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Department of Aerospace Engineering

19AST202 AIRCRAFT PRODUCTION TECHNOLOGY

Machining

Introduction

Machining can be described as a metal removing process in which a cutting tool is used to remove unwanted material from the workpiece to produce a part of the desired shape. The workpiece is usually cut from a larger piece of metal called *stock* which may be available in different shapes, like sheets, solid bars, hollow tubes and beam shapes of various cross sections. Basic elements of machining operations includes three things—tools, workpiece and chips where a tool is used for removing extra material from a workpiece in the form of chips.

Machining process is the most common of all manufacturing processes. It is a very versatile process and can be used to create a variety of shapes, like holes, slots, cuts, flat surfaces, and many other complex shapes. Machining operations can be performed on almost all materials like metals, plastics, composites, and wood. Machining is accomplished with the help of machines known as *Machine Tools*. Based on the different metal removal processes machine tools, like lathes, shapers, planer, drill, milling and grinding machines are used to accomplish this purpose.

Classification of Machining Processes

Machining process can be classified as follows:

Metal Cutting Process

This process involves removal of metal from a workpiece with the help of cutting tools which have a single point cutting edge, such as in lathe and planer, or multiple cutting edges as in drilling or milling.

Grinding Process

The process involves removal of metal from a workpiece using tools made of abrasive particles of irregular geometry, such as in surface grinding and cylindrical grinding.

Finishing Process

Finishing process is characterised by the removal of burrs and other surface flaws by removal of extremely small amount of metal from the surface of the metal such as in lapping, honing and super finishing.

Unconventional Machining Process

Metal removal is achieved by using unconventional methods like laser beam machining, electron beam machining, electron chemical machining, etc.

Figure shows some of the common machining methods.

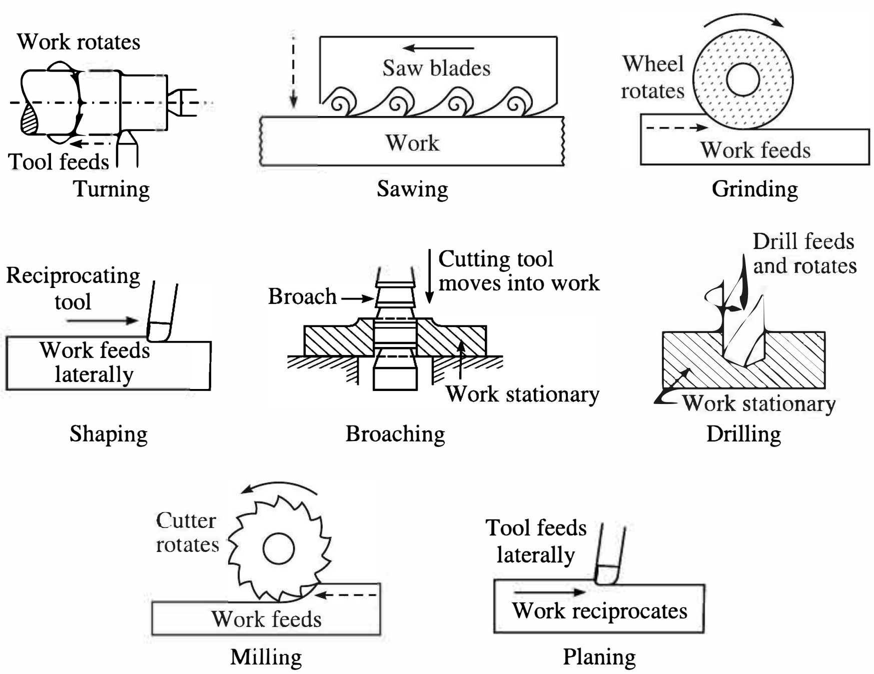


Figure Basic machining processes.

Lathe Machine

The *Lathe* is one of the oldest machine tool available in any machine shops. The working principle of lathe is shown in Figure where in the job to be machined is held and rotated in a lathe chuck and the tool is fed to the job to remove the metal. Lathe removes the material in the form of chips by a single point cutting tool held in the tool post. The job is held and rotated on a lathe by holding it either between the two centres of the lathe, namely live centre and dead centre, or by holding the job in a chuck.

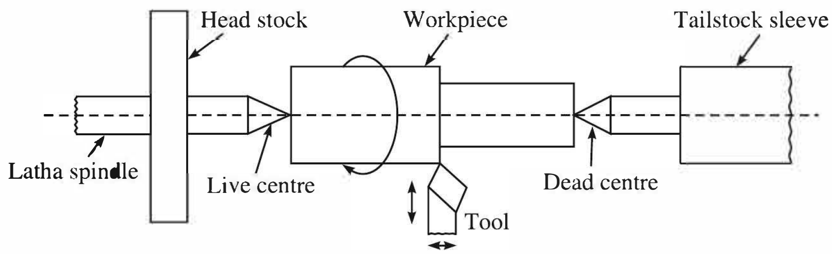


Figure Working principle of lathe machine.

Working Principle

The workpiece is held between two strong and rigid supports called *centres*, or in a chuck or face plate which revolves with the help of a driving mechanism. The cutting tool is also rigidly held in a tool post and is fed against the revolving work. The normal cutting operations called *turning* are performed with the cutting tool fed either parallel or at right angles to the axis of the work. It is also possible that the cutting tool may be fed at an angle relative to the axis of the work for machining tapers and angles on the workpiece. There are many other operations that lathe can perform.

Parts of a Lathe Machine

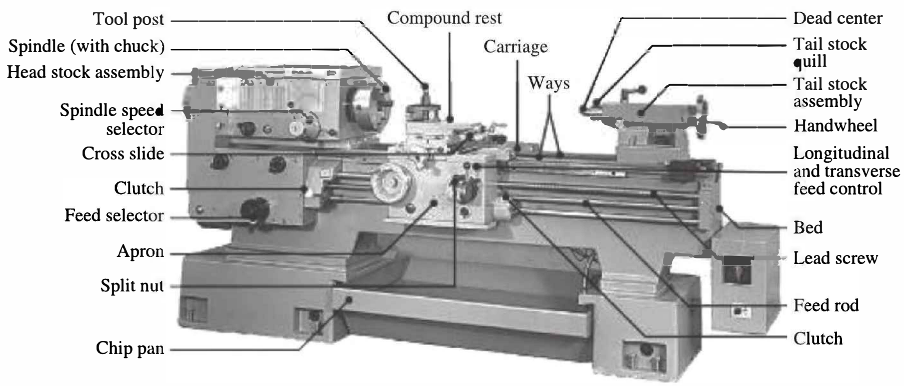
The main parts of lathe are as follows:

1. Bed
2. Head stock
3. Tail stock
4. Carriage
5. Feed mechanism

Figure 7.3 shows the main parts of a standard lathe machine.

Bed

The *Bed* is major component of a lathe machine. It gives support to all the mounting of a lathe, such as tail stock, carriage, head stock, etc. A bed is made



A lathe machine with its major components.

of gray or modular cast iron. The top portion of the bed has two sets of guide ways: outer ways and inner ways. *Outer Ways* provides support to the carriage, and Inner Ways is used for tail stock. Inner and outer guide ways are precision machined parallel to assure accuracy of movement while machining operations.

Head stock

The Head Stock is mounted in a fixed position on the inner ways, usually at the left end. It is used to rotate the workpiece or job at different speeds with the help of a chuck. The headstock is clamped on the left hand side of the bed and serves as housing for the driving pulleys, back gears, headstock spindle, live centre and the feed reverse gear. The headstock spindle is a hollow cylindrical shaft that provides a drive from the motor to work holding devices.

Tail stock

The *Tail Stock* is another main part of the lathe which is situated opposite the head stock on the ways of the bed. It is situated at the top right hand of the bed with a dynamic position. It carries the dead centre, which is used to hold and support the job when it is rotated between the two lathe centres—live centre and dead centre. The tail stock can slide along the bed to accommodate different lengths of the workpiece between the centres. The *Dead Centre* does not revolve with the job and consists of a sleeve, nut and a hand wheel.

Carriage: A carriage is used for supporting, guiding and controlling the motion of a tool against the job during the operation. It is located between the tailstock and headstock. A carriage has two main parts:

Saddle: Saddle is an H-shaped part mounted on the top of the lathe ways. It is used for providing support to the cross slide, compound rest and the tool post.

Cross slide: It is mounted on the top of the saddle and it is used for automatic cross movement of a cutting tool.

Compound rest: It is fitted on the top of the cross slide and is used to support the tool post and the cutting tool.

Tool post: It is used to rigidly clamp the cutting tool at a proper height during the cutting operation. It is located on the compound rest.

Apron: The apron is attached to the front of the carriage. It has the mechanism and controls for moving the carriage and cross slide.

Feed mechanism

Feed Mechanism in lathe is used to impart various types of feeds to the cutting tool. These could be longitudinal feed, cross feed or angular feed depending upon the type of the machining operation required. It consists of a lead screw, quick change gear box, feed gear box, feed reverse lever, reversing mechanism and a half nut mechanism.

Lathe Operations

Lathe is a very versatile machine tool. A large variety of machine operations can be performed on a lathe. Some of the major operations that can be performed using a lathe are as follows:

1. Turning (Plain turning and Step turning)
2. Taper Turning
3. Facing
4. Boring
5. Drilling
6. Threading
7. Knurling
8. Grooving
9. Parting off

Turning

Turning is an operation of removing extra material from the outer surface of the workpiece to obtain finished product. The job may be held between the lathe chuck or lathe centres, and driven with the help of a face plate and a dog carrier. Turning may be of two types

1. Plain Turning
2. Step Turning

Plain turning: It results in a uniform reduction in the diameter of the job throughout its turned length. In this operation longitudinal feed is given to the tool by hand or power.

Step turning: A job may have two or more diameters to be turned on it, each involving shoulders or steps of different diameters. Turnings of such steps is called *step turning*. The process of turning is same as that of plain turning. Figure (a) shows the schematic of turning operation.

Taper turning

Taper Components are those whose diameters are varying gradually from its one end to the other end so as to generate a conical looking shape. Fabrication of such components by lathe machine is called *taper turning*. Taper on a job is usually expressed as the ratio of the difference of end diameters of the tapered job to the axial length of the tapered section. Therefore, taper can be defined as:

$$k = \frac{D - d}{l}.$$

Where, k is the amount of taper, D is the diameter of the large end in mm; d is the diameter of the small end in mm, and l is the axial length of tapered part. Figure b) shows a typical tapering operation.

Various methods of taper turning are:

Swilling the compound rest method: In this method the workpiece is mounted and rotated on the lathe chuck and the tool is fed at an angle to the axis of rotation of the workpiece. It is the most suitable method for taper turning as it does not affect the centring of the job. The angle of taper of tool α can be obtained by:

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

where α is the taper angle, D is the larger diameter, d is the smaller diameter and l is the tapered length.

Tail stock set over method: In this method the axis of rotation of the workpiece is set to an angle to the axis, and the tool is fed parallel to the lathe axis. The angle at which the axis of rotation of the workpiece is set is half of the taper angle, and is given by:

$$S = \frac{L(D - d)}{2l}.$$

Where S is the setover, L is the total length between the lathe centres, l is the length of taper, D is the larger diameter and d is the smaller diameter.

Taper turning with a form tool: In taper turning with form tool, a tool having a straight cutting edge is positioned on the job at half the taper angle and then fed straight into the job to generate a taper surface. However, with this method only tapers of short lengths can be produced.

Taper turning attachment method: In this method, a taper turning attachment, which consists of a bracket or a frame, is guided in a straight path set at an angle to the axis of rotation of the job. This method can produce a very large variety of taper surfaces.

Facing

Facing is the operation of producing a flat surface at the end of a job where the job is usually held in a chuck, and the tool is fed perpendicular to the axis of job operation. The operation is shown in Figure (c).

Boring

Boring is the operation of enlarging the hole of a workpiece having its initial hole made by drilling or by some other method. In this method, a boring tool is held in the tool post and fed into the workpiece to produce the boring operation. Figure (d) shows the boring operation.

Drilling

Drilling is the operation of producing holes in the workpiece with the help of drill tools. A drill tool is held in the tail stock (drill chuck) which itself is mounted in the tail stock in much the same way as the dead centre. The process is shown in Figure (e).

Threading

Threading is the operation of making or cutting threads on a job. Threads may be external (male) and internal (female).The tool used for cutting threads is a single point threading tool. Figure (f) shows the threading operation.

Knurling

Knurling is the operation of producing a rough surface on a smooth surface of cylindrical jobs to provide an effective gripping. This is done by a knurling tool, held in the tool post and pressed against the surface to cut the metal. The process is shown in Figure (g).

Grooving

The term *Grooving* means the process of forming a narrow cavity over a smaller length of the job. The most important difference between grooving and turning is the direction of the cut. A turning tool can be applied for cuts in multiple directions; grooving tool is normally used to cut in a single direction only. The grooves thus formed could be square, round or angular. Figure 7.4(h) depicts a typical grooving operation.

Parting off

Parting off is an operation in which the tool is fed directly to cut off the workpiece at a specific length. Figure (i) shows a parting off operation performed on a lathe. It is normally used to remove the finished end of a workpiece from the part of the stock that is clamped in the chuck.

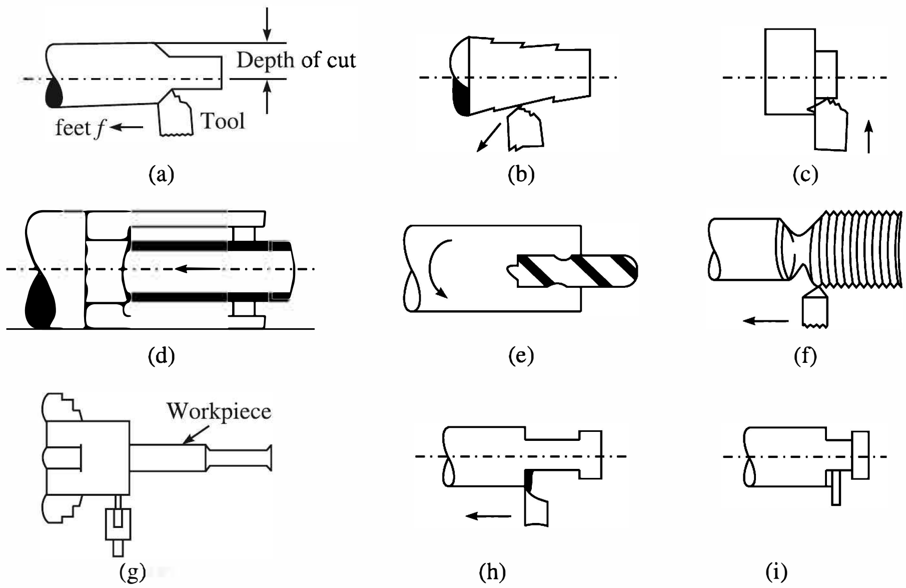


Figure Lathe operations (a) turning, (b) taper turning, (c) facing, (d) boring, (e) drilling, (f) threading, (g) knurling, (h) grooving, and (i) parting off.

Shaper Machine

The *Shaper Machine* is used to produce a flat or plane surface by the shaping operation of a reciprocating single point cutting tool. It can also be used for making slots, grooves and keyways. Figure 7.5 shows a shaping machine.

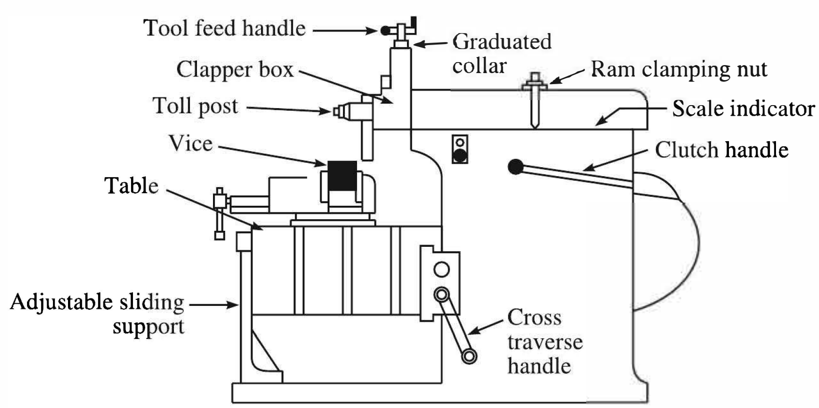


Figure Shaper machine.

Working Principle

In shaper machine, the workpiece is held stationary during cutting, while the tool is mounted on a reciprocating ram which is operated by a quick return motion mechanism. The cutting action takes place in the forward stroke and no material is removed in the return stroke, so it is termed as *Idle Stroke*. The forward and return strokes constitute one operating cycle of the shaper.

Types of Shaper Machines

The shaper is classified in the following ways:

1. According to the position of the ram
   (a) Horizontal type
   (b) Vertical type
   (c) Travelling head type
2. According to the type of mechanism used for movement of ram
   (a) Crank type
   (b) Geared type
   (c) Hydraulic shaper
3. According to the movement of the table
   (a) Standard type
   (b) Universal type
4. According to the type of cutting stroke
   (a) Push cut type
   (b) Draw cut type

Parts of Shaper Machine

Base

Base is heavy structure (made by cast iron) which is fixed to the floor. It supports the machine body frame and all the parts and assemblies. The base also absorbs the vibrations and other forces which are likely to be induced during the shaping operations.

Column

The *Column* is a rigid hollow length which is mounted on the base and provides support to other parts of the machine. It houses the drive mechanism compressing the main drives, the gear box and the quick return mechanism for the ram movement. The top of the column provides guide ways for the ram, and its front provides the guide ways for the cross rail.

Cross rail

The *Cross Rail* is mounted on the front of the body frame on two vertical guide ways of the column. It has two parallel horizontal guide ways in the vertical plane and perpendicular to the axis of ram. It can be moved up and down. The vertical movement of the cross rail facilitates to accommodate the jobs of different heights below the tool.

Saddle

The *Saddle* moves on the cross rail block and carries the work table on it such that crosswise movement of the saddle by rotating the cross feed screw by hand.

Table

The *Table* is connected to the saddle. It is used to hold the workpiece. A table moves along the cross rail to give feed to the workpiece.

Ram

A *Ram* is a reciprocating device which consists of a set of tools for providing motion to the tool for movement. The back and forth motion of the ram in its slides, called *stroke,* is provided by a slotted link mechanism. The stroke can be adjusted according to the length of the workpiece to be machined.

Tool head

A *Tool Head* is fitted to the front end of a ram on a circular plate. It can be moved in any direction for shaping angular shapes.

Planer Machine

A *Planer* is a machine tool used to produce a large flat smooth surface with the application of a single point cutting tool. The main difference between a planer and a shaper is that the planer operates with an action opposite to that of the shaper, i.e. the entire workpiece moves beneath the cutter, instead of the cutter moving above a stationary workpiece. A planer can handle much heavier cuts, and more than one tool post is provided on one machine. In planning operation, the machining operation can be performed much quickly than shaping.

Working Principle

Figure shows a schematic of a planer machine. The planer consists of a rigid bed made of gray cast iron. On the upper surface on V-guide ways are machined all along the length of the bed. The base of the bed is fixed on the ground. Table is also made up of grey cast iron having matching guide ways machined at its bottom so that it can slide longitudinally on the machine bed. The table is provided with T-slots on its top surface, so that the workpiece may be clamped securely on the table.

These are two vertical columns which are attached each side of bed. A cross rail can slide up and down on the two vertical columns. Tool post is mounted on the cross rail and one side tool head is mounted on each column. Vertical tool head can move laterally on the cross rail while side tools head can move up and down on the vertical columns. There is arrangement for advancement or

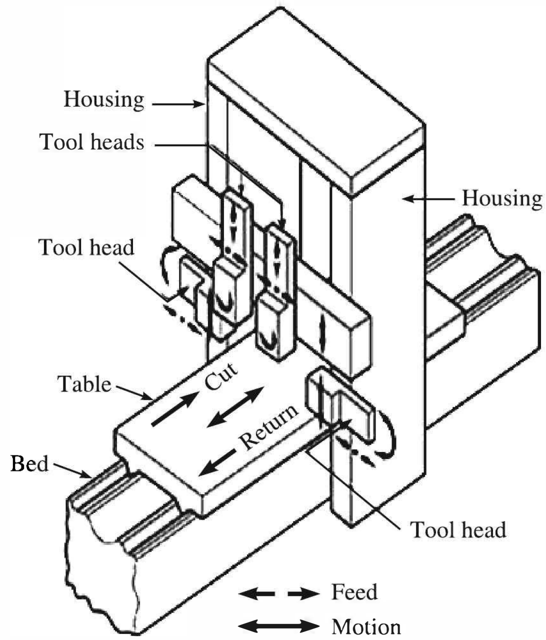


Figure A standard planer machine.

retraction of tools in the tool head. A number of speed and feeds are available for the tool heads. Even on a planer, the tools will cut material only in the forward stroke of the table; its backward stroke is idle.

Types of Planers

Many types of planers are available for doing different types and sizes of jobs. Most commonly used planers are:

1. Standard or Double Housing Planer
2. Open Side Planer
3. Pit Type Planer
4. Plate or Edge Planer
5. Divided Table Planer

Parts of a Planer Machine

The figure of a planer machine is shown in Figure 7.6. The main parts of a planer are as follows:

1. Bed
2. Table
3. Columns
4. Cross-Rail
5. Tool Head

Bed

The *Bed* is a grey cast iron structure whose length is slightly larger than twice the length of the table. It carries two V-guide ways on its top on which the planer table reciprocates. It supports the columns and all other moving parts of the machine.

Table

The *Table* supports the work and reciprocates along the guides of the bed. Usually made of good quality grey cast iron its top face is accurately finished to position the workpiece correctly on it. Its top surface has T-slots along the entire length to facilitate holding of the workpiece. It is driven by hydraulic pressure or electric motor.

Columns

Columns are two box-type vertical structures placed on each side of the bed and fastened there. The front surface of the column has guide ways for accurate movement of cross rails. The side tool head also moves along the columns.

Cross rail

It is a horizontal box-type structure for connecting the two columns. It is always parallel to the table and supports the tool head. It can be moved up or down by screwing the elevating screws.

Tool head

The *Tool Head* is mounted on the cross rail with the help of a saddle. The tool head of a planer is similar to that of a shaper, both in construction and in operation. The saddle can be made to move transversely on the cross rail to provide cross feed. Here the tool posts which are mounted on the cross rail.

Difference between Planer and Shaper

Planer	Shaper
The workpiece reciprocates horizontally.	The tool reciprocates horizontally.
The tool remains stationary during cutting operation.	The workpiece remains stationary during cutting.
It occupies a large floor area and is capable of heavy cuts and feeds.	It occupies less floor area and is used for only light cuts and feeds.
It is preferred for machining large size and heavy workpieces.	It is preferred for machining small and lighter workpieces.
It can accommodate multiple tools.	It usually accommodates only one tool.

Drilling Machine

Drilling is an operation for producing holes in a workpiece by using a rotating tool known as a *Drill.*

Working Principle

In a drilling operation, a hole is produced by feeding the rotating drill in a direction parallel to its axis into a workpiece fixed to the table. *Drill Bits* are cutting tools for creating holes. It is made of tool materials and has three principle parts, viz., the point, the body and the shank. The drill is held and rotated by its *Shank*; the *Point* comprises the cutting edge, while the *Body* is used to guide the bit into the material during machining. During an operation, the metal comes in contact with the two cutting edges of the tool and removes the metal stock. Figure 7.7(a) and (b) shows the schematic diagram of a twist drill and the cutting mechanism of a drill.

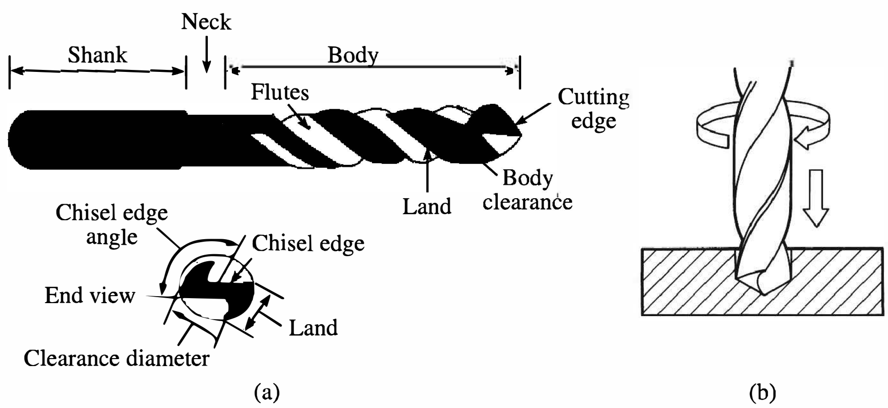


Figure (a) Parts of a twist drill and (b) cutting mechanism of a drill.

The drills used in drilling machines may be of the following types:

Twist drill

Twist Drill shown in Figure (a) is the most common drill used in standard drilling operations. It usually has a taper shank at the end which is fitted into the drilling machine having a tapered sleeve of a matching taper. When a tapered sleeve rotates, the twist drill also rotates along with it due to the friction between two tapered surfaces.

Step drill

A *Step Drill* bit is a drill that has its tip ground down to a different diameter as shown in Figure (b). The transition from the original diameter to the final diameter is straight if it is to be used for counterboring, or tapered if the bit is to be used for countersinking.

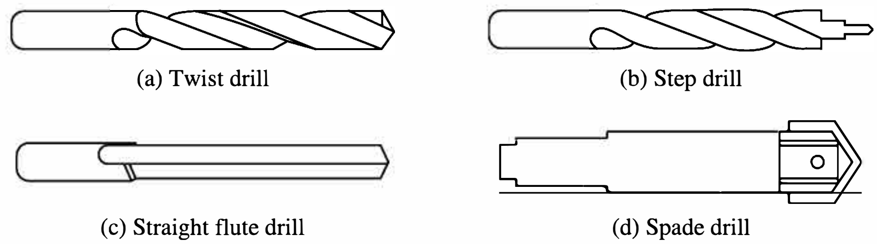


Figure Types of drill bits.

Straight flattened drill

Straight flattened or straight fluted drill has grooves or flutes running parallel to the drill axis. It is generally used for drill soft metals like copper and aluminium. It is not used for each drilling operation due to that, chips do not wear out of the drilled hole automatically. Figure 7.8(c) shows a typical straight fluted drill.

Flat or spade drill

It is forged from tool steel and its cutting angle varies from 90 to 120. These flat drills are used to correct cutting edges very frequently. Figure 7.8(d) shows a spade drill.

Parts of Drilling Machine

Figure shows a drilling machine.

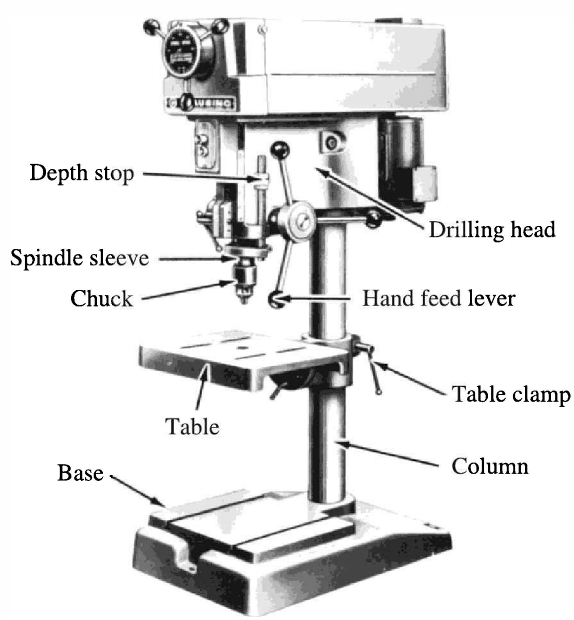


Figure Drilling machine.

The main parts of a drilling machine are:

Base

It is the lowest part on which the vertical column of the drill machine is mounted and it is fixed on the table.

Column

A *Column* is a cylindrical vertical member of the machine that supports the work table and the head containing driving mechanisms.

Table

The *Table* is a rectangular or round-shaped structure mounted with the column used for holding the workpiece.

Drill head

It is mounted on the top of the column and has driving and feeding mechanisms, like pulley, gears, etc.

Spindle

A *Spindle* is a vertical shaft which holds and rotates the drills. It receives power from an electrical motor and transfers it to the drill as a rotary motion.

7.6.3 Drilling Machine Operations

Drilling

Drilling is the most common operation of a drilling machine. This operation is used for producing circular holes to specifications within the prescribed tolerances. This is achieved by using a rotating tool known as a *Drill*.

Countersinking

Countersinking is the operation of making cone shape enlargements at the end of a hole. The tool used for this operation is called *countersink*. The included angle of the countersink usually varies from 60° to 90°. More commonly, the countersinking is used to form recesses for flathead screws. The depth of countersinking is such that the flat head of the screw is flush with the surface.

Reaming

Reaming is an operation to make an existing hole (obtained by drilling), dimensionally more accurate, and to improve its surface finish. It is done with the help of reamer tools.

Boring

Enlarging previous holes (done by drilling or other operation) by application of boring tools known as *Boring*. It is done principally to ensure the correct location of a hole by making it concentric with the axis of rotation of the spindle.

Tapping

It is the operation for making threads in a hole, or producing internal threads in a drilled hole by using a tool known as *Tap*. The process of cutting internal threads using a tap is called *tapping*.

Counterboring

Counterboring enlarges a portion of an existing hole to a larger diameter and makes the surface at the bottom of the larger diameter flat and square. The process of counterboring is essential to provide a recess for bolt heads or nuts. The speed of counterboring is less than that of drilling.

Spot facing

Spot Facing is similar to counterboring, except for the difference that it removes only enough material around a hole to produce a machined flat surface normal to the hole axis to provide a seat for the washer. The counterbore can do the spot facing operation also.

Figure shows different drilling operations.

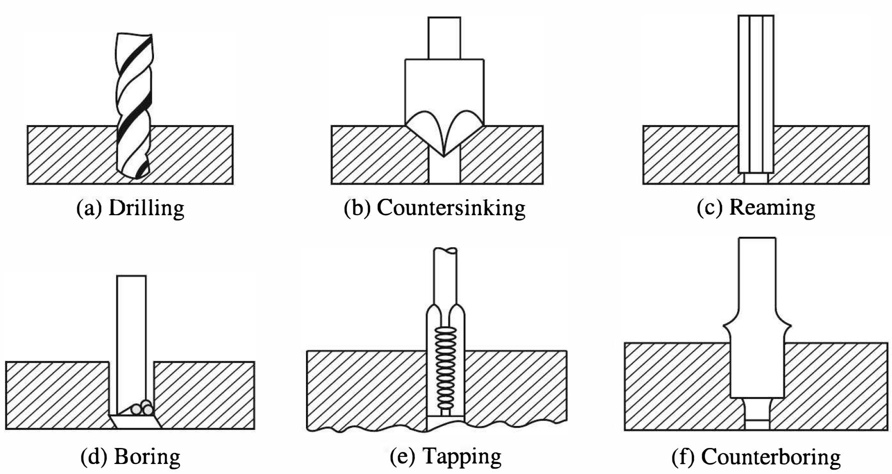


Figure Various drilling operations.

Milling Machine

Milling is a machining process which is performed with a rotary cutting tool called a *milling cutter* having several cutting edges arranged on the periphery of the cutter. With various attachments, milling machines can be used for many other machining operations, like boring, slotting, circular milling dividing, and drilling. This machine can also be used for cutting keyways, racks and gears.

The milling process is used to generate flat surfaces or a curved profile, and many other intricate shapes with great accuracy and having very good surface finish.

Working Principle

A typical milling operation is shown in Figure . The milling machine removes metals with a fast rotating multi-tooth cutter, each tooth having a cutting edge which removes metal from the workpiece when the workpiece fixed on the machine table is fed to the cutter. The cutter teeth come in contact with the workpiece intermittently and machine it. The machine can hold more than one cutter at a time. The machine gives better surface finish and dimensional accuracy.

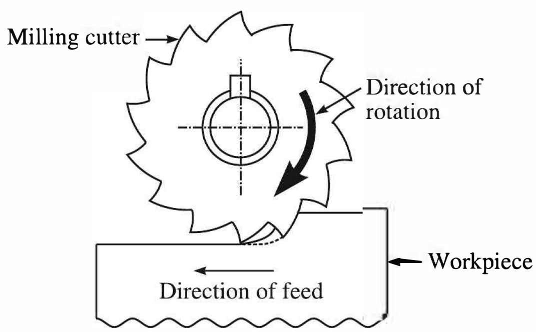


Figure Milling operation.

7.7.2 Parts of Milling Machine

Figure shows the schematic of a vertical milling machine. The major parts of the machine are as follows:

Base

The *Base* is made by cast iron and it provides support to the column and other parts which are mounted on it. It is fixed on the floor through foundation bolts.

Column

The *Column* is a cylindrical-shaped strong structure mounted vertically on the base. It is the main supporting frame for most parts of the machine. It houses all the driving mechanisms for the spindle and table feed and encloses the electric motor which runs the machine.

Knee

The *Knee* is a rigid casting mounted on the front face of the column. The knee provides support to saddle and table, and can slide up and down with the help

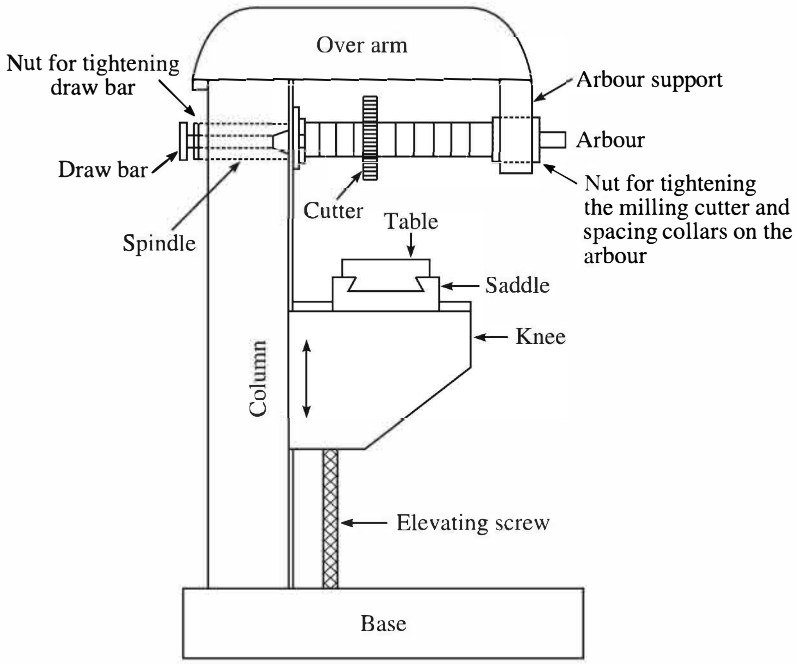


Figure Vertical milling machine.

of an elevating screw. This movement helps to adjust the distance between the cutter and the job mounted on the table. Its top surface contains horizontal ways for cross traverse of a saddle.

Saddle

The *Saddle* is placed on top of the knee which slides on guide ways. It is a part between the knee and table, and is used to provide cross-feed to the table.

Table

The *Table* is a rectangular casting located on top of the saddle. It rests on the guide ways on the saddle and provides support to the workpiece. The top surface of a table is accurately machined and contains a T-slot to rigidly clamp the workpiece. It can impart the following motions to the job:

1. Vertical (up and down) movement
2. Cross (in or out) or transverse motion
3. Longitudinal (back and forth) motion

Overarm

It is used for supporting the arbour or spindle and is mounted on the top of the column. The length of the overarm is adjustable so that it may be set nearest to the cutter fitted on the arbour.

Spindle

The *Spindle* holds and drives the various cutting tools. It is mounted in the upper part of the column and gets driving power from a motor to transmit it further to the arbour.

Arbour

An *Arbour* is a shaft on which the milling tool is mounted. One end of the arbour is tapered to fit the spindle on which the milling tools are securely mounted and rotated.

Types of Milling Machines

Milling machines are classified as horizontal or vertical milling machines based on the positioning of the axis of their milling spindle. Some types of milling machines are as follows:

1. Knee-type milling machine
   (a) Horizontal milling machine
   (b) Universal milling machine
2. Ram-type milling machine

Milling Operations

The following operations normally can be performed on a milling machine:

Machining

Machining is done to produce horizontal or vertical flat surfaces of contours of infinite variety with straight or spiral elements.

Face milling

Facing operation of all kinds of elements and produce flat surfaces which are at right angle to the axis of the cutter.

Plain or slab milling

It involves machining flat surfaces which are parallel to the axis of the cutter.

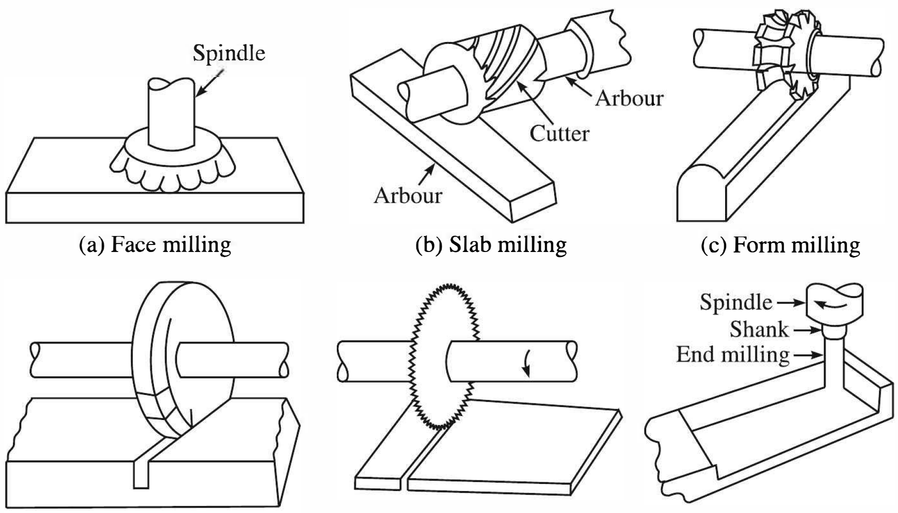
Angular milling

Angular Milling is the operation of producing a flat surface at any angle.

Form milling

Form Milling is used for machining surfaces having an irregular outline. This is the operation which is used for making teeth on a gear.

Figure shows some of the machining operations that can be performed using a milling machine.



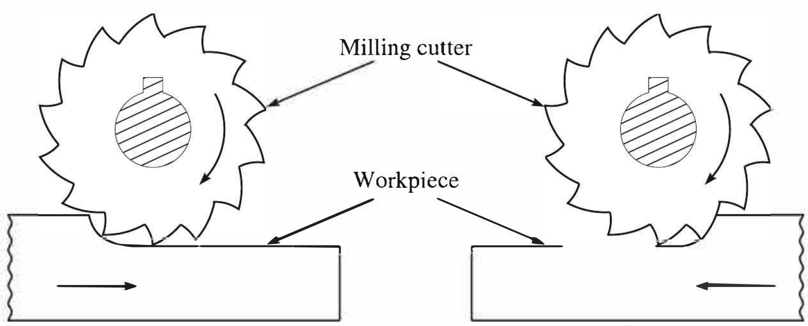
(a) Face milling (b) Slab milling (c) Form milling

(d) Slotting (e) Slitting (f) End milling

Figure Different milling operations.

Up Milling and Down Milling Operations

Milling operation can also be described based on the direction of feed of the workpiece under the milling cutter. They are Up Milling and Down Milling. Figure shows the schematics of up and down milling processes.



(a) (b)

Figure (a) Up milling and (b) down milling.

Up milling

Up Milling is also known as *Conventional Milling Process*, in which the direction of the workpiece is opposite to that of the cutter rotation as shown in Figure (a). Each tooth of the cutter starts the cut with zero depth of the cut which gradually increases and reaches the maximum value as the tooth leaves the cut. The chip thickness at the start is zero and increases to the maximum at the end of the cut.

Down milling

Down Milling is also known as *Climb Milling*, in which the feed direction of the workpiece is same as that of the cutter rotation as is shown in Figure (b). The maximum thickness of the chip at the start of the cut decreases to zero thickness at the end of the cut. It is useful for cutting off stock or for milling comparatively deep or long slots.

Difference between Up Milling and Down Milling

Up Milling	Down Milling
It is the conventional milling operation.	It is known as climb milling. It is used in special cases.
Workpiece is fed in a direction opposite to the cutter rotation.	Workpiece is fed in the direction of the cutter rotation.
Chip thickness is minimum at the beginning and maximum at the end of cutting.	Chip thickness is maximum at beginning and minimum at the end of cutting.

Grinding

Grinding is a metal cutting process in which the unwanted material is removed from the workpiece. It is a finishing process which provides very close tolerances with the help of a rotating cutting tool against or over the workpiece. The cutting tool used is an abrasive wheel which is rotated at a very high speed at about 30 m/s, and the work is fed to the grinding wheel to remove excess material from the workpiece surfaces.

Working Principle

Grinding involves the use of a rotating wheel containing abrasive particles rigidly bonded to its surface. Each of the abrasive particles acts as a single point cutting tool and therefore the grinding wheel can be visualised as a multipoint cutting tool. The wheel is rotated at a very high speed and the workpiece is brought into the contact with the tool in a controlled manner. The process removes material in very small chips of 0.25 mm to 0.50 mm or even smaller depending upon the surface finish required. The grinding operation can provide an extremely high quality of surface finish (of the order of 25 μ) and accuracy of shape and dimension. Grinding can also be used for very hard materials. Figure shows the schematic of a surface grinding operation.

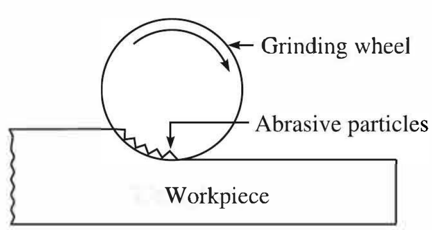


Figure Grinding operation.

Classification of Grinding Machine

The grinding process can be classified according to the quality of the surface finish produced, and according to the surface generated. These are as follows:

According to the quality of surface finish

1. Rough grinding
2. Precision or fine grinding

Rough grinding: These grinders are used for the removal of material without any reference to the quality of finish required. The surface thus obtained does not possess very good surface finish. In most of the cases, rough grinding is followed by precision grinding. Some of the most commonly used rough grinders are:

1. Bench grinders
2. Portable grinders
3. Abrasive grinders
4. Swing form grinders

Precision or fine grinding: These grinders are used to provide excellent surface finish with a much better dimensional accuracy. The resultant surface has a very fine finish and very good tolerances.

According to the type of surface generated

These are further classified as:

1. Surface grinders
2. Cylindrical grinders (external or internal)
3. Internal grinders
4. Special grinders

Parts of Grinding Machine

The major parts of a grinding machine are as follows:

1. Bed
2. Column
3. Saddle
4. Work table
5. Grinding wheel
6. Wheel head
7. Wheel guard

Figure shows a schematic diagram of a horizontal spindle surface grinding machine.

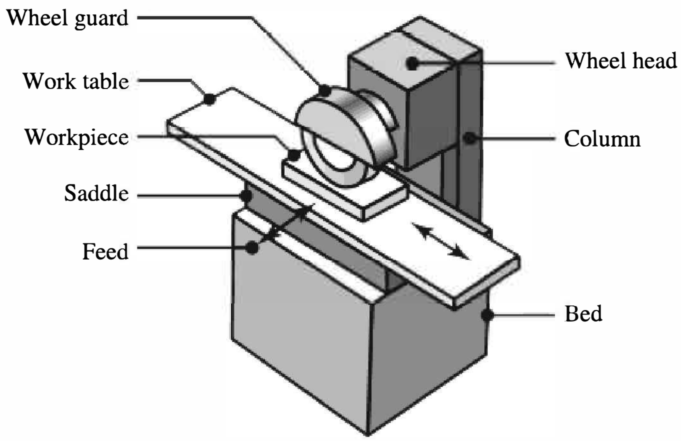


Figure Surface grinding machine.

Grinding Wheel

A *Grinding Wheel* is a multi-teeth cutter made up of many hard particles known as *Abrasives*. Abrasive particles or grains are mixed with a suitable binding material which acts as a matrix or holder of these abrasives during the use of the grinding wheel.

Classification of wheels

Classification of grinding wheels is based on the following characteristics:

Grit or grain: *Grit* or *Grain* indicates the size of an abrasive grain. It is indicated by a number. The higher the number, the smaller is the size of grains. Grain size varies from grain size number. For example, coarser grain size varies from grain size number 10 to 24, medium grain size from 30 to 60, fine grain size from 80 to 180, and very fine grain size from 220 to 600.

Grade: *Grade* refers to the hardness or tenacity with which the binding material or bond holds the abrasive grains in place. The bond hardness is usually represented by the letters of English alphabet– 'A' represents very soft grade, 'M' and 'N' represent medium grade, while 'Z' represents very hard grade hardness.

Structures: *Structure* refers to the relative spacing between the abrasive grains structure and is denoted by the number of cutting edges per unit area of wheel face, as well as by the number and size of void spaces between grains.

Grinding Operations

Surface grinding

It is used to produce flat, angular or contoured surfaces by feeding work in a horizontal plane under a rotating grinding wheel. Work is attached to a reciprocating or rotating table. Most surface grinding machines use a horizontal spindle which can be moved up and down allowing either the edge or the face of the grinding wheel to contact the work (Figure 7.17).

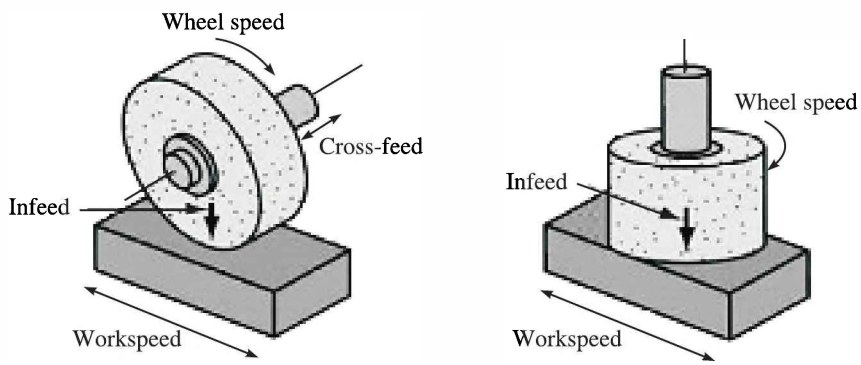


Figure Surface grinding (a) horizontal spindle and (b) vertical spindle.

Cylindrical grinding

It is used for grinding the contoured or curved surfaces. The cylindrical workpiece rotates about a fixed axis in a way that the surfaces to be ground are concentric to that axis of rotation. A typical cylindrical grinder consists of a wheel head, which includes the spindle and drive motor, and a cross slide that moves the wheel head to and from the workpiece for grinding and means to hold and drive the workpiece (Figure .

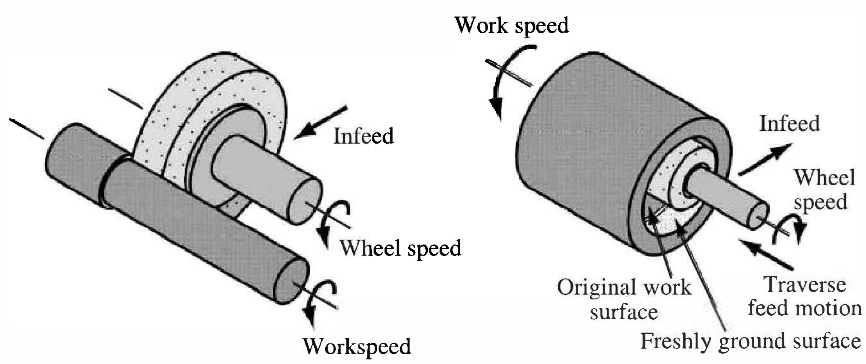


Figure 8 Cylindrical grinding (a) external and (b) internal.

Centreless grinding

In *Centreless Grinding* the workpiece rotates between a grinding wheel and a regulating wheel. The work is supported from below by a fixed work-rest blade (Figure). In this kind of grinding process a number of workpieces can be ground simultaneously and in a continuous stream.

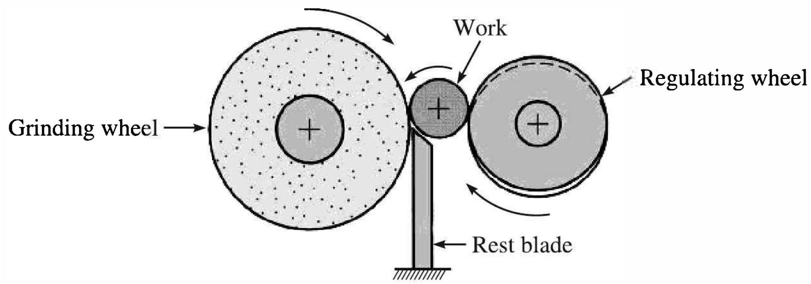


Figure Centreless grinding.

It can be seen that in all the machining processes a machine tool uses a cutting tool which is made up of a material much harder than the material of the workpiece. The cutting tool has sharp edge(s). Removal of material is achieved by moving the cutting tool and the part relative to each other. The sharp edges of a cutting tool penetrate the workpiece and produce a small cut by a shearing action. The process is repeated a number of times, increasing the depth of cut of the toll each time, to achieve the desired size reduction in the workpiece. Machining processes are important because they can produce the desired part geometry with better accuracy finish than produced by forging or casting.