WORKSHOP TECHNOLOGY - III

Chapter 1- Milling

Syllabus

- Specification and working principle of milling machine
- Classification, brief description and applications of milling machine
- Main parts of column and knee type milling machine
- Milling machine accessories and attachment – Arbors, adaptors, collets, vices, circular table, indexing head and tail stock, vertical milling attachment
- Milling methods - up milling and down milling
- Identification of different milling cutters and work mandrels
- Work holding devices
- Milling operations – face milling, angular milling, form milling, straddle milling and gang milling.
- Cutting parameters
- Indexing on dividing heads, plain and universal dividing heads.
- Indexing methods: direct, Plain or simple, compound, differential and angular indexing, numerical problems on indexing.

Milling is the most common form of machining, a material removal process, which can create a variety of features on a part by cutting away the unwanted material. The milling process requires a milling machine, workpiece, fixture, and cutter. The workpiece is a piece of pre-shaped material that is secured to the fixture, which itself is attached to a platform inside the milling machine. The cutter is a cutting tool with sharp teeth that is also secured in the milling machine and rotates at high speeds. By feeding the workpiece into the rotating cutter, material is cut away from this workpiece in the form of small chips to create the desired shape.

Milling is typically used to produce parts that are not axially symmetric and have many features, such as holes, slots, pockets, and even three dimensional surface contours. Parts that are fabricated completely through milling often include components that are used in limited quantities, perhaps for prototypes, such as custom designed fasteners or brackets. Another application of milling is the fabrication of tooling for other processes. For example, three-dimensional molds are typically milled. Milling is also commonly used as a secondary process to add or refine features on parts that were manufactured using a different process. Due to the high tolerances and surface finishes that milling can offer, it is ideal for adding precision features to a part whose basic shape has already been formed.

1.1 Process Cycle

The time required to produce a given quantity of parts includes the initial setup time and the cycle time for each part. The setup time is composed of the time to setup the milling machine, plan the tool movements (whether performed manually or by machine), and install the fixture device into the milling machine. The cycle time can be divided into the following four times:

1. *Load/Unload time* - The time required to load the workpiece into the milling machine and secure it to the fixture, as well as the time to unload the finished part. The load time can depend on the size, weight, and complexity of the workpiece, as well as the type of fixture.
2. *Cut time* - The time required for the cutter to make all the necessary cuts in the workpiece for each operation. The cut time for any given operation is calculated by dividing the total cut lengthfor that operation by the feed rate, which is the speed of the cutter relative to the workpiece.

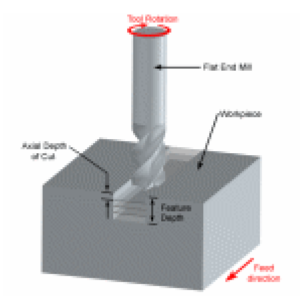
3. *Idle time* - Also referred to as non-productive time, this is the time required for any tasks that occur during the process cycle that do not engage the workpiece and therefore remove material. This idle time includes the tool approaching and retracting from the workpiece, tool movements between features, adjusting machine settings, and changing tools.
4. *Tool replacement time* - The time required to replace a tool that has exceeded its lifetime and therefore become to worn to cut effectively. This time is typically not performed in every cycle, but rather only after the lifetime of the tool has been reached. In determining the cycle time, the tool replacement time is adjusted for the production of a single part by multiplying by the frequency of a tool replacement, which is the cut time divided by the tool lifetime.

Following the milling process cycle, there is no post processing that is required. However, secondary processes may be used to improve the surface finish of the part if it is required. The scrap material, in the form of small material chips cut from the workpiece, is propelled away from the workpiece by the motion of the cutter and the spraying of lubricant. Therefore, no process cycle step is required to remove the scrap material, which can be collected and discarded after the production.

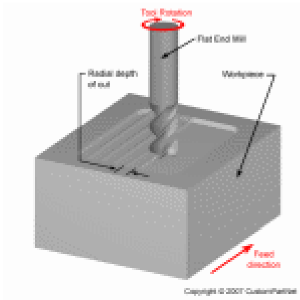
1.2 Cutting parameters

In milling, the speed and motion of the cutting tool is specified through several parameters. These parameters are selected for each operation based upon the workpiece material, tool material, tool size, and more.

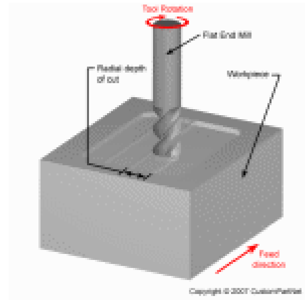
- *Cutting feed* - The distance that the cutting tool or workpiece advances during one revolution of the spindle and tool, measured in inches per revolution (IPR). In some operations the tool feeds into the workpiece and in others the workpiece feeds into the tool. For a multi-point tool, the cutting feed is also equal to the feed per tooth, measured in inches per tooth (IPT), multiplied by the number of teeth on the cutting tool.
- *Cutting speed* - The speed of the workpiece surface relative to the edge of the cutting tool during a cut, measured in surface feet per minute (SFM).
- *Spindle speed* - The rotational speed of the spindle and tool in revolutions per minute (RPM). The spindle speed is equal to the cutting speed divided by the circumference of the tool.
- *Feed rate* - The speed of the cutting tool's movement relative to the workpiece as the tool makes a cut. The feed rate is measured in inches per minute (IPM) and is the product of the cutting feed (IPR) and the spindle speed (RPM).
- *Axial depth of cut* - The depth of the tool along its axis in the workpiece as it makes a cut. A large axial depth of cut will require a low feed rate, or else it will result in a high load on the tool and reduce the tool life. Therefore, a feature is typically machined in several passes as the tool moves to the specified axial depth of cut for each pass.



- *Radial depth of cut* - The depth of the tool along its radius in the workpiece as it makes a cut. If the radial depth of cut is less than the tool radius, the tool is only partially engaged and is making a peripheral cut. If the radial depth of cut is equal to the tool diameter, the cutting tool is fully engaged and is making a slot cut. A large radial depth of cut will require a low feed rate, or else it will result in a high load on the tool and reduce the tool life. Therefore, a feature is often machined in several steps as the tool moves over the step-over distance, and makes another cut at the radial depth of cut.



Peripheral cut

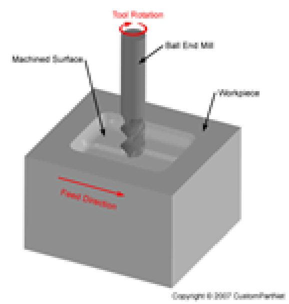


Slot cut

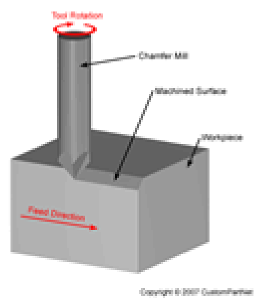
1.3 Operations

During the process cycle, a variety of operations may be performed to the workpiece to yield the desired part shape. The following operations are each defined by the type of cutter used and the path of that cutter to remove material from the workpiece.

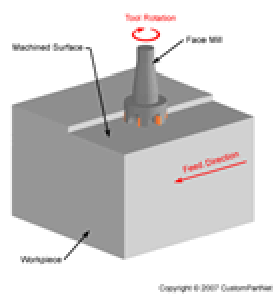
<u>End milling</u> **-** An end mill makes either peripheral or slot cuts, determined by the step-over distance, across the workpiece in order to machine a specified <u>feature</u>, such as a profile, slot, pocket, or even a complex surface contour. The depth of the feature may be machined in a single pass or may be reached by machining at a smaller axial depth of cut and making multiple passes.



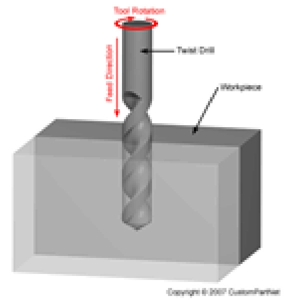
<u>Chamfer milling</u> **-** A chamfer end mill makes a peripheral cut along an edge of the workpiece or a feature to create an angled surface, known as a chamfer. This chamfer, typically with a 45 degree angle, can be machined on either the exterior or interior of a part and can follow either a straight or curved path.



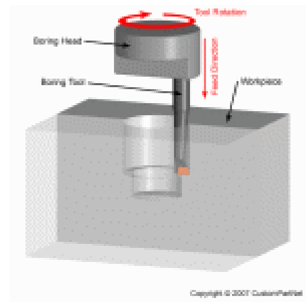
<u>Face milling</u> **-** A face mill machines a flat surface of the workpiece in order to provide a smooth finish. The depth of the face, typically very small, may be machined in a single pass or may be reached by machining at a smaller axial depth of cut and making multiple passes.



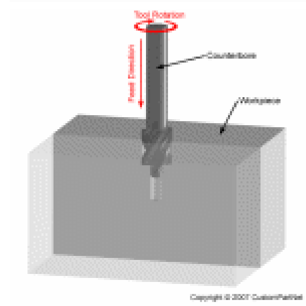
Drilling - A drill enters the workpiece axially and cuts a hole with a diameter equal to that of the tool. A drilling operation can produce a blind hole, which extends to some depth inside the workpiece, or a through hole, which extends completely through the workpiece.



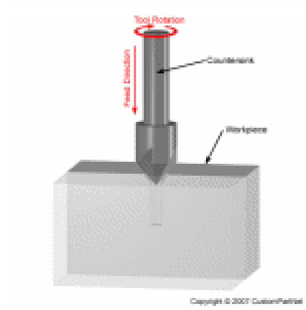
Boring - A boring tool enters the workpiece axially and cuts along an internal surface to form different features. The boring tool is a single-point cutting tool, which can be set to cut the desired diameter by using an adjustable boring head. Boring is commonly performed after drilling a hole in order to enlarge the diameter or obtain more precise dimensions.



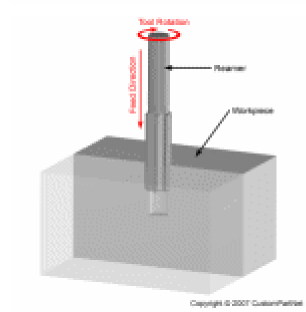
Counterboring - An counterbore tool enters the workpiece axially and enlarges the top portion of an existing hole to the diameter of the tool. Counterboring is often performed after drilling to provide space for the head of a fastener, such as a bolt, to sit below the surface of a part. The counterboring tool has a pilot on the end to guide it straight into the existing hole.



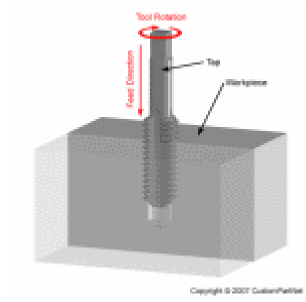
Countersinking - A countersink tool enters the workpiece axially and enlarges the top portion of an existing hole to a cone-shaped opening. Countersinking is often performed after drilling to provide space for the head of a fastener, such as a screw, to sit flush with the workpiece surface. Common included angles for a countersink include 60, 82, 90, 100, 118, and 120 degrees.



Reaming - A reamer enters the workpiece axially and enlarges an existing hole to the diameter of the tool. Reaming removes a minimal amount of material and is often performed after drilling to obtain both a more accurate diameter and a smoother internal finish.



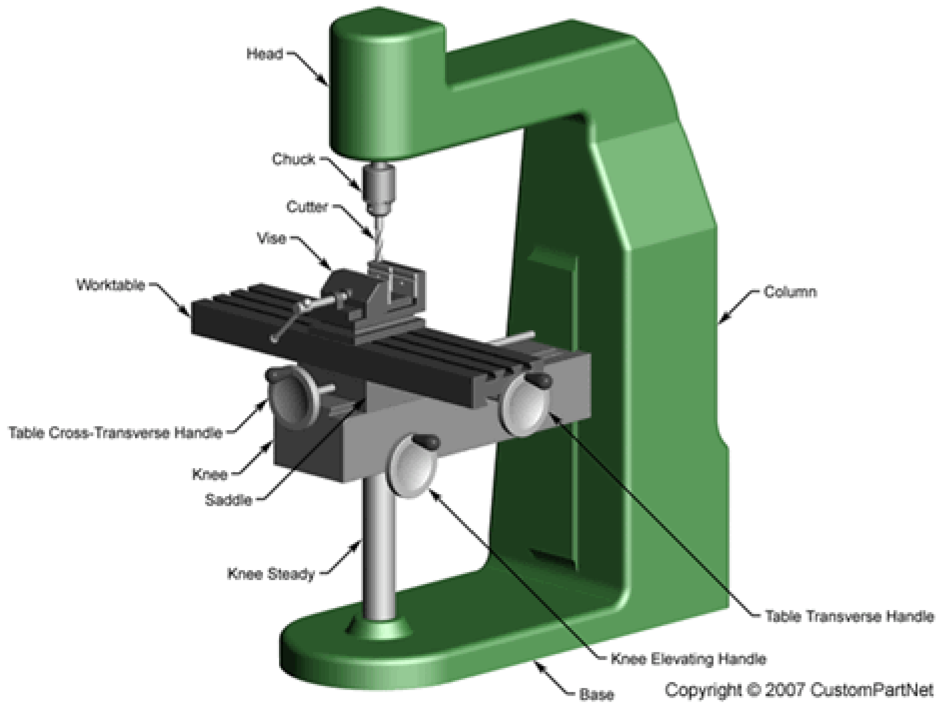
Tapping - A tap enters the workpiece axially and cuts internal threads into an existing hole. The existing hole is typically drilled by the required tap drill size that will accommodate the desired tap. Threads may be cut to a specified depth inside the hole (bottom tap) or the complete depth of a through hole (through tap).



1.4 Equipment

Milling machines can be found in a variety of sizes and designs, yet they still possess the same main components that enable the workpiece to be moved in three directions relative to the tool. These components include the following:

- *Base and column* - The base of a milling machine is simply the platform that sits on the ground and supports the machine. A large column is attached to the base and connects to the other components.
- *Table* - The workpiece that will be milled is mounted onto a platform called the table, which typically has "T" shaped slots along its surface. The workpiece may be secured in a fixture called a vise, which is secured into the T-slots, or the workpiece can be clamped directly into these slots. The table provides the horizontal motion of the workpiece in the X-direction by sliding along a platform beneath it, called the saddle.
- *Saddle* - The saddle is the platform that supports the table and allows its longitudinal motion. The saddle is also able to move and provides the horizontal motion of the workpiece in the Y-direction by sliding transversely along another platform called the knee.
- *Knee* - The knee is the platform that supports the saddle and the table. In most milling machines, sometimes called column and knee milling machines, the knee provides the vertical motion (Z direction) of the workpiece. The knee can move vertically along the column, thus moving the workpiece vertically while the cutter remains stationary above it. However, in a fixed bed machine, the knee is fixed while the cutter moves vertically in order to cut the workpiece.



1.5 Manual vertical milling machine

The above components of the milling machine can be oriented either vertically or horizontally, creating two very distinct forms of milling machine. A horizontal milling machine uses a cutter that is mounted on a horizontal shaft, called an arbor, above the workpiece. For this reason, horizontal milling is sometimes referred to as arbor milling. The arbor is supported on one side by an overarm, which is connected to the column, and on the other side by the spindle. The spindle is driven by a motor and therefore rotates the arbor. During milling, the cutter rotates along a horizontal axis and the side of the cutter removes material from the workpiece. A vertical milling machine, on the other hand, orients the cutter vertically. The cutter is secured inside a piece called a collet, which is then attached to the vertically oriented spindle. The spindle is located inside the milling head, which is attached to the column. The milling operations performed on a vertical milling machine remove material by using both the bottom and sides of the cutter.

Milling machines can also be classified by the type of control that is used. A manual milling machine requires the operator to control the motion of the cutter during the milling operation. The operator adjusts the position of the cutter by using hand cranks that move the table, saddle, and knee. Milling machines are also able to be computer controlled, in which case they are referred to as a computer numerical control (CNC) milling machine. CNC milling machines move the workpiece and cutter based on commands that are preprogrammed and offer very high precision. The programs that are written are often called G-codes or NC-codes. Many CNC milling machines also contain another axis of motion besides the standard X-Y-Z motion. The angle of the spindle and cutter can be changed, allowing for even more complex shapes to be milled.

1.6 Tooling

The tooling that is required for milling is a sharp cutter that will be rotated by the spindle. The cutter is a cylindrical tool with sharp teeth spaced around the exterior. The spaces between the teeth are called flutes and allow the material chips to move away from the workpiece. The teeth may be straight along the side of the cutter, but are more commonly arranged in a helix. The helix angle reduces the load on the teeth by distributing the forces. Also, the number of teeth on a cutter varies. A larger number of teeth will provide a better surface finish. The cutters that can be used for milling operations are highly diverse, thus allowing for the formation of a variety of features. While these cutters differ greatly in diameter, length, and by the shape of the cut they will form, they also differ based upon their orientation, whether they will be used horizontally or vertically.

A cutter that will be used in a horizontal milling machine will have the teeth extend along the entire length of the tool. The interior of the tool will be hollow so that it can be mounted onto the arbor. With this basic form, there are still many different types of cutters that can be used in horizontal milling, including those listed below.

- Plane (helical) mill
- Form relieved mill
- Staggered tooth mill
- Double angle mill

Another operation known as a straddle milling is also possible with a horizontal milling machine. This form of milling refers to the use of multiple cutters attached to the arbor and used simultaneously. Straddle milling can be used to form a complex feature with a single cut.

For vertical milling machines, the cutters take a very different form. The cutter teeth cover only a portion of the tool, while the remaining length is a smooth surface, called the shank. The shank is the section of the cutter that is secured inside the collet, for attachment to the spindle. Also, many vertical cutters are designed to cut using both the sides and the bottom of the cutter. Listed below are several common vertical cutters.

- Flat end mill
- Ball end mill
- Chamfer mill
- Face mill
- Twist drill
- Reamer
- Tap

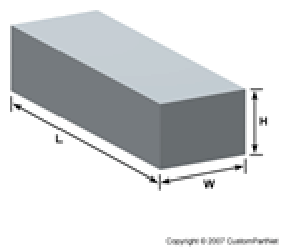
All cutters that are used in milling can be found in a variety of materials, which will determine the cutter's properties and the workpiece materials for which it is best suited. These properties include the cutter's hardness, toughness, and resistance to wear. The most common cutter materials that are used include the following:

- High-speed steel (HSS)
- Carbide
- Carbon steel
- Cobalt high speed steel

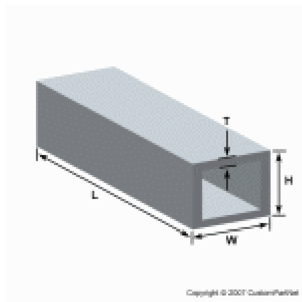
The material of the cutter is chosen based upon a number of factors, including the material of the workpiece, cost, and tool life. Tool life is an important characteristic that is considered when selecting a cutter, as it greatly affects the manufacturing costs. A short tool life will not only require additional tools to be purchased, but will also require time to change the tool each time it becomes too worn. The cutters listed above often have the teeth coated with a different material to provide additional wear resistance, thus extending the life of the tool. Tool wear can also be reduced by spraying a lubricant and/or coolant on the cutter and workpiece during milling. This fluid is used to reduce the temperature of the cutter, which can get quite hot during milling, and reduce the friction at the interface between the cutter and the workpiece, thus increasing the tool life. Also, by spraying a fluid during milling, higher feed rates can be used, the surface finish can be improved, and the material chips can be pushed away. Typical cutting fluids include mineral, synthetic, and water soluble oils.

1.7 Materials

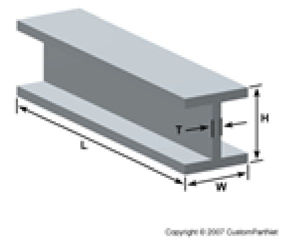
In milling, the raw form of the material is a piece of stock from which the workpieces are cut. This stock is available in a variety of shapes such as flat sheets, solid bars (rectangular, cylindrical, hexagonal, etc.), hollow tubes (rectangular, cylindrical, etc.), and shaped beams (I-beams, L-beams, T-beams, etc.). Custom extrusions or existing parts such as castings or forgings are also sometimes used.



Rectangular bar



Rectangular tube



I-beam

Milling can be performed on workpieces in variety of materials, including most metals and plastics. Common materials that are used in milling include the following:

- Aluminum
- Brass
- Magnesium
- Nickel
- Steel
- Thermoset plastics
- Titanium
- Zinc

When selecting a material, several factors must be considered, including the cost, strength, resistance to wear, and machinability. The machinability of a material is difficult to quantify, but can be said to posses the following characteristics:

- Results in a good surface finish
- Promotes long tool life
- Requires low force and power to mill
- Provides easy collection of chips

1.8 Possible Defects

Most defects in milling are inaccuracies in a feature's dimensions or surface roughness. There are several possible causes for these defects, including the following:

- *Incorrect cutting parameters* - If the cutting parameters such as the feed rate, spindle speed, or axial depth of cut are too high, the surface of the workpiece will be rougher than desired and may contain scratch marks or even burn marks. Also, a large depth of cut may result in vibration of the cutter and cause inaccuracies in the cut.

- *Dull cutter* - As a cutter is used, the teeth will wear down and become dull. A dull cutter is less capable of making precision cuts.
- *Unsecured workpiece* - If the workpiece is not securely clamped in the fixture, the friction of milling may cause it to shift and alter the desired cuts.

1.9 Design Rules

Workpiece

- Select a material that minimizes overall cost. An inexpensive workpiece may result in longer cut times and more tool wear, increasing the total cost
- Minimize the amount of milling that is required by pre-cutting the workpiece close to the desired size and shape
- Select the size of the workpiece such that a large enough surface exists for the workpiece to be securely clamped. Also, the clamped surface should allow clearance between the tool and thefixture for any cuts

Features

- Minimize the number of setups that are required by designing all features on one side of the workpiece, if possible
- Design features, such as holes and threads, to require tools of standard sizes
- Minimize the number of tools that are required
- Ensure that the depth of any feature is less than the tool length and therefore will avoid the collet contacting the workpiece
- Lower requirements for tolerance and surface roughness, if possible, in order to reduce costs
- Design internal vertical edges to have a corner radius equal to that of a standard tool. If another component with an external sharp edge must fit, then drill a hole to provide a relief area
- Avoid very long and thin features
- Use chamfers rather than a corner radius for outside horizontal edges
- Avoid undercuts

1.10 Cost Drivers

Material cost

The material cost is determined by the quantity of material stock that is required and the unit price of that stock. The amount of stock is determined by the workpiece size, stock size, method of cutting the stock, and the production quantity. The unit price of the material stock is affected by the material and the workpiece shape. Also, any cost attributed to cutting the workpieces from the stock also contributes to the total material cost.

Production cost

The production cost is a result of the total production time and the hourly rate. The production time includes the setup time, load time, cut time, idle time, and tool replacement time. Decreasing any of these time components will reduce cost. The setup time and load time are dependent upon the skill of the operator. The cut time, however, is dependent upon many factors that affect the cut length and feed rate. The cut length can be shortened by optimizing the number of operations that are required and reducing the feature size if possible. The feed rate is affected by the operation type, workpiece material, tool material, tool size, and various cutting parameters such as the axial depth of cut. Lastly, the tool replacement time is a direct result of the number of tool replacements which is discussed regarding the tooling cost.

1.11 Tooling cost

The tooling cost for machining is determined by the total number of cutting tools required and the unit price for each tool. The quantity of tools depends upon the number of unique tools required by the various operations to be performed and the amount of wear that each of those tools experience. If the tool wear exceeds the lifetime of a tool, then a replacement tool must be purchased. The lifetime of a tool is dependant upon the tool material, cutting parameters such as cutting speed, and the total cut time. The unit price of a tool is affected by the tool type, size, and material.

Chapter 2- Grinding

Syllabus

- Purpose of grinding
- Various elements of grinding wheel – Abrasive, Grade, structure, Bond
- Common wheel shapes and types of wheel – built up wheels, mounted wheels and diamond wheels. Specification of grinding wheels as per BIS.
- Truing, dressing, balancing and mounting of wheel.
- Grinding methods – Surface grinding, cylindrical grinding and centreless grinding.
- Grinding machine – Cylindrical grinder, surface grinder, internal grinder, centreless grinder, tool and cutter grinder.
- Selection of grinding wheel

Grinding is an abrasive machining process that uses a grinding wheel as the cutting tool.

A wide variety of machines are used for grinding:

- Hand-cranked knife-sharpening stones (grindstones)
- Handheld power tools such as angle grinders and die grinders
- Various kinds of expensive industrial machine tools called grinding machines
- Bench grinders

Grinding practice is a large and diverse area of manufacturing and toolmaking. It can produce very fine finishes and very accurate dimensions; yet in mass production contexts it can also rough out large volumes of metal quite rapidly. It is usually better suited to the machining of very hard materials than is "regular" machining (that is, cutting larger chips with cutting tools such as tool bits or milling cutters), and until recent decades it was the only practical way to machine such materials as hardened steels. Compared to "regular" machining, it is usually better suited to taking very shallow cuts, such as reducing a shaft's diameter by half a thousandth of an inch or 12.7 μm.

Grinding is a subset of cutting, as grinding is a true metal-cutting process. Each grain of abrasive functions as a microscopic single-point cutting edge (although of high negative rake angle), and shears a tiny chip that is analogous to what would conventionally be called a "cut" chip (turning, milling, drilling, tapping, etc.)[*citation needed*]. However, among people who work in the machining fields, the term *cutting* is often understood to refer to the macroscopic cutting operations, and *grinding* is often mentally categorized as a "separate" process. This is why the terms are usually used separately in shop-floor practice.

Lapping and sanding are subsets of grinding.

2.1 Processes

Selecting which of the following grinding operations to be used is determined by the size, shape, features and the desired production rate.

2.1.1 Surface grinding

Surface grinding uses a rotating abrasive wheel to remove material, creating a flat surface. The tolerances that are normally achieved with grinding are $\pm 2\times10^{-4}$ inches (5.1 μm) for grinding a flat material and $\pm 3\times10^{-4}$ inches (7.6 μm) for a parallel surface.[1]

The surface grinder is composed of an abrasive wheel, a workholding device known as a chuck, either electromagnetic or vacuum, and a reciprocating table.

Grinding is commonly used on cast iron and various types of steel. These materials lend themselves to grinding because they can be held by the magnetic chuck commonly used on grinding machines and do not melt into the wheel, clogging it and preventing it from cutting. Materials that are less commonly ground are aluminum, stainless steel, brass, and plastics. These all tend to clog the cutting wheel more than steel and cast iron, but with special techniques it is possible to grind them.

2.1.2 Cylindrical grinding

Cylindrical grinding (also called center-type grinding) is used to grind the cylindrical surfaces and shoulders of the workpiece. The workpiece is mounted on centers and rotated by a device known as a drive dog or center driver. The abrasive wheel and the workpiece are rotated by separate motors and at different speeds. The table can be adjusted to produce tapers. The wheel head can be swiveled. The five types of cylindrical grinding are: outside diameter (OD) grinding, inside diameter (ID) grinding, plunge grinding, creep feed grinding, and centerless grinding.[2]

A cylindrical grinder has a grinding (abrasive) wheel, two centers that hold the workpiece, and a chuck, grinding dog, or other mechanism to drive the work. Most cylindrical grinding machines include a swivel to allow the forming of tapered pieces. The wheel and workpiece move parallel to one another in both the radial and longitudinal directions. The abrasive wheel can have many shapes. Standard disk-shaped wheels can be used to create a tapered or straight workpiece geometry, while formed wheels are used to create a shaped workpiece. The process using a formed wheel creates less vibration than using a regular disk-shaped wheel.[3]

Tolerances for cylindrical grinding are held within ±0.0005 inches (13 μm) for diameter and ±0.0001 inches (2.5 μm) for roundness. Precision work can reach tolerances as high as ±0.00005 inches (1.3 μm) for diameter and ±0.00001 inches (0.25 μm) for roundness. Surface finishes can range from 2 microinches (51 nm) to 125 microinches (3.2 μm), with typical finishes ranging from 8 to 32 microinches (0.20 to 0.81 μm).

2.1.3 Creep-feed grinding

Creep-feed grinding (CFG) was invented in Germany in the late 1950s by Edmund and Gerhard Lang. Unlike normal grinding, which is used primarily to finish surfaces, CFG is used for high rates of material removal, competing with milling and turning as a manufacturing process choice. Depths of cut of up to 6 mm (0.25 inches) are used along with low workpiece speed. Surfaces with a softer-grade resin bond are used to keep workpiece temperature low and an improved surface finish up to 1.6 μm Rmax

With CFG it takes 117 s to remove 1 in^3 (16 cm^3) of material, whereas precision grinding would take more than 200 s to do the same. CFG has the disadvantage of a wheel that is constantly degrading, requires high spindle power (51 hp or 38 kW), and is limited in the length of part it can machine.[4]

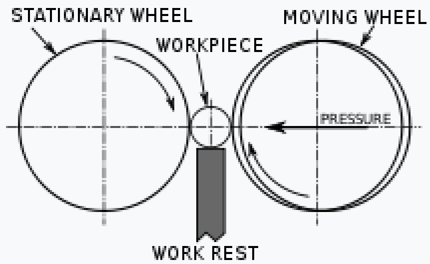
To address the problem of wheel sharpness, **continuous-dress creep-feed grinding** (CDCF) was developed in 1970s. It dresses the wheel constantly during machining, keeping it in a state of specified sharpness. It takes only 17 s to remove 1 in^3 (16 cm^3) of material, a huge gain in productivity. 38 hp (28 kW) spindle power is required, with a low to conventional spindle speeds. The limit on part length was erased.

High-efficiency deep grinding (HEDG) uses plated superabrasive wheels, which never need dressing and last longer than other wheels. This reduces capital equipment investment costs. HEDG can be used on long part lengths and removes material at a rate of 1 in^3 (16 cm^3) in 83 s. It requires high spindle power and high spindle speeds.[4]

Peel grinding, patented under the name of Quickpoint in 1985 by Erwin Junker Maschinenfabrik, GmbH in Nordrach, Germany, uses a thin superabrasive grinding disk oriented almost parallel to a cylindrical workpiece operates somewhat like a lathe turning tool.[4]

Ultra-high speed grinding (UHSG) can run at speeds higher than 40,000 fpm (200 m/s), taking 41 s to remove 1 in^3 (16 cm^3) of material, but is still in the R&D stage. It also requires high spindle power and high spindle speeds.[4]

Others[edit]



Centerless grinding

Form grinding is a specialized type of cylindrical grinding where the grinding wheel has the exact shape of the final product. The grinding wheel does not traverse the workpiece.[5]

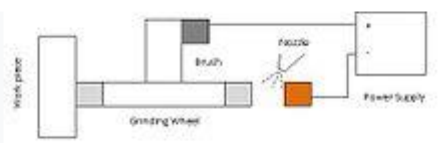
Internal grinding is used to grind the internal diameter of the workpiece. Tapered holes can be ground with the use of internal grinders that can swivel on the horizontal.

Centerless grinding is when the workpiece is supported by a blade instead of by centers or chucks. Two wheels are used. The larger one is used to grind the surface of the workpiece and the smaller wheel is used to regulate the axial movement of the workpiece. Types of centerless grinding include through-feed grinding, in-feed/plunge grinding, and internal centerless grinding.

Pre-grinding When a new tool has been built and has been heat-treated, it is pre-ground before welding or hardfacing commences. This usually involves grinding the **OD** slightly higher than the finish grind OD to ensure the correct finish size.

Electrochemical grinding

is a type of grinding in which a positively charged workpiece in a conductive fluid is eroded by a negatively charged grinding wheel. The pieces from the workpiece are dissolved into the conductive fluid.



A schematic of ELID grinding

Electrolytic in-process dressing (**ELID**) **grinding** is one of the most accurate grinding methods. In this ultra precision grinding technology the grinding wheel is dressed electrochemically and in-process to maintain the accuracy of the grinding. An ELID cell consists of a metal bonded grinding wheel, a cathode electrode, a pulsed DC power supply and electrolyte. The wheel is connected to the positive terminal of the DC power supply through a carbon brush whereas the electrode is connected to the negative pole of the power supply. Usually alkaline liquids are used as both electrolytes and coolant for grinding. A nozzle is used to inject the electrolyte into the gap between wheel and electrode. The gap is usually maintained to be approximately 0.1mm to 0.3 mm. During the grinding operation one side of the wheel takes part in the grinding operation whereas the other side of the wheel is being dressed by electrochemical reaction. The dissolution of the metallic bond material is caused by the dressing which in turns results continuous protrusion of new sharp grits.[6]

2.2 Grinding wheel

Main article: Grinding wheel

A grinding wheel is an expendable wheel used for various grinding and abrasive machining operations. It is generally made from a matrix of coarse abrasive particles pressed and bonded together to form a solid, circular shape, various profiles and cross sections are available depending on the intended usage for the wheel. Grinding wheels may also be made from a solid steel or aluminium disc with particles bonded to the surface.

2.3 Lubrication

The use of fluids in a grinding process is often necessary to cool and lubricate the wheel and workpiece as well as remove the chips produced in the grinding process. The most common grinding fluids are water-soluble chemical fluids, water-soluble oils, synthetic oils, and petroleum-based oils. It is imperative that the fluid be applied directly to the cutting area to prevent the fluid being blown away from the piece due to rapid rotation of the wheel.

Work Material	Cutting Fluid	Application
Aluminum	Light-duty oil or wax	Flood
Brass	Light-duty oil	Flood
Cast Iron	Heavy-duty emulsifiable oil, light-duty chemical oil, synthetic oil	Flood
Mild Steel	Heavy-duty water-soluble oil	Flood
Stainless Steel	Heavy-duty emulsifiable oil, heavy-duty chemical oil, synthetic oil	Flood
Plastics	Water-soluble oil, heavy-duty emulsifiable oil, dry, light-duty chemical oil, synthetic oil	Flood

2.4 The workpiece

Workholding methods[edit]

The workpiece is manually clamped to a lathe dog, powered by the faceplate, that holds the piece in between two centers and rotates the piece. The piece and the grinding wheel rotate in opposite directions and small bits of the piece are removed as it passes along the grinding wheel. In some instances special drive centers may be used to allow the edges to be ground. The workholding method affects the production time as it changes set up times.

Workpiece materials[edit]

Typical workpiece materials include aluminum, brass, plastics, cast iron, mild steel, and stainless steel. Aluminum, brass and plastics can have poor to fair machinability characteristics for cylindrical grinding. Cast Iron and mild steel have very good characteristics for cylindrical grinding. Stainless steel is very difficult to grind due to its toughness and ability to work harden, but can be worked with the right grade of grinding wheels.

Workpiece geometry[edit]

The final shape of a workpiece is the mirror image of the grinding wheel, with cylindrical wheels creating cylindrical pieces and formed wheels creating formed pieces. Typical sizes on workpieces range from 0.75 in to 20 in (18 mm to 1 m) and 0.80 in to 75 in (2 cm to 4 m) in length, although pieces from 0.25 in to 60 in

(6 mm to 1.5 m) in diameter and 0.30 in to 100 in (8 mm to 2.5 m) in length can be ground. Resulting shapes can be straight cylinders, straight-edged conical shapes, or even crankshafts for engines that experience relatively low torque.

Effects on workpiece materials[edit]

Mechanical properties will change due to stresses put on the part during finishing. High grinding temperatures may cause a thin martensitic layer to form on the part, which will lead to reduced material strength from microcracks.

Physical property changes include the possible loss of magnetic properties on ferromagnetic materials.

Chemical property changes include an increased susceptibility to corrosion because of high surface stress.

Chapter 3- Gear Manufacturing and Finishing Processes

Syllabus

- Gear hobbing
- Gear shaping

3.1 Gear manufacturing

refers to the making of gears. Gears can be manufactured by a variety of processes, including casting, forging, extrusion, powder metallurgy, and blanking. As a general rule, however, machining is applied to achieve the final dimensions, shape and surface finish in the gear. The initial operations that produce a semifinishing part ready for gear machining as referred to as blanking operations; the starting product in gear machining is called a gear blank.

3.2 Selection of materials

The gear material should have the following properties:[2]

- High tensile strength to prevent failure against static loads
- High endurance strength to withstand dynamic loads
- Low coefficient of friction
- Good manufacturability

3.3 Gear manufacturing processes

There are multiple ways in which gear blanks can be shaped through the cutting and finishing processes.

Gear forming[edit]

In gear form cutting, the cutting edge of the cutting tool has a shape identical with the shape of the space between the gear teeth. Two machining operations, milling and broachingcan be employed to form cut gear teeth.[3]

Form milling*[edit]*

In form milling, the cutter called a form cutter travels axially along the length of the gear tooth at the appropriate depth to produce the gear tooth. After each tooth is cut, the cutter is withdrawn, the gear blank is rotated, and the cutter proceeds to cut another tooth. The process continues until all teeth are cut

Broaching*[edit]*

Broaching can also be used to produce gear teeth and is particularly applicable to internal teeth. The process is rapid and produces fine surface finish with high dimensional accuracy. However, because broaches are expensive and a separate broach is required for each size of gear,this method is suitable mainly for high-quality production.

3.4 Gear generation

In gear generation, the tooth flanks are obtained as an outline of the subsequent positions of the cutter, which resembles in shape the mating gear in the gear pair. There are two machining processes employed shaping and milling. There are several modifications of these processes for different cutting tool used.[4]

3.5 Gear hobbing

Gear hobbing is a machining process in which gear teeth are progressively generated by a series of cuts with a helical cutting tool. All motions in hobbing are rotary, and the hob and gear blank rotate continuously as in two gears meshing until all teeth are cut..

Finishing operations

As produced by any of the process described, the surface finish and dimensional accuracy may not be accurate enough for certain applications. Several finishing operations are available, including the conventional process of shaving, and a number of abrasive operations, including grinding, honing, and lapping.

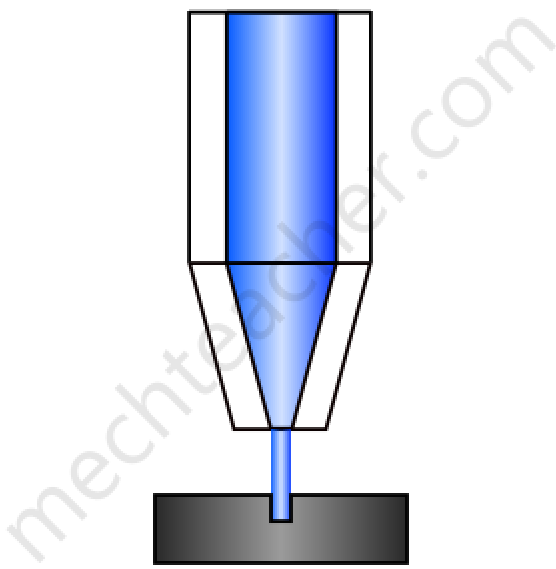
Chapter 4- Modern Machining Processes

Syllabus

- Mechanical Process - Ultrasonic machining (USM): Introduction, principle, process, advantages and limitations, applications
- Electro Chemical Processes - Electro chemical machining (ECM) – Fundamental principle, process, applications, Electro chemical Grinding (ECG) – Fundamental principle, process, application
- Electrical Discharge Machining (EDM) - Introduction, basic EDM circuit, Principle, metal removing rate, dielectric fluid, applications
- Laser beam machining (LBM) – Introduction, machining process and applications
- Electro beam machining (EBM)- Introduction, principle, process and applications

4.1 Unconventional Machining Processes – Introduction and Classification

Unconventional Machining Processes Add comments
Jun 162013



An unconventional machining process (or non-traditional machining process) is a special type of machining process in which there is no direct contact between the tool and the workpiece. In unconventional machining, a form of energy is used to remove unwanted material from a given workpiece.

Why unconventional machining processes are used?

The answer is simple. In several industries, hard and brittle materials like tungsten carbide, high speed steels, stainless steels, ceramics etc., find a variety of applications.

For example, tungsten carbide is used for making cutting tools while high speed steel is used for making gear cutters, drills, taps, milling cutters etc.

If such materials are machined with the help of conventional machining processes, either the tool undergoes extreme wear (while machining hard workpiece) or the workpiece material is damaged (while machining brittle workpiece).

This is because, in conventional machining, there is a direct contact between the tool and the workpiece. Large cutting forces are involved and material is removed in the form of chips. Huge amounts of heat is produced in the workpiece. This induces residual stresses, which degrades the life and quality of the workpiece material.Hence, conventional machining produces poor quality workpiece with poor surface finish (if the workpiece is made of hard and brittle material).To overcome all these drawbacks, we use unconventional machining processes to machine hard and brittle materials.We also use unconventional machining processes to machine soft materials, in order to get better dimensional accuracy.

4.2 Classification of unconventional machining processes:

Unconventional machining processes can be broadly classified into several types based on four main criteria. The classification of unconventional machining processes is given below:

1. Based on the type of energy used
    1. Mechanical Energy based Unconventional Machining Processes (e.g. Abrasive Jet Machining, Water Jet Machining)
    2. Electrical Energy based Unconventional Machining Processes (e.g. Electrical Discharge Machining)
    3. Electrochemical Energy based Unconventional Machining Processes (e.g. Electrochemical Grinding)
    4. Chemical Energy based Unconventional Machining Processes (e.g. Chemical Machining)
    5. Thermo-electrical (or Electro-thermal) Energy based Unconventional Machining Processes (e.g. Plasma Arc Machining)
2. Based on the source of energy
    1. Current
    2. Voltage
    3. Hydraulic Pressure
    4. Pneumatic Pressure
    5. Ionised Particles
    6. Light
3. Based on the medium of energy transfer
    1. Electrons
    2. Atmosphere
    3. Ions

    4. Electrolyte
    5. Pressurized gas
    6. Water
    7. Ultrasonic waves
    8. Plasma
    9. Laser
    10. Chemical reagent
    11. Radiation
4. Based on the mechanism of material removal
    1. Erosion
    2. Electric Discharge
    3. Shear
    4. Chemical Etching
    5. Vapourisation
    6. Melting
    7. Ion Displacement
    8. Blasting

Chapter 5 -Metallic Coating Processes

Syllabus

- Metal spraying – Wire process, powder process, applications
- Powder coating

A **coating** is a covering that is applied to the surface of an object, usually referred to as the **substrate**. The purpose of applying the coating may be decorative, functional, or both. The coating itself may be an all-over coating, completely covering the substrate, or it may only cover parts of the substrate. An example of all of these types of coating is a product label on many drinks bottles- one side has an all-over functional coating (the adhesive) and the other side has one or more decorative coatings in an appropriate pattern (the printing) to form the words and images.

Paints and lacquers are coatings that mostly have dual uses of protecting the substrate and being decorative, although some artists paints are only for decoration, and the paint on large industrial pipes is presumably only for the function of preventing corrosion.

Functional coatings may be applied to change the surface properties of the substrate, such as adhesion, wettability, corrosion resistance, or wear resistance. In other cases, e.g. semiconductor device fabrication (where the substrate is a wafer), the coating adds a completely new property, such as a magnetic response or electrical conductivity, and forms an essential part of the finished product.

A major consideration for most coating processes is that the coating is to be applied at a controlled thickness, and a number of different processes are in use to achieve this control, ranging from a simple brush for painting a wall, to some very expensive machinery applying coatings in the electronics industry. A further consideration for 'non-all-over' coatings is that control is needed as to where the coating is to be applied. A number of these non-all-over coating processes are printing processes.

Many industrial coating processes involve the application of a thin film of functional material to a substrate, such as paper, fabric, film, foil, or sheet stock. If the substrate starts and ends the process wound up in a roll, the process may be termed "roll-to-roll" or "web-based" coating. A roll of substrate, when wound through the coating machine, is typically called a **web**.

Coatings may be applied as liquids, gases or solids.

5.1 Functions of coatings

- Adhesive – adhesive tape, pressure-sensitive labels, iron-on fabric
- Changing adhesion properties
  - Non-stick PTFE coated- cooking pans
  - Release coatings for example silicone-coated release liners for many self-adhesive products
  - primers encourage subsequent coatings to adhere well (also sometimes have anti-corrosive properties)
- Optical coatings
  - Reflective coatings for mirrors
  - Anti-reflective coatings example on spectacles
  - UV- absorbent coatings for protection of eyes or increasing the life of the substrate
  - Tinted as used in some coloured lighting, tinted glazing, or sunglasses
- Catalytic e.g. some self-cleaning glass
- Light-sensitive as previously used to make photographic film
- Protective coatings
  - Most surface coatings or paints are to some extent protecting the substrate e.g.
    - Sealing and waterproofing wood
    - Sealing the surface of concrete
      - Film-forming sealers and floor paint

            - Seamless polymer/resin flooring
            - Bund wall/containment lining
        - Waterproofing and damp proofing of concrete walls
        - Roof coating
        - Concrete bridge deck membranes
        - Sealing and waterproofing of masonry
        - Preserving machinery, equipment and structures [1]
            - Maintenance coatings/paints for metals, alloys and concrete
            - Chemical resistant coatings
        - Wear resistance
            - Anti-Friction, Wear and Scuffing Resistance Coatings for Rolling-element bearings[2]
            - Hard anti-scratch coating on plastics and other materials e.g. of titanium nitride to reduce scratching and abrasion loss
            - Barrier coatings on concrete, metals and alloys subject to erosion/abrasive attack
    - Anti-corrosion [3]- ensure metal components have the longest possible lifespan.
        - Underbody sealant for cars
        - Many plating products
        - Preserving equipment and structural steel from degradation
        - Under thermal insulation and under protective fireproofing for structural steel
    - Passive fire protection
    - Insulation
    - Waterproof fabric and waterproof paper
    - Anti-graffiti
    - Antimicrobial surface
    - Foul release and anti-fouling
- Magnetic properties such as for magnetic media like cassette tapes, floppy disks, and some mass transit tickets
- Electrical or electronic properties
    - Conformal Antenna, e.g., metal coatings on plastic airframes
    - Conductive coatings e.g. to manufacture some types of resistors
    - Insulating coatings e.g. on magnet wires used in transformers
- Scent properties such as scratch and sniff stickers and labels
- Decorative- often to impart a specific colour, but also to create a particular reflective property such as gloss or matt.

5.2 Coating Analysis

Numerous methods exist for evaluating coatings, including both destructive and non-destructive methods. The most common destructive method is microscopy of a mounted cross-section of the coating and substrate. The most common non-destructive techniques include ultrasonic thickness measurement, XRF coatings thickness measurement, and ultra-micro hardness testing.

5.3 Coating processes

Coating processes may be classified as follows:

Vapor deposition[edit]

Chemical vapor deposition[edit]
Main article: Chemical vapor deposition

- Metalorganic vapour phase epitaxy
- Electrostatic spray assisted vapour deposition (ESAVD)
- Sherardizing
- Some forms of Epitaxy

- Molecular beam epitaxy
-

5.4 Physical vapor deposition

Main article: Physical vapor deposition

- Cathodic arc deposition
- Electron beam physical vapor deposition (EBPVD)
- Ion plating
- Ion beam assisted deposition (IBAD)
- Magnetron sputtering
- Pulsed laser deposition
- Sputter deposition
- Vacuum deposition
- Vacuum evaporation, evaporation (deposition)
- Pulsed electron deposition (PED)
-

5.5 Chemical and electrochemical techniques

- Conversion coating
    - Autophoretic, the registered trade name of a proprietary series of autodepositing coatings specifically for ferrous metal substrates[4]
    - Anodising
    - Chromate conversion coating
    - Plasma electrolytic oxidation
    - Phosphate (coating)
- Ion beam mixing
- Pickled and oiled, a type of plate steel coating
- Plating
    - Electroless plating
    - Electroplating

5.6 Spraying

- Spray painting
- High velocity oxygen fuel (HVOF)
- Plasma spraying
- Thermal spraying
- Kinetic metallization (KM)
- Plasma transferred wire arc thermal spraying
- The common forms of Powder coating

5.7 Roll-to-roll coating processes

Common roll-to-roll coating processes include:

- Air knife coating
- Anilox coater
- Flexo coater
- Gap Coating
    - Knife-over-roll coating
- Gravure coating

- Hot melt coating- when the necessary coating viscosity is achieved by temperature rather than solution of the polymers etc. This method commonly implies slot-die coating above room temperature, but it also is possible to have hot-melt roller coating; hot-melt metering-rod coating, etc.
- Immersion dip coating
- Kiss coating
- Metering rod (Meyer bar) coating
- Roller coating
  - Forward roller coating
  - Reverse roll coating
- Silk Screen coater
  - Rotary screen
- Slot Die coating - Slot die coating was originally developed in the 1950s.[5] Slot die coating has a low operational cost and is easily scaled processing technique for depositing thin and uniform films rapidly, while minimizing material waste.[6] Slot die coating technology is used to deposit a variety of liquid chemistries onto substrates of various materials such as glass, metal, and polymers by precisely metering the process fluid and dispensing it at a controlled rate while the coating die is precisely moved relative to the substrate.[7] The complex inner geometry of conventional slot dies require machining or can be accomplished with 3-D printing.[8]
- Extrusion coating - generally high pressure, often high temperature, and with the web travelling much faster than the speed of the extruded polymer
  - Curtain coating- low viscosity, with the slot vertically above the web and a gap between slotdie and web.
  - Slide coating- bead coating with an angled slide between the slotdie and the bead. Commonly used for multilayer coating in the photographic industry.
  - Slot die bead coating- typically with the web backed by a roller and a very small gap between slotdie and web.
  - Tensioned-web slotdie coating- with no backing for the web.
- Inkjet printing
- Lithography
- Flexography

5.8 Physical coating processes

- Langmuir-Blodgett[9]
- Spin coating
- Dip coating

Chapter 6- Metal Finishing Processes

Syllabus

- Purpose of finishing surfaces.
- Surface roughness-Definition and units
- Honing Process, its applications
- Description of hones.
- Brief idea of honing machines.
- Lapping process, its applications.
- Description of lapping compounds and tools.
- Brief idea of lapping machines.
- Super finishing process, its applications.
- Polishing
- Buffing

6.1 INTRODUCTION

Quality of surface is an important factor to decide the performance of a manufactured product. Surface quality affect product performance like assembly fit, aesthetic appeal that a potential customer might have for the product. A surface is defined as the exterior boundary of an object with its surroundings, which may be any other object, a fluid or space or combination of these. The surface encloses the object's bulk mechanical and physical properties. A surface is what we touch, when we held a manufactured object. Normally dimensions of the object are specified in its drawing relating the various surfaces to each other. These nominal surfaces, representing the intended surface contour of the manufactured part, are defined by line in the drawing (machine). The nominal surfaces of the object are represented by perfect straight lines, perfect circles, round holes, absolute perpendicularity and straightness. A variety of processes are used to make the designed parts. In totality the manufacturing result is wide variations in surface characteristics. It is important to know the technology of surface generation. Only then the root causes of deviations can be determined and fixed to get the good results. Objectives After studying this unit, you should be able to • meaning of metal finishing and surface preparation, • surface roughness, • different process of surface finish, • super finishing operations, and • machine-tool used in surface finishing operations.

6.2 DEFINITIONS

Some important definitions are being described here which determine the quality of a generated surfaces. The surface parameters described here are not only responsible for aesthetic point of view but also their correctness and accuracy influence performance of the object correctly. Angularity The extent to which a part feature such as a surface or axis is at a specified angle relative to a reference surface. If angle is maintained exactly at 90o it is called perpendicularity. If the angle is maintained exactly at 0o it is called parallelism. 26 Manufacturing Practices-II Circularity For a surface of revaluation such as cylinder, circular hole, or cone, circulating is the degree to which all points on the intersection of the surface and plane perpendicular to axis of revaluation are equidistant from the axis. For a sphere, circulating is the degree to which all points on the intersection of the surface and a plane centre. Same is also called roundness. Concentricity The degree to which any two or more part features such as a cylindrical surface and a circular hole have a common axis. Cylindricity The degree to which all points on a surface of revaluation such as a cylinder are equidistant from the axis of revaluation. Flatness The extent to which all points on a surface lie in a single plane. Straightness The degree to which a part feature such as a line or axis is a straight line.

6.3 OBJECTIVES OF SURFACE PREPARATION

Surfaces are very important due to various commercial and technological reasons. These reasons may be different depending on different applications of the product. The main objectives are described below. (a) All smooth surfaces which are free from scratches and blemishes provide good a 27 Metal Finishing Processes Figure 3.1 : Features of Surface Texture Surface Roughness It refers to small, finely spaced deviations from nominal surface that are determined by the material characteristics and the process used. Waviness It is defined as the deviations of much larger spacing occurring due to work deflection, vibration, heat treatment and other similar factors. Roughness is generally superimposed on the waviness.

Lay

Lay is the predominant direction or pattern of the surface texture. It is the result of and determined by the manufacturing method employed to generated the surface. Flaws Flaws are irregularities that occur sometimes on the surface. Flaws are not the characteristics of the process but these are the faults. Examples of flaws are cracks, scratches, inclusions, etc. Surface Roughness/Surface Finish Surface roughness and surface finish are opposite to each other, these are quantitative parameters. Surface roughness can be expressed in units of length after its measurement. "Measurement of finely spaced deviations of actual surface from nominal surface (datum) in the units of length (μm) are the measurement of surface roughness. Lesser the value of surface roughness better the surface finish is said. There are two popular methods of expressing measured value of surface roughness. According to "AA" method surface roughness is the average of vertical deviations from the nominal surface over a specified surface length. Average Roughness (AA) 0 ( ) lm m Y dx L = ∫ where, Y = Vertical deviations from nominal surface, and Lm = Specified length on surface. According to root mean square method, "Value of surface roughness is square root of the mean of the squared deviations from nominal surface over the measuring length (sampling length)" RMS value is always observed more than the arithmetic average because larger deviations play more prominent role. 2 0 | | lm rms m Y R dx L = ∫ All the notations have the same meanings above. Lay Direction Cracks Crater Formation Waviness Spacing Waviness Height 28 Manufacturing Practices-II 3.5 SURFACE FINISHING PROCESSES Manufacturing process employed determines surface finish level. Some processes are inherently capable of producing better surfaces than others. The processes recognized for good surface finish are honing, lapping, polishing and surface finishing. Tolerance and range of surface roughness produced by different processes are given below. Process Tolerance (mm) Roughness (μm) Grinding ± 0.008 5 to 75 Lapping ± 0.005 2 to 15 Honing ± 0.005 4 to 30 Super Finishing ± 0.003 1 to 10 Different surface finishing processes are described below. Honing Honing is a surface finishing operation based on abrasive action performed by a set of bonded abrasive sticks. It is generally used to finish bores of cylinders of IC engine, hydraulic cylinders, gas barrels, bearings, etc. It can reduce the level of surface roughness below 32 μm. It produces a characteristics surface pattern as cross hatched which is a fit case to retain lubrication layer to facilitate motion to moving parts, their best example is IC engine. The honing tool used to finish internal surface is shown in Figure 3.2. The honing tool consists of a set of bonded abrasive sticks. The number of sticks mounted on a tool depends on its circumferential area. Number of sticks may be more than a dozen. Figure 3.2 : Honing Tool and its Operation The motion of a honing tool a combination of rotation and reciprocation (linear). The motion is managed in such a way that a given point on the abrasive stick does not trace the same path repeatedly. The honing speed may be kept upto 10 cms per sec. Lower speeds are recommended for better surface finish. Manufacturing defects like slight eccentricity a way surface, light tapper, less of circulating can also be corrected by honing process. The process of honing is always supported by flow of coolants. It flashes away the small chips and maintains a low and uniform temperature of tool and work. Honing Machines Honing machines resembles with vertical drilling machines in their construction. Reciprocating motion of spindle is obtained by hydraulic Driver Universal Joint Bonded Abrasive Sticks (Hones) Rotary Motion Reciprocatin g Rotary Motion Work Piece Internal Surface to be finished Hones or Sticks (Made of Hard Abrasives like Aluminum oxide) 29 means. The rotary motion may be by hydraulic motor or by a gear train. Metal Finishing Processes Depending upon the movement of spindle or hones a machine may be vertical honing machine or horizontal honing machine. Generally honing vertical honing machines are used. Horizontal honing machines are recommended for finishing internal of long gun barrels. Lapping Lapping is also one of the abrasive processes used to produce finished (smoothly accurate) surfaces. It gives a very high degree of accuracy and smoothness so it is used in production of optical lenses, metallic bearing surfaces, measuring gauges, surface plates and other measuring instruments. All the metal parts that are subjected to fatigue loading or those surfaces that must be used to establish a seal with a mating part are often lapped. The process of lapping uses a bonded abrasive tool and a fluid suspension having very small sized abrasive particles vibrating between the workpiece and the lapping tool. The process of lapping is shown in Figure 3.3. The fluid with abrasive particles is referred as lapping compound. It appears as a chalky paste. Normally the fluid used in lapping compound is oil or kerosene. The fluid should have slightly lubricating properties to make the action of abrasive mild in nature. Abrasives used in lapping compound are aluminium oxide and silicon carbide. Their girt size is kept 300 to 600 μm. It is hypothesized that two alternative cutting mechanisms are working in the process of lapping. Figure 3.3 : Lapping Process In first mechanism the abrasive particles roll and slide between the lapping tool and workpiece. These particles produce small cuts on both surfaces. Another mechanism suppose to work in lapping is that the abrasives become imbedded in the lap surface to give cutting action like in case of grinding. It is assumed that lapping is due to the combination of these two above mentioned mechanism. Lapping can be done manually but use of lapping machine makes the process accurate, consistent and efficient. Machine Lapping Machine lapping is recognized as fast lapping process. Gudgeon pins with 25 mm diameter and 75 mm long can be lapped at the rate of 500 units per hour. Mechanical lapping machines have vertical construction with the work holder mounted on the lower table which is given oscillatory motion. The upper lap is stationery and floating while lower one revolves at 60 rpm. Some special purpose lapping machines are available for lapping of small parts such as piston pins ball bearing races, etc. in machine lapping a pressure upto 0.02 N/mm2 for soft material and 0.5 N/mm2 for hard material is applied. Lapping Applications Materials processed by lapping range from steel, cast iron to non-ferrous metal like copper, brass and lead. Wooden parts, made of hard wood, can also be finished using wood laps. Lapping removes material at a very slow rate. So lapping is generally followed by accurate machining of workpieces. Lapping is a costlier process so its applications are justified only when very Lapping Tool Lapping Compound Lense Blank (Work Piece) 30 Manufacturing Practices-II high grade of surface finishing is required. Lapped surfaces are well resistant to corrosion and wear, used in manufacturing of high precision parts. Polishing and Buffing Polishing and buffering are similar surface finishing operations. Polishing is used to remove scratches and burrs from a machined surface. It develops a very smooth surface by means of abrasive grains embedded to a polishing wheel rotating at high rpm. Rotating speed is equivalent to 2300 meter per minutes. The rotating wheels are made of softer materials like canvas, leather or paper. Thus, the wheels are enough flexible to finish the cavities and internal of intricate shapes. Polishing Polishing is carried out with the help of above mentioned polishing wheels. Abrasive grains are bonded by gluing to the outside periphery of the wheel. After the abrasives have been worn down and used up, the wheel is replenished with new girts. Depending on the girt size polishing is divided into three categories. (a) Rough Polishing : Girt size is maintained 20 to 80. (b) Finish Polishing : Girt size is kept 80 to 120. (c) Fine Finish : For polishing to give very fine finishing abrasive girt size is maintained to above 120. In case of fine finishing process oil, tallow or beeswax is used as lubricating agent. There is a limitation of polishing process that the parts with irregular shapes, sharp corners, deep recesses and sharp projections are difficult to polish. Polishing Tool Polishing can be done by hand, but for mass production work, specially designed semi-automatic and automatic polishing machines are available. Abrasive particles are Al2O3 or diamond. Carrier of abrasive particles has already been discussed. Polished surfaces may be buffed to obtain an even finer surface. Polishing does not improve dimensionless accuracy as done by lapping. Different between Lapping and Polishing Lapping and polishing differ in the following manner, polishing produce a shiny surface but lapping does not produce bright shiny surface. Lapping removes metal from the surface to be finished, however, polishing removes negligible amount of metal. Lapping involves cutting action but polishing consists of producing a kind of plastic flow of the surface crystals so that the high spots are made to fill the low spots. Buffing Buffing is similar to polishing in appearance, but its function is different. Buffing is used to provide attractive surfaces with high luster. Buffing is like a polishing operation in which the workpiece is brought in contact with a revolving cloth buffing wheel that usually has been charged with a very find abrasive as shown in Figure

3.4. Buffing status is some where in between polishing and lapping. A minor cutting action with microchip is done in case of buffing. Buffing wheels are made of discs of liners, cotton, broad cloth and canvas. These are made more or less firm by the amount of stitching used to fasten the layers of the cloth together. Buffing tools are enough flexible to polish 31 upto interior of intricate cavities. The buffing tools are named as BUFFING Metal Finishing Processes ROUGES. There are semi-automatic buffing machines available consisting of a series of individually drivers buffing wheel which can be adjusted to the desired position so as to buff different positions of the workpiece. The workpieces are held in fixtures on a suitable rotating worktable so as to move the buffing wheels. Figure 3.4 : Buffing Wheel Performing Buffing Operation Application of buffing produces mirror like finish. It is used for finishing of automobile parts, boats, bicycles, sport items, tools, furniture, fixtures, commercial and residential hardware, house hold utensils and home appliances, etc. Super Finishing Super finishing is an alternative process similar to honing. This also uses bonded abrasive stick moved with a reciprocating motion and pressed against the surface to be finished. The relative motion between the abrasive stick and the workpiece is varied so that individual grains do not retrace the same path. Cutting fluid is used in the process for cooling of tool workpiece interface. Coolant also washes away the tiny chips produced in the process. The time needed for super finishing is very small. Workpiece may be super finished to a roughness of the order of 0.075 μm within 50 seconds. Sometimes the process of super finishing can be continued upto 3 minutes for very fine quality of finish. Super finishing can be differentiated from honing in the following ways : (a) Super finishing stroke length is comparatively shorter but frequency is larger. It is upto 1500 stokes/minute. (b) It requires low pressure application as compared to honing process. (c) During the process fed is given to workpiece, the fed rate in case of super finishing operation is smaller than honing. (d) Grit size of abrasive used in case of super finishing is smaller than that is used with hones. Major applications of super finishing are finishing of computer memory drums, sewing machine parts, automotive cylinders, brake drums, bearing components, pistons piston rods, pins, axles, shafts, clutch plates, guide pins, etc. Feed Direction Direction of Rotation Fabric Wheel Buffing Paste on the Surface Work Piece 32 Manufacturing Practices-II 3.6

6.4 LATHE ATTACHMENTS USED FOR SUPER FINISHING

Super finishing can also be carried out lathe machine. Some attachments of centre lathe along with their capabilities and uses are listed below. Automatic Plunge Centreless Micro-finishing Machine It is used for finishing of piston pins, cam followers, rollers, piston rods, etc. The surface finish can be obtained upto 0.2 µ (Ra) value. Centreless Micro-finishing Machine with Roller Support and Auxiliary Drivers The dimensions of the job that can be processed by this attachment is diameter 25 to 150 mm and job length upto 2000 mm. It is capable to finish the surface of roughness of 0.3 µ (Ra) to 0.025 µ (Ra). It is used for surface finish of hydraulic cylinder piston rods; shock absorber front fork tubes, IC engine parts, etc. Attachment for Finishing of Engines and Gearbox Parts It can be used for surface finishing of IC engine parts and gears, shafts, etc. Most of the attachments designed and developed for lathe machine meant for some specific purpose. With all the attachment lathe provides the following facilities : (a) Base to work with the workpiece. (b) Check to hold the workpiece/tool. (c) Tool post to hold any processing tool. (d) It provides motive power or a controlled relative motion between the workpiece and tool. However, there is no end of lathe attachments used for super finishing operation. Any attachment utilizing the above mentioned lathe facilities can be designed and developed.