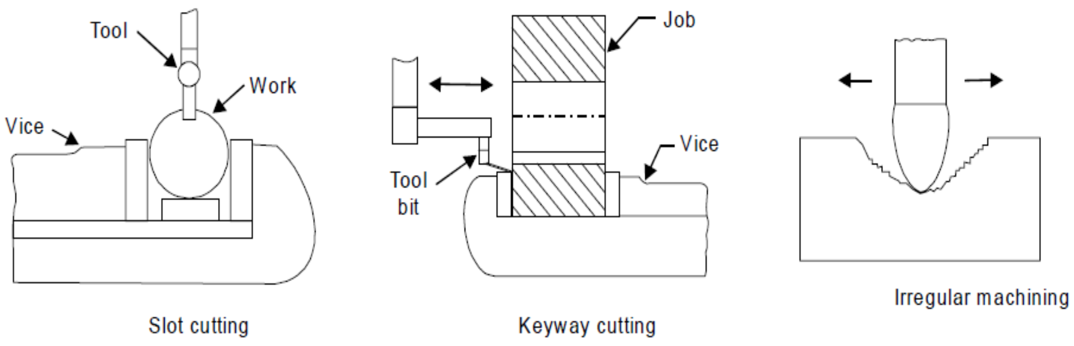


Fig: (d) slot cutting (e)key way cutting (f) Shaping irregular surfaces

2.5 Planning operations:

Figure depicts the working principle of a planer. In a planer, the work which is supported on the table reciprocates past the stationary cutting tool and the feed is imparted by the lateral movement of the tool. The tool is clamped in the tool holder and work on the table. Like shaper, the planner is equipped with clapper box to raise the tool in idle stroke.

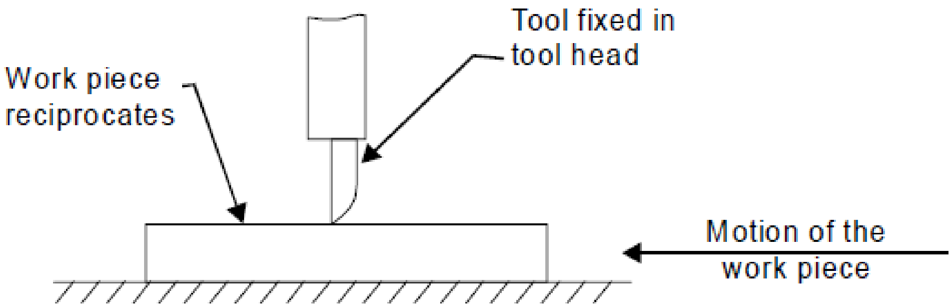


Fig.: principle of planing operation

2.5.1: Differences between Shaper and planer

Sl. No	Shaper	Planer
1	The work is held stationary and the cutting tool on the ram is moved back and forth across the work	In a planer, the tool is stationary and the work piece travels back and forth under the tool
2	It is used for shaping much smaller jobs	A planer is meant for much larger jobs than can be undertaken on a shaper.
3	A shaper is a light machine	It is heavy duty machine
4	Shaper can employ light cuts and finer feeds	Planer can employ heavier cuts and coarse feed
5	Shaper uses one cutting tool at a time	Several tools can cut simultaneously on a planer
6	The shaper is driven by quick return motion mechanism	The planer table is driven either by gear drives or hydraulic means

2.7 Drilling operations:

Though drilling is the primary operation performed in a drilling machine, a number of similar operations are also performed on holes using different tools. The different operations that can be performed in a drilling machine are:

1. Drilling
2. Reaming
3. Boring
4. Counter boring
5. Countersinking
6. Spot facing
7. Tapping

2.7.1 Drilling:

This is the operation of making a circular hole by removing a volume of metal from the job by a rotating cutting tool called drill as shown in Figure. Drilling removes solid metal from the job to produce a circular hole. Before drilling, the hole is located by drawing two lines at right angle and a center punch is used to make an indentation for the drill point at the center to help the drill in getting started. A suitable drill is held in the drill machine and the drill machine is adjusted to operate at the correct cutting speed. The drill machine is started and the drill starts rotating. Cutting fluid is made to flow liberally and the cut is started. The rotating drill is made to feed into the job. The hole, depending upon its length, may be drilled in one or more steps. After the drilling operation is complete, the drill is removed from the hole and the power is turned off.

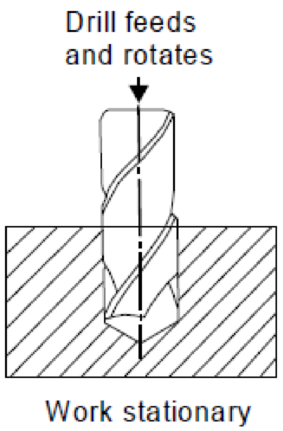


Fig: Drilling operations

2.7.2 Reaming:

This is the operation of sizing and finishing a hole already made by a drill. Reaming is performed by means of a cutting tool called reamer as shown in Figure. Reaming operation serves to make the hole smooth, straight and accurate in diameter. Reaming operation is performed by means of a multi-tooth tool called reamer. Reamer possesses several cutting edges on outer periphery and may be classified as solid reamer and adjustable reamer.

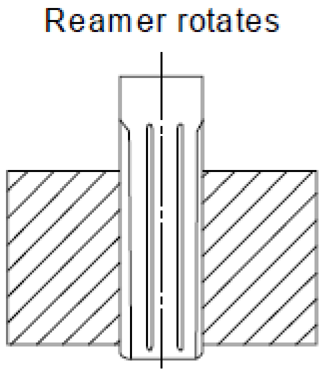


Fig.: Reaming Operation

2.7.3 Boring:

Figure shows the boring operation where enlarging a hole by means of adjustable cutting tools with only one cutting edge is accomplished. A boring tool is employed for this purpose.

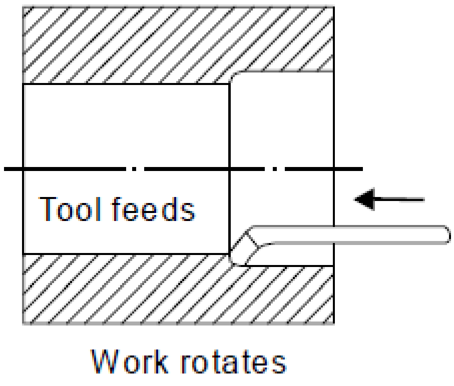


Fig.: Boring Operations

2.7.4 Counter boring:

Counter boring operation is shown in Figure. It is the operation of enlarging the end of a hole cylindrically, as for the recess for a counter-sunk rivet. The tool used is known as counter-bore.

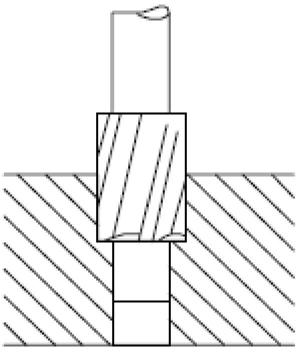


Fig.: Counter Boring

2.7.5: Counter Sinking:

Counter-sinking operation is shown in Figure. This is the operation of making a Cone shaped enlargement of the end of a hole, as for the recess for a flat head screw. This is done for providing a seat for counter sunk heads of the screws so that the latter may flush with the main surface of the work.

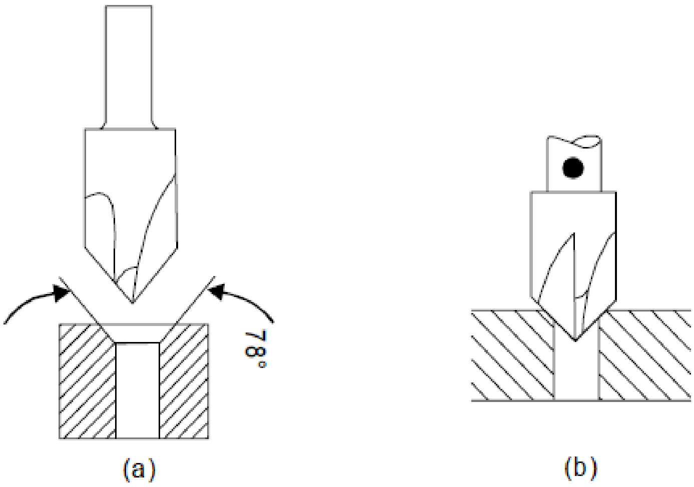


Fig.: Counter Sinking operation

2.7.6: Spot Facing:

This is the operation of removing enough material to provide a flat surface around a hole to accommodate the head of a bolt or a nut. A spot-facing tool is very nearly similar to the counter-bore.

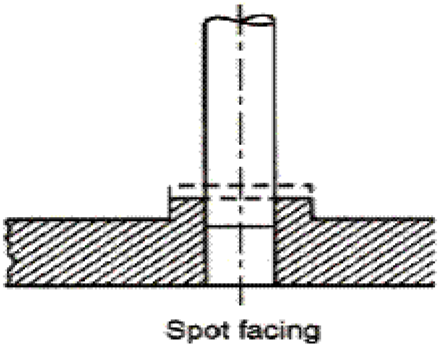


Fig.: Spot Facing

2.7.7 Tapping:

It is the operation of cutting internal threads by using a tool called a tap. A tap is similar to a bolt with accurate threads cut on it. To perform the tapping operation, a tap is screwed into the hole by hand or by machine. The tap removes metal and cuts internal threads, which will fit into external threads of the same size. For all materials except cast iron, a little lubricate oil is applied to improve the action. The tap is not turned continuously, but after every half turn, it should be reversed slightly to clear the threads. Tapping operation is shown in Figure.

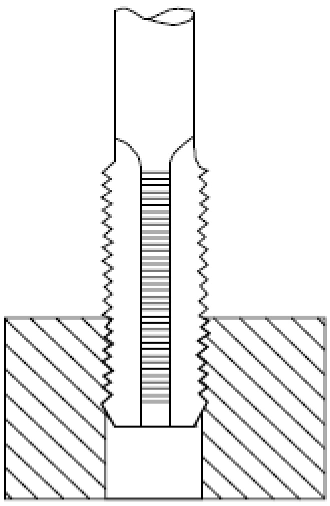


Fig.: Tapping operations

2.8 Milling operations:

Unlike a lathe, a milling cutter does not give a continuous cut, but begins with a sliding motion between the cutter and the work. Then follows a crushing movement, and then a cutting operation by which the chip is removed. Many different kinds of operations can be performed on a milling machine but a few of the more common operations will now be explained. These are:

2.8.1 Plain milling or slab milling
Figure (a) illustrates the plain and slab milling operation. It is a method of producing a plain, flat, horizontal surface parallel to the axis of rotation of the cutter.

2.8.2 Face milling
Figure (b) illustrates the face milling operation. It is a method of producing a flat surface at right angles to the axis of the cutter.

2.8.3 Side milling
Figure (c) illustrates the side milling operation. It is the operation of production of a flat vertical surface on the side of a work-piece by using a side milling cutter.

2.8.4 Angular milling
Figure (d) illustrates angular milling operation. It is a method of producing a flat surface making an angle to the axis of the cutter.

2.8.5 Gang-milling
Figure (e) illustrates the gang milling operation. It is a method of milling by means of two or more cutters simultaneously having same or different diameters mounted on the arbor of the milling machine.

2.8.6 Form milling
Figure (f) illustrates the form milling operation. It is, a method of producing a surface having an irregular outline.

2.8.7 End milling
Figure (g) illustrates end milling operation. It is a method of milling slots, flat surfaces, and profiles by end mills.

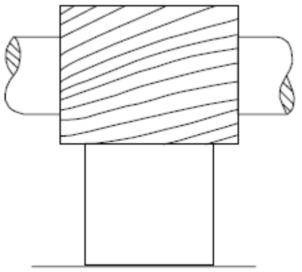
2.8.8 Profile milling
Figure (h) illustrates profile milling operation. It is the operation of reproduction of an outline of a template or complex shape of a master die on a workpiece.

2.8.9 Saw milling
Figure (i) illustrates saw milling operation. It is a method of producing deep slots and cutting materials into the required length by slitting saws.

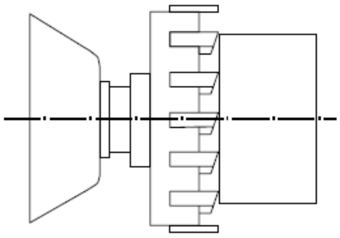
2.8.10 T-slot milling
Figure (j) illustrates T-slot milling operation.

2.8.11 Keyway milling
Figure (k) illustrates keyway milling operation.

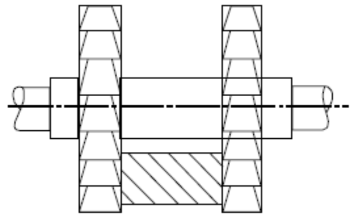
2.8.12 Gear cutting milling
Figure (l) illustrates gear cutting milling operation.



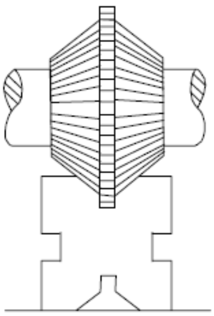
(a) Plane milling



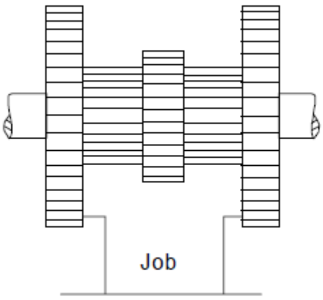
(b) Face milling



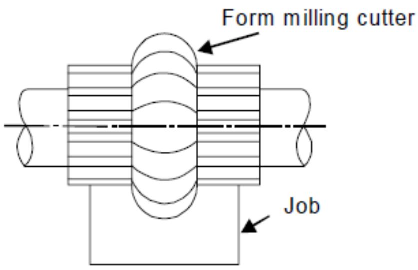
(c) Side milling



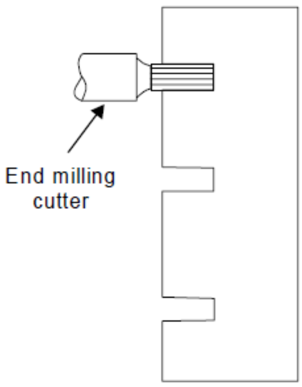
(d) Angular milling



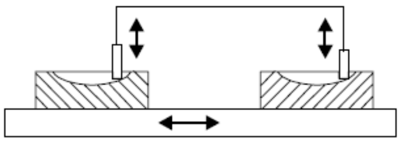
(e) Gang milling



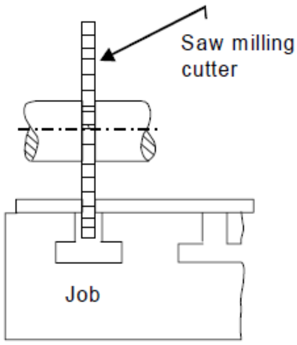
(f) Form Milling



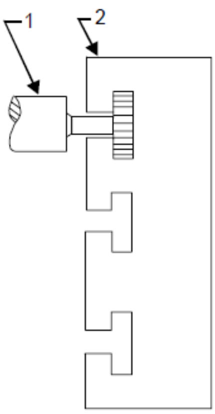
(g) End milling



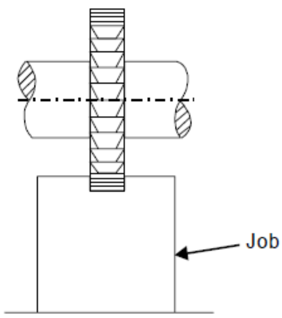
(h) Profile milling



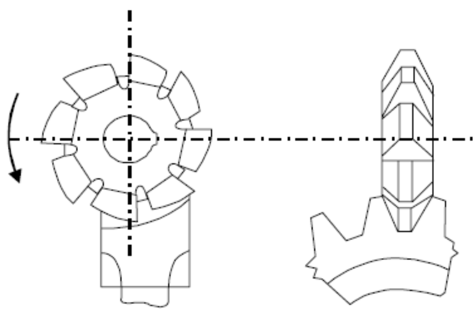
(i) Saw milling



(j)
T - Slot
Milling



(k) Key way milling



(l) Gear Cutting Milling

2.9 Grinding Operations

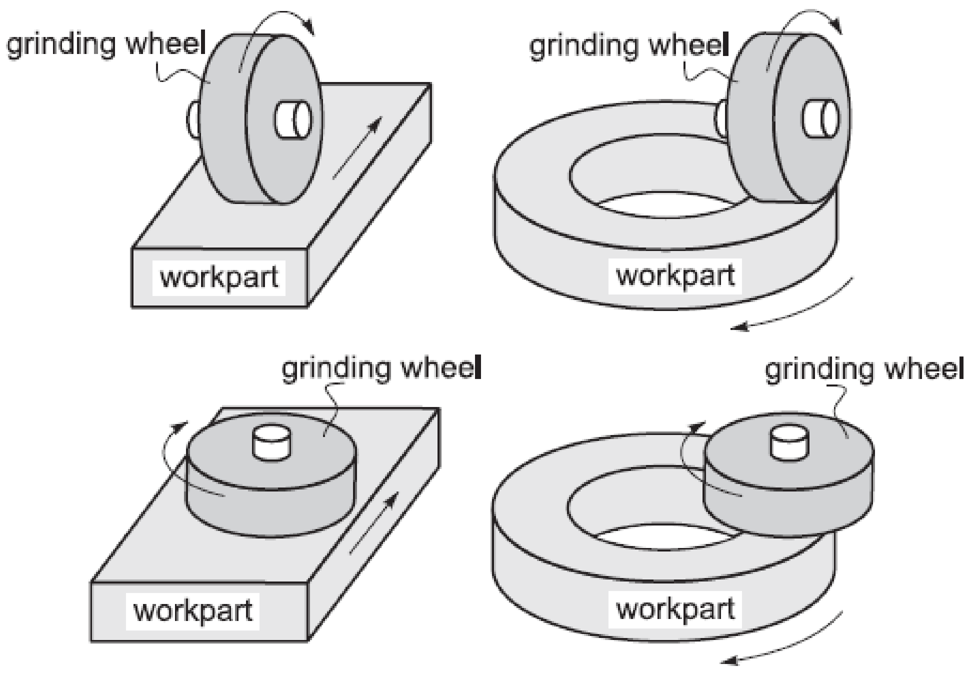
Grinding is a material removal process in which abrasive particles arc contained in a bonded grinding wheel that operates at very high surface speeds. The grinding wheel is usually disk shaped and is precisely balanced for high rotational speeds.

Grinding operations are carried out with a variety of wheel-work part configurations. The basic type of grinding are,

- surface grinding,
- cylindrical grinding, and
- centreless grinding.

2.9.1 Surface grinding:

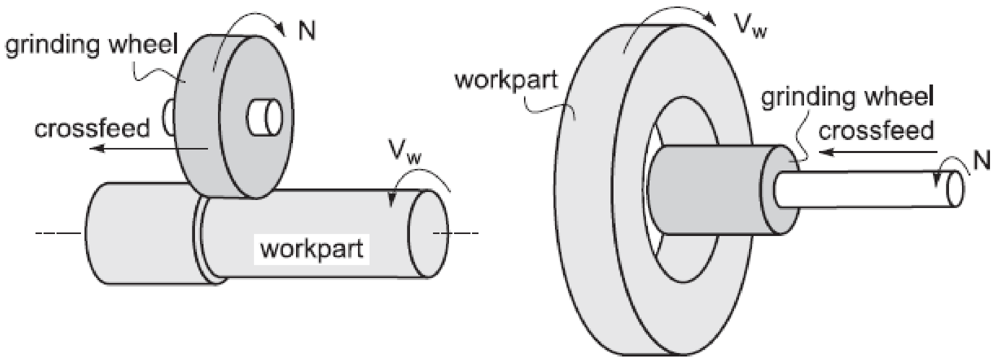
Surface grinding is an abrasive machining process in which the grinding wheel removes material from the plain flat surfaces of the workpiece.
In surface grinding, the spindle position is either horizontal or vertical, and the relative motion of the workpiece is achieved either by reciprocating the workpiece past the wheel or by rotating it. The possible combinations of spindle orientations and workpiece motions yield four types of surface grinding processes illustrated in the figure:



Four types of surface grinding with horizontal or vertical spindles, and with reciprocating linear motion or rotating motion of the workpiece.

2.9.2 Cylindrical grinding

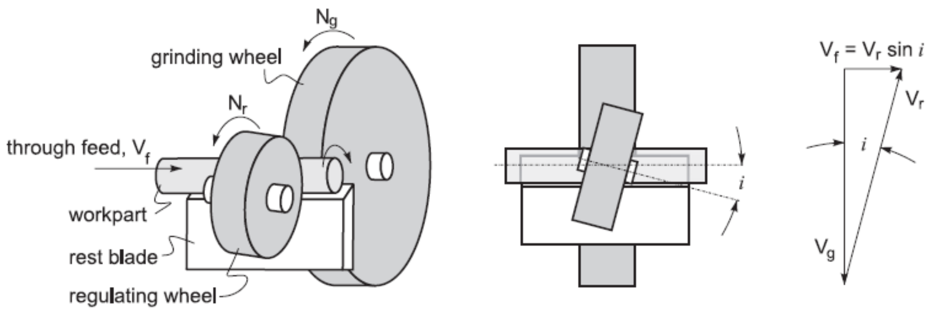
In this operation, the external or internal cylindrical surface of a workpiece are ground. In external cylindrical grinding (also center-type grinding) the workpiece rotates and reciprocates along its axis, although for large and long work parts the grinding wheel reciprocates. In internal cylindrical grinding, a small wheel grinds the inside diameter of the part. The workpiece is held in a rotating chuck in the headstock and the wheel rotates at very high rotational speed. In this operation, the workpiece rotates and the grinding wheel reciprocates.



Two types of surface grinding, (*Left*) external, and (*Right*) internal.

2.9.3 Centerless grinding

Centerless grinding is a process for continuously grinding cylindrical surfaces in which the workpiece is supported not by centers or chucks but by a rest blade. The workpiece is ground between two wheels. The larger grinding wheel does grinding, while the smaller regulating wheel, which is tilted at an angle i, regulates the velocity V_f of the axial movement of the workpiece. Centerless grinding can also be external or internal, traverse feed or plunge grinding. The most common type of centerless grinding is the external traverse feed grinding, illustrated in the figure:



External traverse feed centerless grinding. The regulating wheel is tilted at an angle *i* to control the velocity of through feed.

2.10 Machining parameters:

The parameters which effect on the machining process are

1. **Speed:**
   It expresses with the number of rotations (rpm) of a spindle. When the rotating speed is high, processing speed becomes quick, and a processing surface is finely finished. However, since a little operation mistakes may lead to the serious accident, it is better to set low rotating speed at the first stage.

2. **Depth of Cut**
   The depth of cut affects to the processing speed and the roughness of surface. When the cutting depth is big, the processing speed becomes quick, but the surface temperature becomes high, and it has rough surface. Moreover, a life of byte also becomes short. If you do not know a suitable cutting depth, it is better to set to small value.
3. **Feed**
   The feed of the tool also affects to the processing speed and the roughness of surface. When the sending speed is high, the processing speed becomes quick. When the sending speed is low, the surface is finished beautiful. There are 'manual sending' which turns and operates a handle, and 'automatic sending' which advances a byte automatically. A beginner must use the manual sending. Because serious accidents may be caused, such as touching the rotating chuck around the byte in automatic sending.

OUTCOMES:

- Describe various machining processes pertaining to relative motions between tool & work piece

QUESTIONS:

1. Explain the working of auxillary cutting motions in machine tool.
2. What is machining? Give classification of machining process.
3. List and explain the operations carried over lathe machine.
4. What are the operations performed on Drilling machine?
5. Differentiate between shaping and planning
6. List and Explain various operations performed on milling machine.
7. Describe the parameters which affects the machining operations.

FURTHER READING:

1. “Metal cutting principles”, Milton C. Shaw, Oxford University Press, Second Edition,2005.
2. “Manufacturing Technology”, Vol 2, P N Rao, McGraw Hill Education, 3rd Edition

3. “Workshop Technology, Vol-II”, by Hazara Chowdary