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School of Mechanical
Department of Aeronautical Engineering

UNIT – I - SAEA1302 - AIRCRAFT PRODUCTION TECHNIQUES

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Department of Aeronautical Engineering

INTRODUCTION

The aviation maintenance technician (AMT) spends a major portion of each day using a wide variety of hand tools to accomplish maintenance tasks. This chapter contains an overview of some of the hand tools an AMT can expect to use. An AMT encounters many special tools as their experience widens; large transport category aircraft have different maintenance tasks from those of a light aeroplane, and special hand tools are often required when working on complex aircraft.

This chapter outlines the basic knowledge required in using the most common hand tools and measuring instruments used in aircraft repair work. This information, however, cannot replace sound judgment on the part of the individual, nor additional training as the need arises. There are many times when ingenuity and resourcefulness can supplement the basic rules. Sound knowledge is required of these basic rules and of the situations in which they apply. The use of tools may vary, but good practices for safety, care, and storage of tools remain the same.

General Purpose Tools Hammers and Mallets

some of the hammers that the aviation mechanic may be required to use. Metalhead hammers are usually sized according to the weight of the head without the handle.

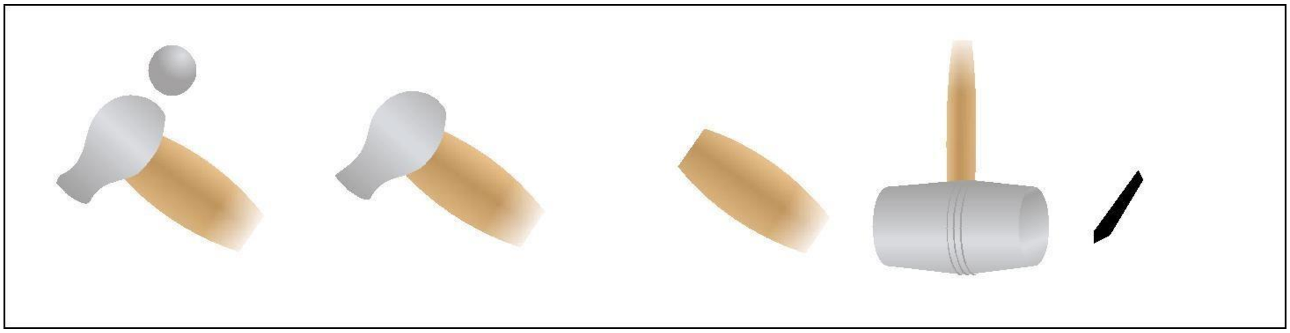

Fig – 1 Types of Hammer

Occasionally it is necessary to use a soft-faced hammer, which has a striking surface made of wood, brass, lead, rawhide, hard rubber, or plastic. These hammers are intended for use in forming soft metals and striking surfaces that are easily damaged. Soft-faced hammers should not be used for striking punch heads, bolts, or nails, as using one in this fashion will quickly ruin this type of hammer.

A mallet is a hammer-like tool with a head made of hickory, rawhide, or rubber. It is handy for shaping thin metal parts without causing creases or dents with abrupt corners. Always use a wooden mallet when pounding a wood chisel or a gouge.When using a hammer or mallet, choose the one best suited for the job. Ensure that the handle is tight. When striking a blow with the hammer, use the forearm as an extension of the handle. Swing the hammer by bending the elbow, not the wrist. Always strike the work squarely with the full face of the hammer. When striking a metal tool with a metal hammer, the use of safety glasses or goggles is strongly encouraged.Always keep the faces of hammers and mallets smooth and free from dents, chips, or gouges to prevent marring the work.

Screwdrivers

The screwdriver can be classified by its shape, type of blade, and blade length. It is made for only one purpose, i.e., for loosening or tightening screws or screw head bolts. The figure shows several different types of screwdrivers. When using the common screwdriver, select the largest screwdriver whose blade will make a good fit in the screw that is to be turned. A common screwdriver must fill at least 75 percent of the screw slot. If the screwdriver is the wrong size, it cuts and burrs the screw slot, making it worthless. The damage may be so severe that the use of screw extractor may be required. A screwdriver with the wrong size blade may slip and damage adjacent parts of the structure.-

Fig 2 – Screw Driver

Phillips Screwdriver the common screwdriver is used only where slotted head screws or fasteners are found on aircraft. An example of a fastener that requires the use of a common screwdriver is the Camlock style fastener that is used to secure the cowling on some aircraft.Both the Phillips and Reed & Prince recessed heads are optional on several types of screws. As shown in Figure, the Reed & Prince recessed head forms a perfect cross. The screwdriver used with this screw is pointed on the end. Since the Phillips screw has a slightly larger centre in the cross, the Phillips screwdriver is blunt on the end. The Phillips screwdriver is not interchangeable with the Reed & Prince.

Pliers and Plier-Type Cutting Tools

As shown in Figure, the pliers used most frequently in aircraft repair work are the diagonal, needle nose, and duckbill. The size of pliers indicates their overall length, usually ranging from 5 to 12 inches.Round nose pliers are used to crimp metal. They are not made for heavy work because too much pressure will spring the jaws, which are often wrapped to prevent scarring the metal.Needle nose pliers have half-round jaws of varying lengths. They are used to hold objects and make adjustments in tight places. Duckbill pliers resemble a ―duck‘s bill‖ in that the jaws are thin, flat, and shaped like a duck‘s bill. They are used exclusively for twisting safety wire.Diagonal pliers are usually referred to as diagonals or ―dikes. ‖ The diagonal is a short-jawed cutter with a blade set at a slight angle on each jaw. This tool can be used to cut wire, rivets, small screws, and cotter pins, besides being practically indispensable in removing or installing safety wire. The duckbill pliers and the diagonal cutting pliers are used extensively in aviation for the job of safety wiring.

Two important rules for using pliers are:

- Do not make pliers work beyond their capacity. The long-nosed variety is especially delicate. It is easy to spring or break them, or nick the edges. If this occurs, they are practically useless.
- Do not use pliers to turn nuts. In just a few seconds, a pair of pliers can damage a nut more than years of service.

Fig – 3 – Tyes of Pliers Punches

Punches

Punches are used to locate centres for drawing circles, to start holes for drilling, to punch holes in sheet metal, to transfer the location of holes in patterns, and to remove damaged rivets, pins or bolts. Solid or hollow punches are the two types generally used. Solid punches are classified according to the shape of their points. Figure shows several types of punches.

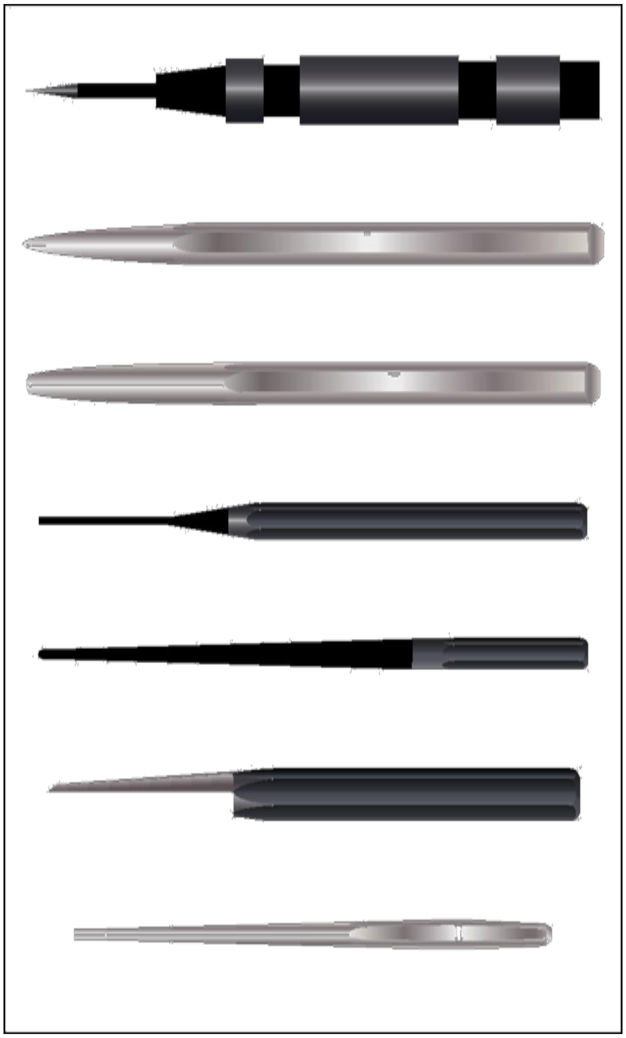

Fig 4 – Types of Punches

Prick punches are used to place reference marks on the metal. This punch is often used to transfer dimensions from a paper pattern directly on the metal. To do this, first, place the paper pattern directly on the metal. Then go over the outline of the pattern with the prick punch, tapping it lightly with a small hammer and making slight indentations on the metal at the major points on the drawing. These indentations can then be used as reference marks for cutting the metal. A prick punch should never be struck a heavy blow with a hammer because it may bend the punch or cause excessive damage to the material being worked.Large indentations in metal, which are necessary to start a twist drill, are made with a centre punch. It should never be struck with enough force to dimple the material around the indentation or to cause the metal to protrude through the other side of the sheet. A centre punch has a heavier body than a prick punch and is ground to a point with an angle of about 60°. The drive punch, which is often called a tapered punch, is used for driving out damaged rivets, pins, and bolts that sometimes bind in holes. The drive punch is therefore made with a flat face instead of a point. The size of the punch is determined by the width of the face, which is usually 1⁄8 inch to 1⁄4 inch.

Wrenches

The wrenches most often used in aircraft maintenance are classified as open-end, box-end, socket, adjustable, ratcheting and special wrenches. The Allen wrench, although seldom used, is required on one special type of recessed screw. One of the most widely used metals for making wrenches is chrome-vanadium steel. Wrenches made of this metal are almost unbreakable. Solid, nonadjustable wrenches with open parallel jaws on one or both ends are known as open-end wrenches. These wrenches may have their jaws parallel to the handle or at an angle up to 90°; most are set at an angle of 15°. The wrenches are designed to fit a nut, bolt head, or other objects, which makes it possible to exert a turning action.

Box-end wrenches are popular tools because of their usefulness in close quarters. They are called box wrenches since they box, or surround, the nut or bolt head. Practically all well-manufactured box- end wrenches are made with 12 points so they can be used in places having as little as 15° swing. In Figure, point A on the illustrated double broached hexagon wrench is nearer the centerline of the head and the wrench handle than point B, and also the centerline of nut C. If the wrench is inverted and installed on nut C, point A will be centred over the side ―Y‖ instead of side ―X.‖ The centerline of the handle will now be in the dotted line position wrench over) the position of the wrench that a 15° arc may be made with the wrench handle.

Sockets with detachable handles usually come in sets and fit several types of handles, such as the T, ratchet, screwdriver grip, and speed handle. Socket wrench handles have a square lug on one end that fits into a square recess in the socket head. The two parts are held together by a light spring-loaded poppet. Two types of sockets, a set of handles, and an extension bar are shown in Figure.

The adjustable wrench is a handy utility tool that has smooth jaws and is designed as an open-end wrench. One jaw is fixed, but the other may be moved by a thumbscrew or spiral screwworm adjustment in the handle. The width of the jaws may be varied from 0 to 1⁄2 inch or more. The angle of the opening to the handle is 221⁄2 degrees on an adjustable wrench. One adjustable wrench does the work of several open-end wrenches. Although versatile, they are not intended to replace the standard open-end, box-end, or socket wrenches.

Fig 5 – Types of wrenches

The crowfoot wrench is normally used when access-ing nuts that must be removed from studs or bolt that cannot be accessed using other tools. The flare nut wrench has the appearance of a box-end wrench that has been cut open on one end. This opening allows the wrench to be used on the B-nut of a fuel, hydraulic, or oxygen line. Since it mounts using the standard square adapter, like the crowfoot wrench, it can be used in conjunction with a torque wrench.

Strap Wrenches

The strap wrench can prove to be an invaluable tool for the AMT. By their very nature, aircraft components such as tubing, pipes, small fittings, and round or irregularly shaped components are built to be as light as possible, while still retaining enough strength to function properly. The misuse of pliers or other gripping tools can quickly damage these parts. If it is necessary to grip a part to hold it in place, or to rotate it to facilitate removal, consider using a strap wrench that uses a plastic covered fabric strap to grip the part.

Fig – 6 – Strap Wrenches

Hacksaws

The common hacksaw has a blade, a frame, and a handle. The handle can be obtained in two styles: pistol grip and straight. Hacksaw blades have holes in both ends; they are mounted on pins attached to the frame. When installing a blade in a hacksaw frame, mount the blade with the teeth pointing forward, away from the handle.Blades are made of high-grade tool steel or tungsten steel and are available in sizes from 6 to 16 inches in length. The 10-inch blade is most commonly used. There are two types, the all-hard blade and the flexible blade. Inflexible blades, only the teeth are hardened.Selection of the best blade for the job involves finding the right type and pitch. An all-hard blade is best for sawing brass, tool steel, cast iron, and heavy cross-section materials. A flexible blade is usually best for sawing hollow shapes and metals having a thin cross-section.

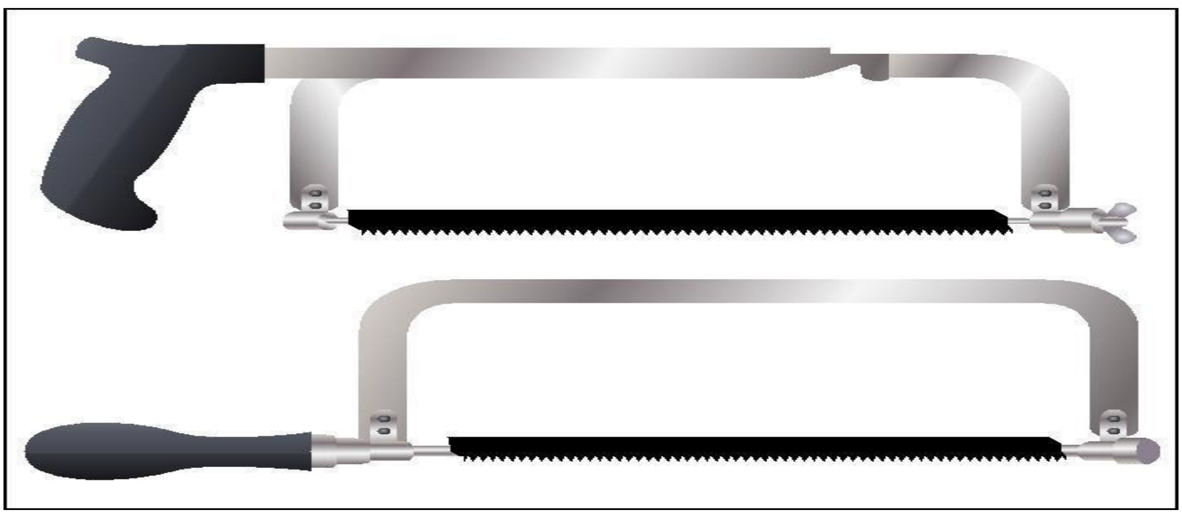

Fig 7 Hacksaws.

The pitch of a blade indicates the number of teeth per inch. Pitches of 14, 18, 24, and 32 teeth per inch are available. A blade with 14 teeth per inch is preferred when cutting machine steel, cold-rolled steel, or structural steel. A blade with 18 teeth per inch is preferred for solid stock aluminium, bearing metal, tool steel, and cast iron. Use a blade with 24 teeth per inch when cutting thick-walled tubing, pipe, brass, copper, channel, and angle iron.

Chisels

A chisel is a hard steel cutting tool that can be used for cutting and chipping any metal softer than the chisel itself. It can be used in restricted areas and for such work as shearing rivets or splitting seized or damaged nuts from bolts. The size of a flat cold chisel is determined by the width of the cutting edge. Lengths will vary, but chisels are seldom under 5 inches or over 8 inches long.

Fig 8 Chisels

Chisels are usually made of eight-sided tool steel bar stock, carefully hardened and tempered. Since the cutting edge is slightly convex, the centre portion receives the greatest shock when cutting, and the weaker corners are protected. The cutting angle should be 60° to 70° for general use, such as for cutting wire, strap iron, or small bars and rods.When using a chisel, hold it firmly in one hand. With the other hand, strike the chisel head squarely with a ball-peen hammer.

When cutting square corners or slots, a special cold chisel called a cape chisel should be used. It is like a flat chisel except the cutting edge is very narrow. It has the same cutting angle and is held and used in the same manner as any other chisel.Rounded or semicircular grooves and corners that have fillets should be cut with a round nose chisel. This chisel is also used to re-centre a drill that has moved away from its intended centre.The diamond point chisel is tapered square at the cutting end and then ground at an angle to provide the sharp diamond point. It is used for cutting B-grooves and inside sharp angles.

Files

Most files are made of high-grade tool steels that are hardened and tempered. Files are manufactured in a variety of shapes and sizes. They are known either by the cross-section, the general shape or by their particular use. The cuts of files must be considered when selecting them for various types of work and materials.

Files are used to square ends, file rounded corners, remove burrs and slivers from metal, straighten uneven edges, file holes and slots, and smooth rough edges.

Files have three distinguishing features: (1) their length, measured exclusive of the tang ;

(2) their kind or name, which has reference to the relative coarseness of the teeth; and (3) their cut.

Files are usually made in two types of cuts: single cut and double-cut. The single-cut file has a single row of teeth extending across the face at an angle of 65° to 85° with the length of the file. The size of the cuts depends on the coarseness of the file. The double-cut file has two rows of teeth that cross each other. For general work, the angle of the first row is 40° to 45°. The first row is generally referred to as ―overcut,‖ and the second row as ―upcut;‖ the upcut is somewhat finer and not as deep as the overcut.

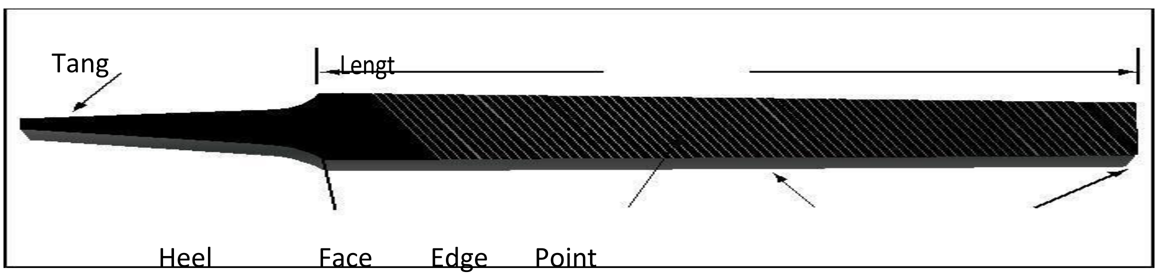

Fig 9 - Files

Particles of metal collect between the teeth of a file and may make deep scratches in the material being filed. When these particles of metal are lodged too firmly between the teeth and cannot be removed by tapping the edge of the file, remove them with a file card or wire brush. Draw the brush across the file so that the bristles pass down the gullet between the teeth.

Definition of metrology

- Linear measuring instruments: Vernier, micrometre and interval measurement- Slip gauges and classification. The interferometer, optical flats and limit gauges Comparators: Mechanical, pneumatic and electrical types, applications.
- Angular measurements: -Sine bar, optical bevel protractor, Taper measurements
- Metrology is the name given to the science of pure measurement.
- Engineering Metrology is restricted to measurements of length & angle
- The Linear Measurement includes measurements of length, diameters, heights and thickness
- The Angular measurement includes the measurement of angles or tapers
- Measurement systems are mainly used in industries for quality control.
- Often widely using measurements are
    - Linear Measurement
    - Angular measurement

- A very common measurement is that of dimensions, i.e., length, width, height of an object
- Dimensions of the measuring instruments are classified as follows
    - Low resolution devices (up to 0.25mm)
    - Medium resolution devices (up to 0.0025mm)
    - High resolution devices (less than microns)

Low-resolution devices

- Steel rule
- Steel rule with assistance of
    - Calipers
    - Dividers &
    - Surface gauges
- Thickness gauges

Medium resolution devices

- Micrometer
- Micrometer with assistance of
  - Telescoping
  - Extendable ball gauges
- Vernier calipers
- Dial indicators
- Microscope

High-resolution devices

- Gauge blocks
- Gauge block with assistance of
  - Mechanical comparator
  - Electronic comparator
  - Pneumatic comparator
  - Optical flats

Linear Measuring Instruments

- Vernier caliper
- Micrometer
- Slip gauge or gauge blocks
- Optical flats
- Interferometer
- Comparators

Vernier caliper

- Components of vernier calipers are
  - Main scale

- Vernier scale

- Fixed jaw
- Movable jaw

- Types of vernier callipers
  - Type A vernier calliper
  - Type B vernier calliper
  - Type C verniercalliper

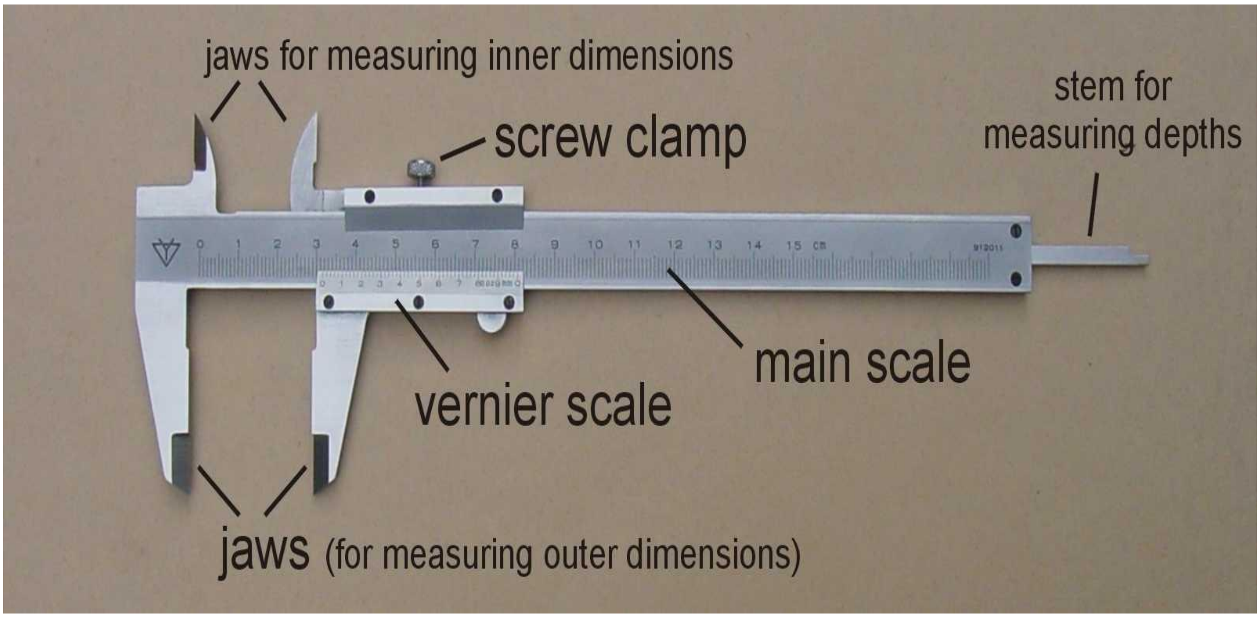

Fig 10 - Type A Vernier Caliper

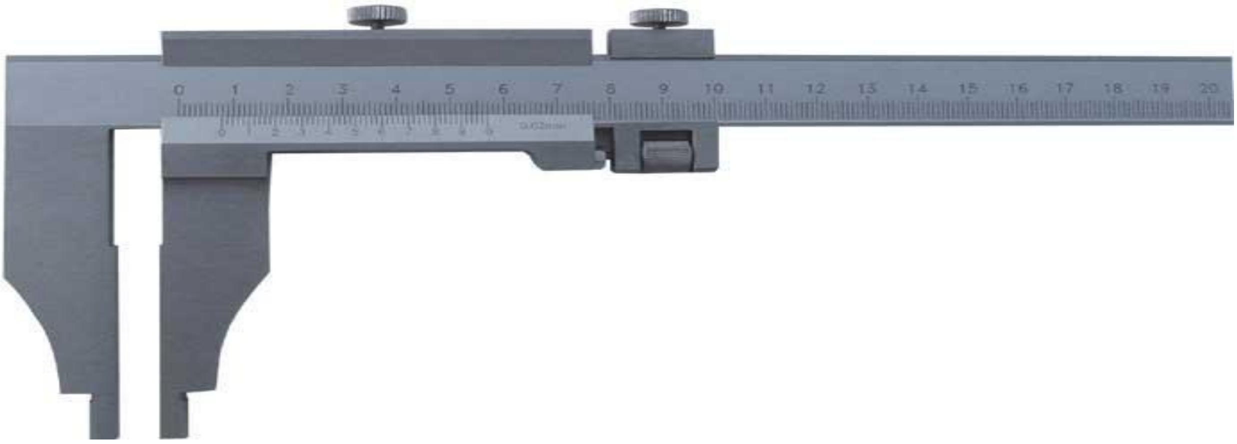

Fig – 11 Type B Vernier Caliper

VERNIER CALIPER

- Vernier calipers are available in size of 150 mm, 225 mm, 900 mm and 1200 mm.
- The selection of the size depends on the measurements to be taken.
- Vernier calipers are precision instruments, and extreme care should be taken while handing them.

Vernier Depth Gauge

A vernier depth is very commonly used precision instrument for measuring depth of holes recesses, slot and step.

Its construction and method of reading are similar to those of a vernier caliper.

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VERNIER HEIGHT GAUGE

The main parts of a vernier height gauge and their function are given.

1.base

2.beam

3.vernier slide

4. fine setting device

5. vernier plate

6. locking screws

7. scriber

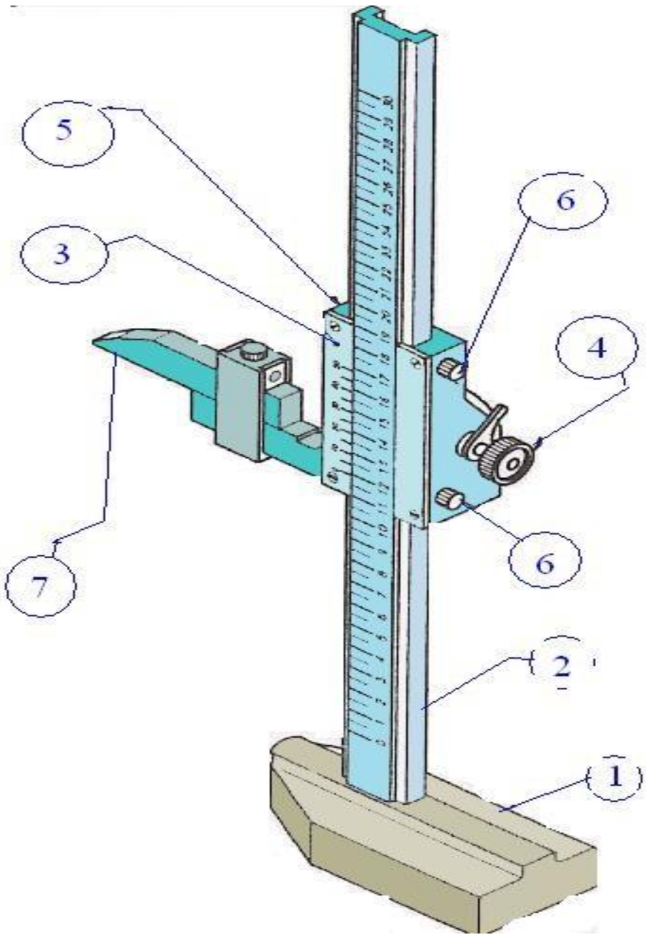

fig 12- Vernier height Gauge

MICRO METER

A micro meter is a precision instrument used to measure a job, generally within an accuracy of 0. 01mm.Micrometer used to take the outside measurements are known as outside micrometer.

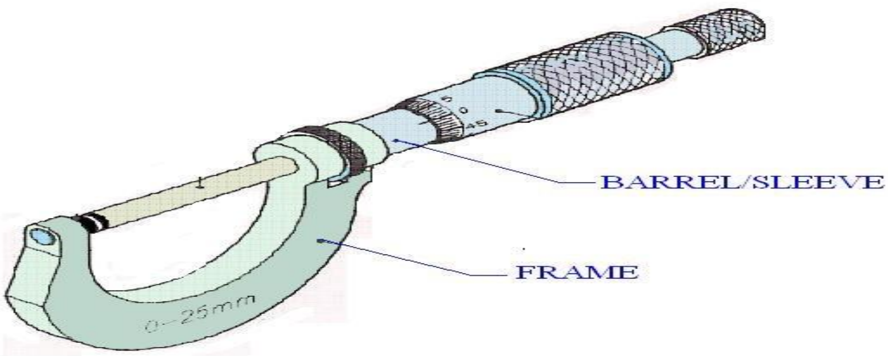

Fig 13- Micrometer

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Lathe

Automation is incorporated in a machine tool or machining system as a whole for higher productivity with consistent quality aiming meeting the large requirements and overall economy. Such automation enables quick and accurate auxiliary motions, i.e., handling operations like a tool – work mounting, bar feeding, tool indexing etc. repeatable with minimum human intervention but with the help of special or additional mechanism and control systems. These systems may be of the mechanical, electro-mechanical, hydraulic or electronic type or their combination.
It is already mentioned that according to the degree of automation machine tools are classified as,

- Non-automatic where most of the handling operations irrespective of processing operations, are done manually, like centre lathes etc.
- Semiautomatic
- Automatic where all the handling or auxiliary operations, as well as the processing operations, are carried out automatically.

General-purpose machine tools may have both fixed automation and flexible automation where the latter one is characterized by Computer Numerical Control (CNC).

Amongst the machine tools, lathes are the most versatile and widely used. Here automation of lathes only has been discussed.

The conventional general-purpose automated lathes can be classified as,

(a) Semiautomatic:
- capstan lathe (ram type turret lathe)
- turret lathe
- multiple spindle turret lathe
- copying (hydraulic) lathe

(b) Automatic:
- Automatic cutting off the lathe
- Single spindle automatic lathe
- Swiss-type automatic lathe
- multiple spindle automatic lathes

The other categories of semiautomatic and automatic lathes are:

- Vertical turret lathe
- Special purpose lathes
- Non-conventional type, i.e., flexibly automatic CNC lathes, turning centre etc.

(a) Semiautomatic lathes

The characteristic features of such lathes are ;

- some major auxiliary motions and handling operations like bar feeding, speed change, tool change etc. are done quickly and consistently with lesser human involvement
- the operators need lesser skill and putting lesser effort and attention
- suitable for batch or small lot production
- costlier than centre lathes of the same capacity.

Capstan and Turret lathes

The semiautomatic lathes, capstan lathe and turret lathe are very similar in construction, operation and application. Fig. schematically shows the basic configuration of capstan lathe and Fig. shows that of turret lathe.

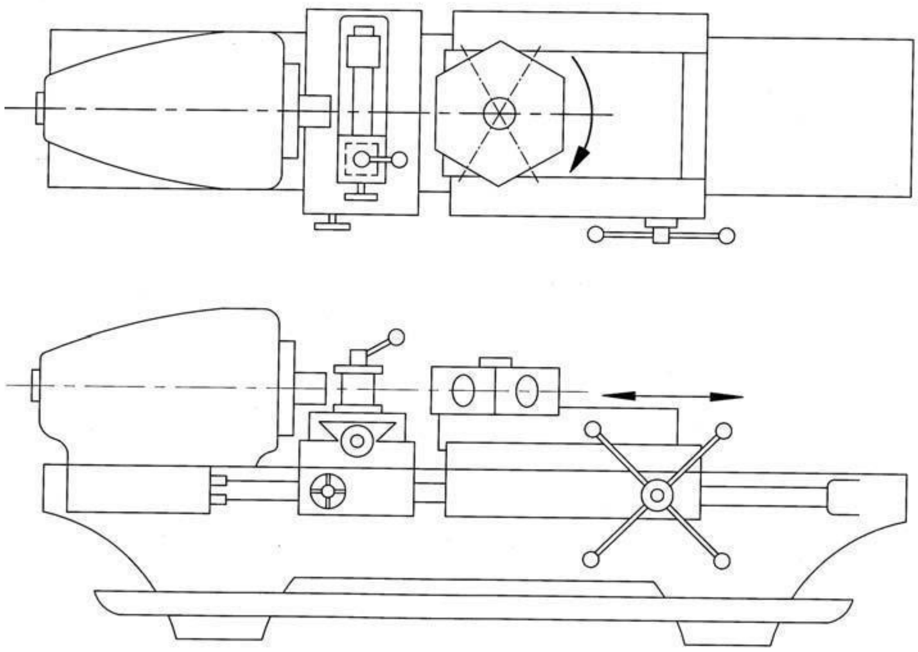

Fig 1 Schematic configuration of capstan lathe.

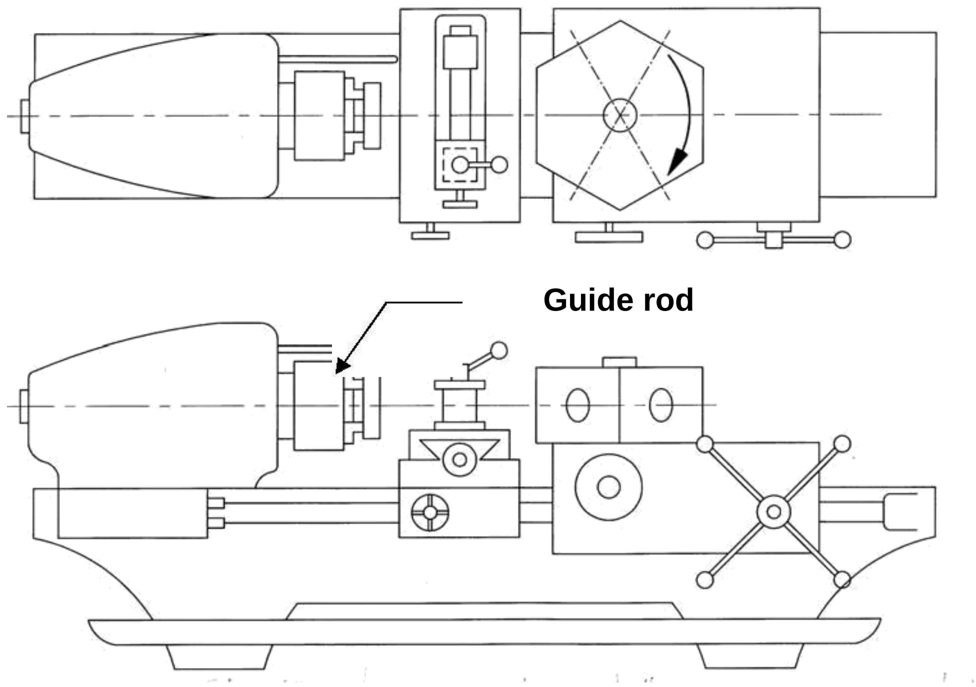

Fig 2 Schematic configuration of a turret lathe.

In contrast to centre lathes, capstan and turret lathes are semiautomatic

- possess an axially movable indexable turret (mostly hexagonal) in place of tailstock
- holds a large number of cutting tools; up to four in indexable tool post on the front slide, one in the rear slide and up to six in the turret (if hexagonal) as indicated in the schematic diagrams.
- are more productive for quick engagement and overlapped functioning of the tools in addition to faster mounting and feeding of the job and rapid speed change.
- enable repetitive production of same job requiring less involvement, effort and attention of the operator for pre-setting of work–speed and feed rate and length of travel of the cutting tools are relatively costlier
- are suitable and economically viable for batch production or small lot production.

There are some differences in between capstan and turret lathes such as,

- Turret lathes are relatively more robust and heavy-duty machines
- Capstan lathes generally deal with short or long rod type blanks held in a

collet, whereas turret lathes mostly work on chucking type jobs held in the quick-acting chucks

- In capstan lathe, the turret travels with limited stroke length within a saddle-type guide block, called auxiliary bed, which is clamped on the main bed as indicated in Fig, whereas in turret lathe, the

heavy turret is mounted on the saddle which directly slides with larger stroke length on the main bed as indicated in Fig

- One additional guide rod or pilot bar is provided on the headstock of the turret lathes as shown in Fig., to ensure rigid axial travel of the turret head
- External screw threads are cut in capstan lathe, if required, using a self-opening die being mounted in one face of the turret, whereas in turret lathes external threads are generally cut, if required, by a single point or multipoint chasing tool being mounted on the front slide and moved by a short leadscrew and a swing type half nut.

Fig. are showing the pictorial views of a typical capstan lathe and a horizontal turret lathe respectively.

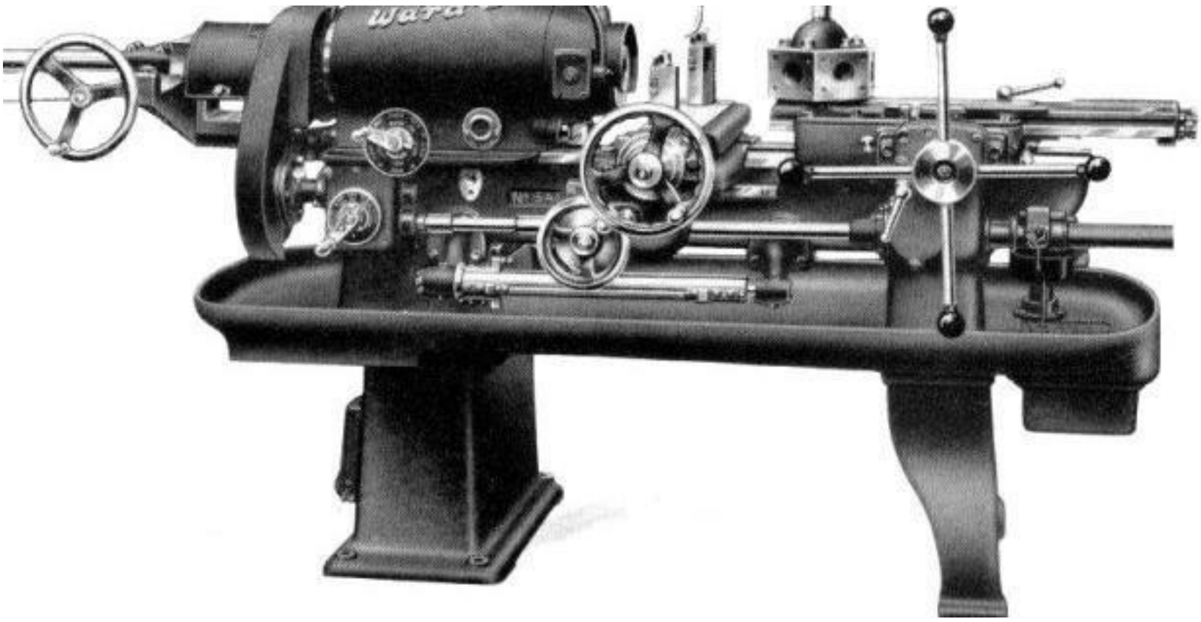

Fig 3 Pictorial view of a capstan lathe

Ram type turret lathes, i.e., capstan lathes are usually single spindle and horizontal axis type. Turret lathes are also mostly single spindle and horizontal type but it may be also

- Vertical type and
- Multi spindle type

Some more productive turret lathes are provided with the preoperative drive which enables on-line pre-setting and engaging the next work-speed and thus helps in reducing the cycle time.

Fig 4 Pictorial view of a turret lathe.

Multiple spindle Vertical Turret lathe

Turret lathes are mostly horizontal axis single spindle type. The multiple spindle vertical turret lathes are characterised by :

- Suitably used for a large lot or mass production of jobs of generally ;

chucking type
relatively large size
requiring a limited number of machining operations

- Machine axis – vertical for
  - lesser floor space occupied
  - easy loading and unloading of blanks and finished jobs
  - relieving the spindles of bending loads due to job – weight.
- Several spindles – four to eight.

Fig. visualise the basic configuration of multiple spindle vertical turret lathes which are comprised mainly of a large disc-type spindle carrier and a tool holding vertical ram as shown.

Parallel processing type :

The spindle carrier remains stationary. Only the tool slides move with cutting tools radially and axially. Identical jobs (say six) are simultaneously mounted and machined in the chucks parallel at all stations each one having the same set of axially and / or radially moving cutting tools.

Progressively processing type :

The spindle carrier with the blanks fitted in the chucks on the rotating spindle is indexed at regular interval by a Geneva mechanism. At each station, the job undergoes a few preset machining works by the axially and / or radially fed cutting tools. The blank getting all the different machining operations progressively at the different work stations is unloaded at a particular station where the finished job is replaced by another fresh blank. This type of lathes is suitable for jobs requiring a large number of operations.

Continuously working type :

Like in parallel processing type, here also each job is finished in the respective station where it was loaded. The set of cutting tools mostly fed only axially along a face of the ram continuously work on the same blank throughout its one cycle of rotation along with the spindle carrier. The tool ram having same toolsets on its faces also rotate simultaneously along with the spindle carrier which after each rotation halts for a while for unloading the finished job and loading a fresh blank at a particular location. Such a system is also suitable for jobs requiring very few and simple machining operations.

- **Hydraulic copying (tracer controlled) lathes**

Jobs having steps, tapers and / or curved profiles, as typically shown in Fig., are conveniently and economically produced in batch or lot in semiautomatically operated tracer controlled hydraulic copying lathe. The movement of the stylus along the template provided with the same desired job-profile) is hydraulically transmitted to the cutting tool tip which replicates the template profile.

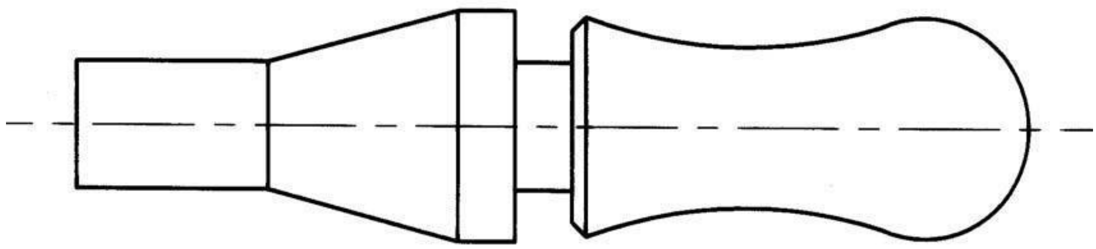

Fig 5 A typical job is suitable for copy turning.

(b) General Purpose Automatic lathes

Automatic lathes are essentially used for a large lot or mass production of small rod type of jobs. Automatic lathes are also classified into some distinguished categories based on constructional features, operational characteristics, number of spindles and applications as follows

- Single spindle
  - Automatic cutting off lathes
  - Automatic (screw cutting) lathe
  - Swiss-type automatic lathe
- Multispindle automatic lathe

Automatic cutting off the lathe

These simple but automatic lathes are used for producing short workpieces of simple form by using few cross-feeding tools. In addition to parting some simple operations like short turning, facing, chamfering etc. are also done.

Single spindle automatic lathe

The general purpose single spindle automatic lathes are widely used for quantity or mass production (by machining) of high-quality fasteners; bolts, screws, studs etc., bushings, pins, shafts, rollers, handles and similar small metallic parts from long bars or tubes of regular section and also often from separate small blanks.

Fig. shows a typical single spindle automatic lathe. Unlike the semiautomatic lathes, single spindle automats are :

- preferably and essentially used for a larger volume of production i.e., large lot production and mass production
- used always for producing jobs of rod, tubular or ring type and of relatively smaller size.
- run fully automatically, including bar feeding and tool indexing, and continuously over a long duration repeating the same machining cycle for each product
- provided with upto five radial tool slides which are moved by cams mounted on a cam shaft
- of relatively smaller size and power but have higher spindle speeds

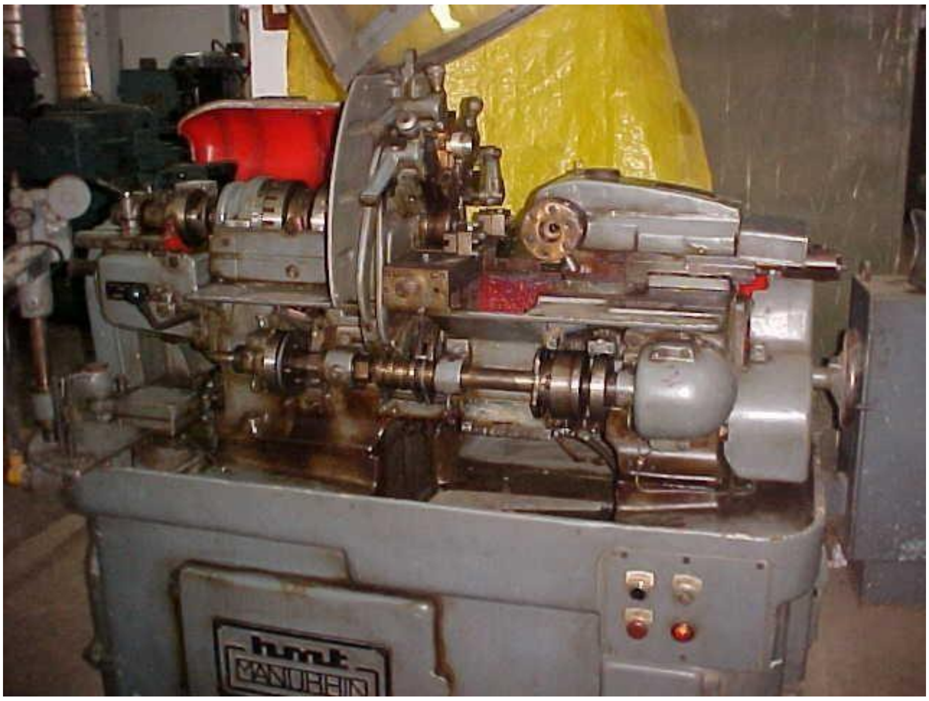

Fig 6 A typical single spindle automatic lathe.

Swiss type automatic lathe

The characteristics and applications of these single spindle automatic lathes are :

- In respect of application :
  Used for lot or mass production of thin slender rod or tubular jobs, like components of small clocks and wrist watches, by precision machining;
  - o Job size (approximately) Diameter range – 2 to 12 mm Length range – 3 to 30 mm

  Dimensional accuracy and surface finish – almost as good as provided by grinding

- In respect of configuration and operation
  - o The headstock travels enabling axial feed of the bar stock against the cutting tools as indicated in Fig.
  - o There is no tailstock or turret
  - o High spindle speed (2000 – 10,000 rpm) for small job diameter

- The cutting tools (upto five in number including two on the rocker arm) are fed radially
- Drilling and threading tools, if required, are moved axially using swivelling device(s)
- The cylindrical blanks are prefinished by grinding and are moved through a carbide guide bush as shown.

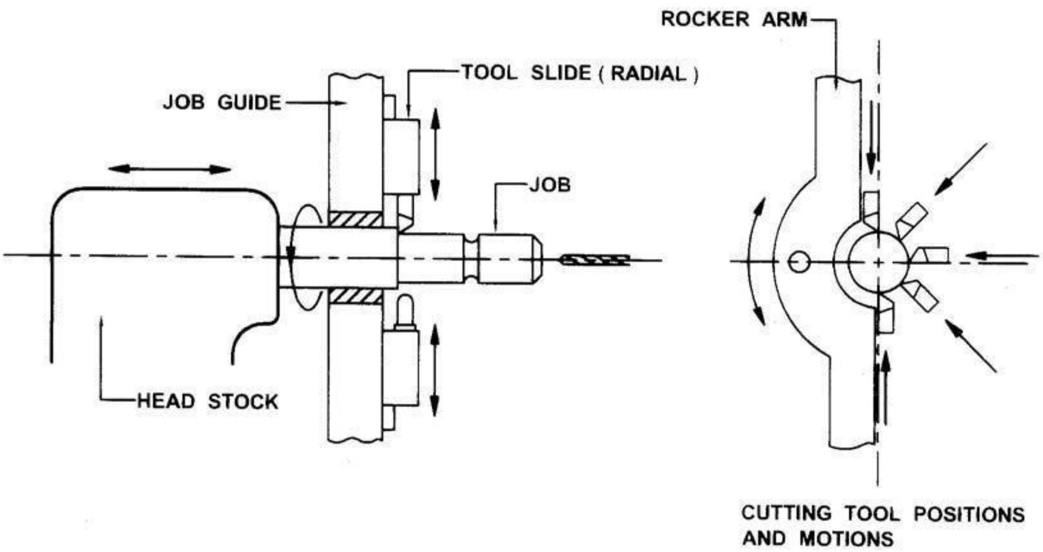

Fig 7 Basic principle of Swiss type automatic lathe.

Multispindle automatic lathes

For further increase in rate of production of jobs usually of smaller size and simpler geometry. Multispindle automatic lathes having four to eight parallel spindles are preferably used. Unlike multispindle turret lathes, multispindle automatic lathes ;

- are horizontal (for working on long bar stocks)
- work mostly on long bar type or tubular blanks

Multiple spindle automats also may be parallel action or progressively working

type. Machining of the inner and outer races in mass production of ball bearings are, for instance, machined in multispindle automatic lathes.

(ii) Kinematic Systems and Working Principles of Semi Automatic And Automatic Lathes

The kinematic systems and basic principles of working of the following general purpose semi-automatic and automatic lathes of common use have been visualised and briefly discussed here :

(a) Semi-automatic lathes :
- Capstan and single spindle turret lathe
- Hydraulic copying lathe

(b) Automatic lathes
- Single spindle automatic (screw cutting) lathe
- Swiss type automatic lathe

Kinematic system and working principle of capstan lathe

Like general configurations and applications, the basic kinematic systems are also very similar in capstan lathes and turret lathes (particularly single spindle bar and horizontal types) in respect of their major functions, i.e.,

- bar feeding mechanism
- turret moving and indexing
- speed and feed drives

Bar feeding mechanism of capstan lathe

Fig. typically shows the kinematic arrangement of feeding and clamping of bar stock in capstan lathes. The bar stock is held and tightly clamped in the push type spring collet which is pushed by a push tube with the help of a pair of bell-crank levers actuated by a taper ring as shown in Fig. Bar feeding is accomplished by four elementary operations;

- unclamping of the job – by opening the collet
- bar feed by pushing it forward
- clamping of the bar by closing the collet
- free return of the bar-pushing element

After a job is complete and part off, the collet is opened by moving the lever manually rightward to withdraw the push force on the collet. Further moving of the lever in the same direction causes forward push of the bar with the help of the ratchet – paul system shown. After the projection of the bar from the collet face to the desired length controlled by a pre-set stop – stock generally held in one face of the turret or in a separate swing stop, the lever is moved leftward resulting closing of the collet by clamping of the barstock. Just before clamping of the collet, the leftward movement of the lever pushes the bar feeder (ratchet) back freely against the paul.

Turret indexing mechanism in capstan and turret lathes

Turret indexing mechanism of capstan and single spindle turret lathe is typically shown schematically in Fig.

- The turret (generally hexagonal) holding the axially moving cutting tools have the following motions to be controlled mechanically and manually ;
- forward axial traverse comprising;
- quick approach – manually done by rotating the pinion as shown
- slow working feed – automatically by engaging the clutch stop at preset position depending upon the desired length of travel of the individual tools
- quick return – manually done by disengaging the clutch and moving the turret back
- indexing of the turret by 60^{o} (or multiple of it) – done manually by further moving the turret slide back.

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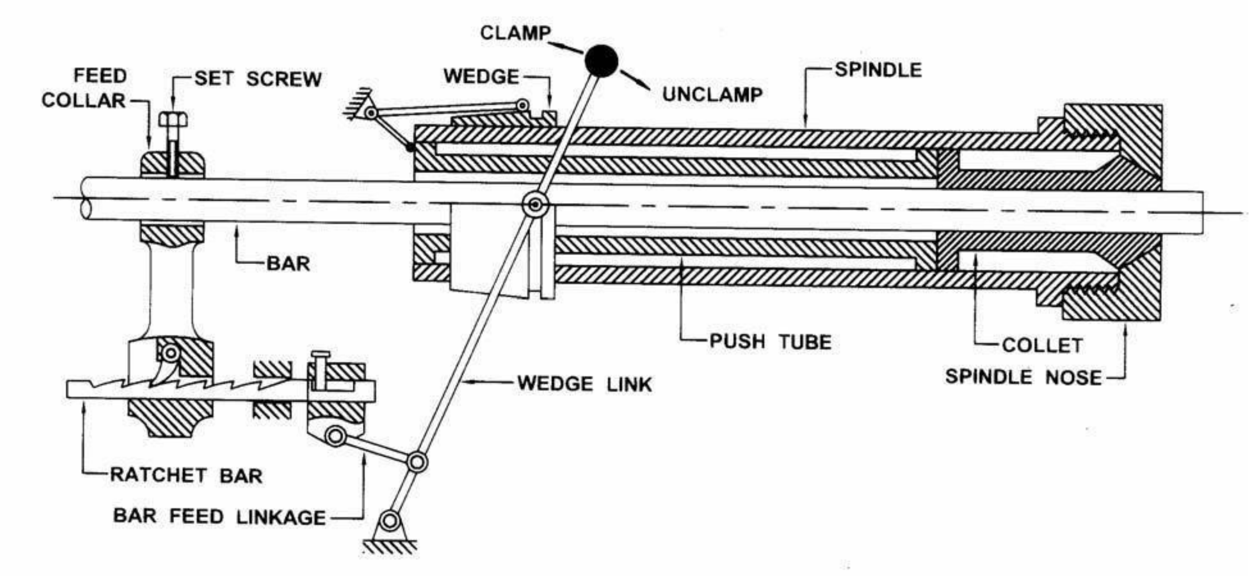

Fig.8 *Typical bar feeding mechanism in capstan lathe.*

Just before indexing at the end of the return stroke, the locking pin is withdrawn by the lever which is lifted at its other end by gradually riding against the hinged wedge as indicated in Fig. Further backward travel of the turret slide causes rotation of the free head by the indexing pin and lever as indicated in Fig. Rotation of the turret head by exact angle is accomplished by insertion of the locking pin in the next hole of the six equispaced holes. After indexing and locking, the turret head is moved forward with the next cutting tool at its front face when the roller of the lever returns through the wider slot of the wedge without disturbing the locking pin as indicated in the figure. The forward motion of the turret head is automatically stopped when the set-screw corresponding to the working tool is arrested by the mechanical stop. The end position and hence length of travel of the tool is governed by presetting the screw. There are six such screws, each one corresponds with particular face or tool of the turret. The drum holding those equispaced six screw with different projection length is rotated along with the indexing (rotation) of the turret head by a pair of bevel gears (1:1) as indicated in Fig. The bottom most screw, which corresponds with the tool on the front face of the turret, when hits or touches the stop, the turret movement is stopped either manually by feeling or automatically by disengaging the clutch between the feed rod and the turret slide. (b) top (inner) view

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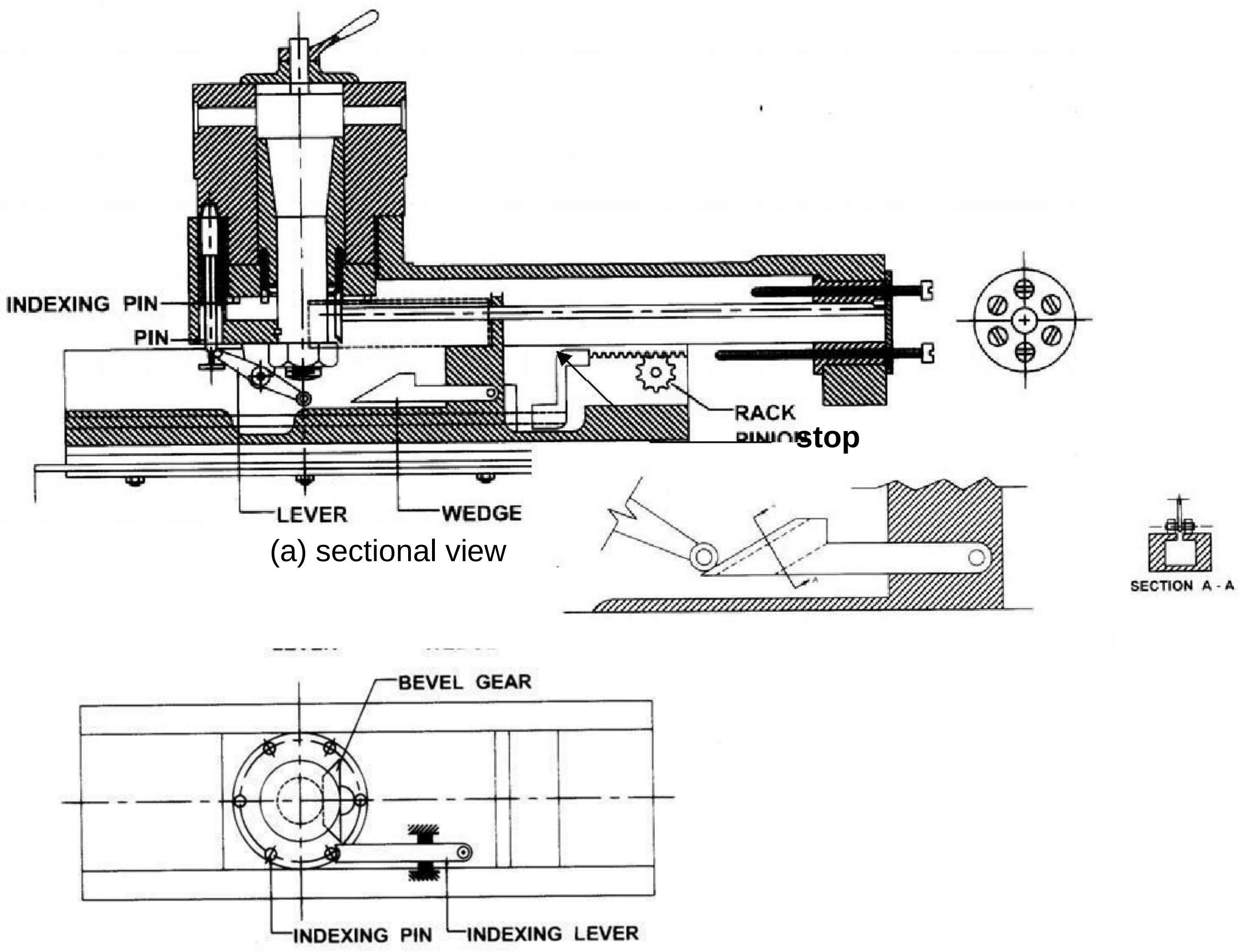

Fig.9*Turret indexing in capstan and turret lathe.*

Kinematics and working principle of hydraulic copying lathe

Hydraulic drive is often preferably used in some machine tools for smooth motions without jerk and noise, self-lubrication, flexible transmission system and stepless variation in speed and feed despite the limitations like larger space requirement, oil leakage, difficult maintenance etc. Fig. typically shows the circuitry of a hydraulically driven (tool travel) drilling machine. The direction and length of travel of the drilling head fitted on the moving piston are controlled by movement of the spool of the direction control valve which is actuated by the pilot valve and governed by the electromechanical stop as indicated in the figure. The rate of travel of the drill head i.e., the feed rate is governed by the throttle or meter controlling valve which is again controlled by a template like cam and a follower coupled with the spool of the throttle valve as shown in Fig. To keep feed rate constant irrespective of the working force on the piston, a pressure reducing valve is provided prior to the throttle valve. The pressure reducing valve helps keep its exit pressure i.e., input pressure of the throttle valve fixed to a preset value irrespective of the input pressure of the pressure reducing valve which varies with the working load on the drill piston. Constant pressure difference keeps constant fluid flow rate through the throttle valve resulting constant feed rate irrespective of the cutting force.

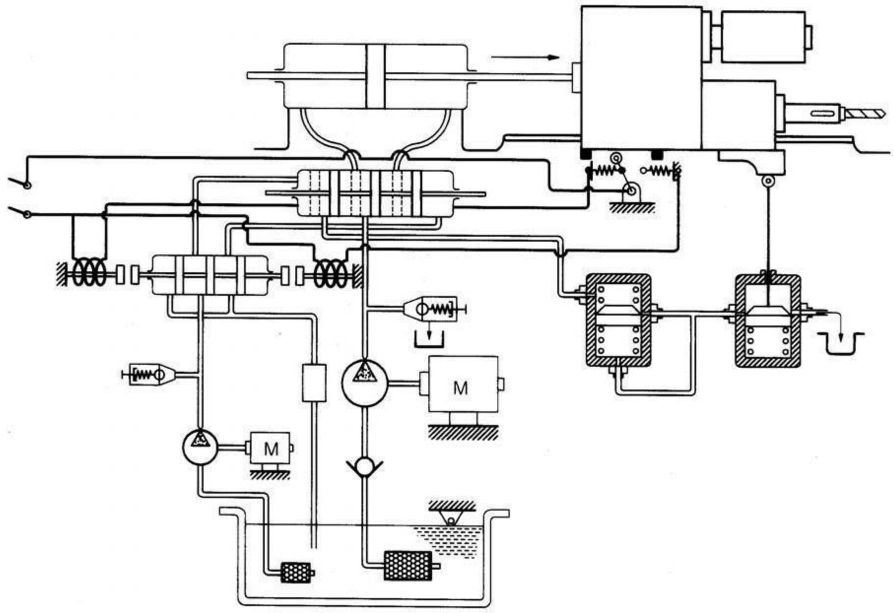

Fig.10 *Circuitry and kinematic system of hydraulically driven machine tool*

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Turning operation is a machining process and is used to produce round parts in shape by a single point cutting tool. Materials are removed by traversing in a direction parallel to the axis of rotation of axis or along a specified path to form a complex rotational shape. The tool is fed either linearly in a direction parallel or perpendicular to the axis of rotation

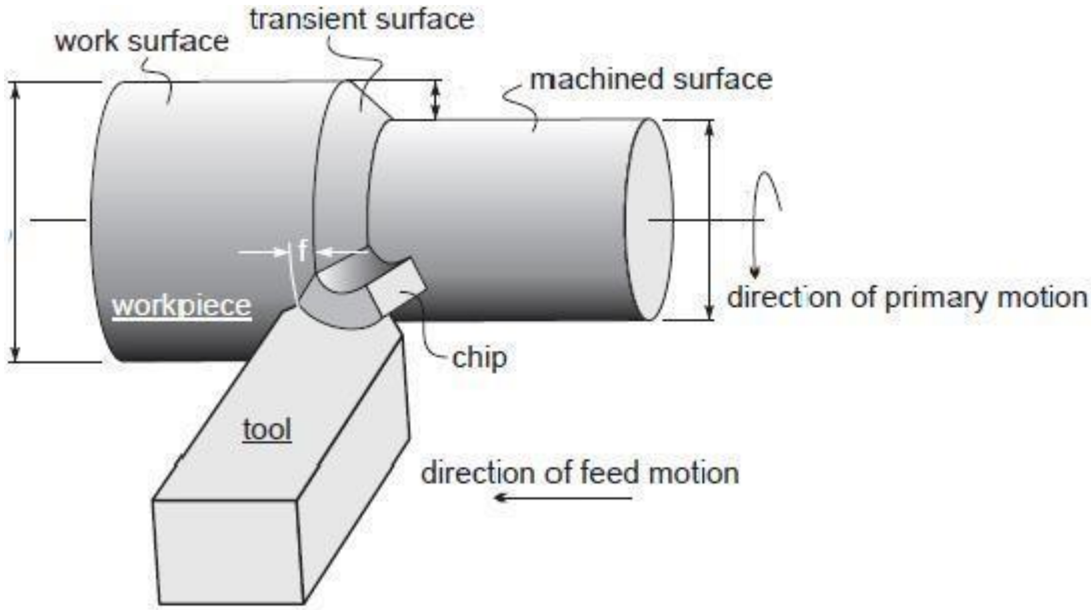


Fig. 1. Turning operation on a round work piece

Drilling

Drilling is a hole making process for which drill is used as a cutting tool for producing round holes of different sizes and depths. **Drilling machines** are subjected for drilling holes, tapping, counter boring, reaming, and general boring operations. Drills may be classified into a large variety of types. **Twist drills** are the most common tools used in drilling and are made in many sizes and lengths. Lengths range **Straight-shank twist drills** from 1/60 in diameter to 11/4 in by1/64; 2in by 1/16 in increment. **Taper-shank drills** range from 1/8 in diam to 13/4 in by 1/64 increments. The cutting tool used for making holes is called as twist drill. Drill consists two parts. The body consists of cutting edge and the shank used for holding. Two cutting edge and two opposite spiral are cut into its surface The flute provides clearance to the chips produced at the cutting edge. The surface on the drill that extends behind the cutting tip to the following flute is termed as flank. The face is the portion of the flute surface adjacent to the cutting tip on which the chip moves. The land or the margin is the cylindrically ground body surface on the leading edge or flank face. The axial rake angle is the angle between face and the line parallel to the drill axis. Tolerances have been set on the various features of all drills so that the products of different manufacturers will be interchangeable in the user's plants. Twist drills are decreased in diameter from point to shank (back taper) to prevent binding. If the web is increased gradually in thickness from point to shank to increase the strength, it is customary to reduce the helix angle as it approaches the shank. The shape of the groove is important, the one that gives a straight cutting edge and allows a full curl to the chip being the best. The helix angles of the flutes vary from $10^0$to 45^0. The standard point angle is 118^0. There are a number of drill grinders on the market designed to give the proper angles. The point may be ground either in the standard or the crankshaft geometry.

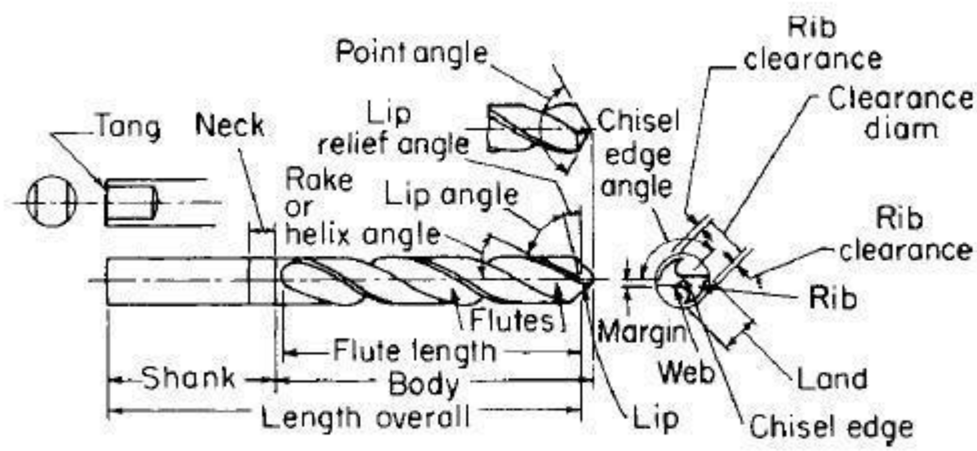


Fig. 2. Straight shank twist drill

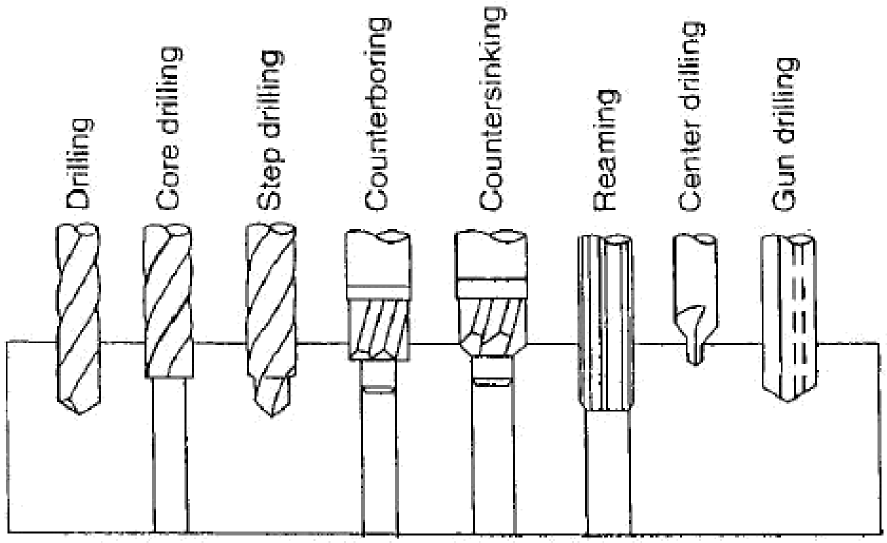


Fig.3. Various types of drills and drilling and reaming operations

Milling

Through milling process flat and complex shapes are formed by using multipoint cutting tool. The axis of rotation of cutting tool is perpendicular to the direction of feed. During each revolution of cutting operation the teeth of milling cutter enter and exit the work piece. Therefore on every rotation the teeth are subjected to impact force and thermal shock.The tool material and geometry must be designed to resist the conditions.

TYPES OF MILLING MACHINE

To satisfy the variety of requirement, milling machine comes in a number of ways, sizes and varieties.

- Knee and column type
- Horizontal
- Vertical
- Universal
- Turret type

These are the general purpose milling machine, which have a high degree of flexibility and employed for all types of works, including batch manufacturing.

- Production (bed) type
- Simplex
- Duplex

Triplex these machines are generally meant for regular production involving large batch sizes. The flexibility is relatively less in these machines than suitable for productivity enhancement.

- Plano millers- these machines are used only for very large work-piece involving table travels in metres.

- Special

type Rotary

table
- Drum type
- Copy milling (die sinking machine)
- Keyway milling machines
- Spline milling machine

These machines are of a special facilities to suit specific applications that catered by the other classes of milling machines.

KNEE AND COLUMN MILLING MACHINE

The knee and column type milling machine is the most commonly used machine in view of its flexibility and easier setup. The knee houses the feed mechanism and mounts the saddle and table. The table basically has the t-slots running along the x-axis for the purpose of work holding. The table moves along the x-axis on the saddle while the saddle moves along the y-axis on the guideways provided on the knee. The feed is provided either manually by hand wheel or connected for automatic by the lead screw, which in turn is coupled to the main spindle drive. The knee can move up and down in a dovetail provided on the column.

Milling machines are generally specified based on the following features.

- Size of the table, which specifies the actual working area on the table and relates to the maximum size of the work-piece that can be accommodated.

- Amount of table travel which gives the maximum axis movement that is possible.
- Horse power of the spindle, which actually specifies the power of the spindle motor used. Smaller machines may come with 1 to 3 hp while the production machines may go from 10 to 50 hp.

Another type of knee and column milling machine possible is the vertical-axis type. Most of the construction is very is very similar to the horizontal-axis type except the spindle type and location. The spindle is located in the vertical direction and is suitable for using the shank-mounted milling cutter such as end mills. In view of the location of the tool, the setting up of the work-piece and observing the machining operation is more convenient.

The universal machine is suitable for milling spur and helical gears, as well as worm gears and cam as it can be swivelled in a horizontal plane about 45 degree to either left or right.

BED-TYPE MILLING MACHINE

These are made more rugged and consequently are capable of removing more material without any chatter. Here the table is directly mounted on the bed and is provided with only the longitudinal motion. The spindle will be moving along with the column to provide the cutting action.

Simplex machines are the ones with only one spindle head while duplex machines have two

spindles. Milling operations are of two types

- Down milling

Here the cutter direction is same direction as the motion of the work piece being fed.

- Up milling

Here work piece is moving towards the cutter, opposing the cutter direction of rotation.Surface finish is better in case of down milling,but the stress load on the teeth is abrupt that may damage the cutter.

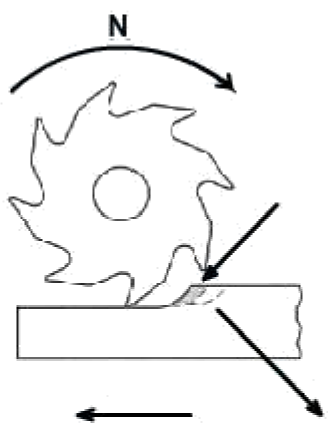


Fig.4. Schematic depiction of down milling (a) and up milling (b) operations

Advantages

1. Suited to machine-thin and hard to hold parts
2. Work need not be clamped tightly
3. Consistent parallelism and size may be maintained particularly on the thin parts
4. Used where break out of the edge of the work piece could not be tolerated.
5. Requires up to 20% less power to cut.
6. Used when cutting off stock or when milling deep, thin slots.

Disadvantages

1. Cannot be used unless the machine has a backlash eliminator and the table jibs have been tightened
2. Cannot be used for machining castings or hot rolled steel, since hard outer scale will damage the cutter.

Grinding

Grinding is the most common form of abrasive machining. It is a material cutting process that engages an abrasive tool whose cutting elements are grains of abrasive material known as grit. These grits are characterized by sharp cutting points, high hot hardness, chemical stability and wear resistance. The grits are held together by a suitable bonding material to give shape of an abrasive tool. Grinding machine is employed to obtain high accuracy along with very high class of surface finish on the work piece. However, advent of new generation of grinding wheels and grinding machines, characterized by their rigidity, power and speed enables one to go for high efficiency deep grinding (often called as abrasive milling) of not only hardened material but also ductile materials.

Grain size

Compared to the normal cutting tool, the abrasive used in grinding wheels are relatively small. The size of an abrasive grain or more generally called grit is identified by a number which is based on the sieve size used. This would vary from a very coarse size of 6 to 8 to a super fine size of 500 or 600. Sieve number is specified in terms of the number of opening per square inch. The surface finish generated would depend upon grain size used. The fine grain will take a very small depth of cut and hence a better surface finish is produced. Fine grains generate less heat are good for faster material removal. Fine grains are used for making the form grinding wheels. Coarse grains are good for higher material removal rates. These have better friability and as a result are not good for intermittent where they are likely to chip easily.

Bonded Abrasives

• A composite of the abrasive powder and a matrix
• Bonding material can be glass, resin, rubber.
• Can be solid discs (grinding wheel) or bonded to paper/cloth which is then stuck to a backing disc. The most commonly used bond materials are

- Vitrified
- Silicate
- Synthetic resin
- Rubber
- Shellac
- Metal

CENTRE-LESS GRINDING

It is used to grind cylindrical work-piece without actually fixing the work-piece using centres or a chuck, due to which the work rotation is not provided separately.

Its process consists of wheel, one large grinding wheel and another smaller regulating wheel. The work- piece is supported by the rest blade and held against the regulating wheel by the grinding force which is mounted at an angle to the plane of grinding wheel. The regulating wheel is generally a rubber or resinoid bonded wheel with wide face. The axial feed of the work-piece is controlled by the angle of tilt of the regulating wheel. Typical work speeds are about 10 to 50 m/mm.

There are three types of centre-less grinding operations possible. They are:

- Through feed centre-less grinding.
- In feed centre-less, the grinding is done by plunge feeding so that any form surface can be produced. This is useful if the work-piece has an obstruction which will not allow it to be traversed past the grinding wheel. The obstruction could be a shoulder, head, round form, etc.

c) End feed centre-less grinding, where tapered work-piece can be machined.

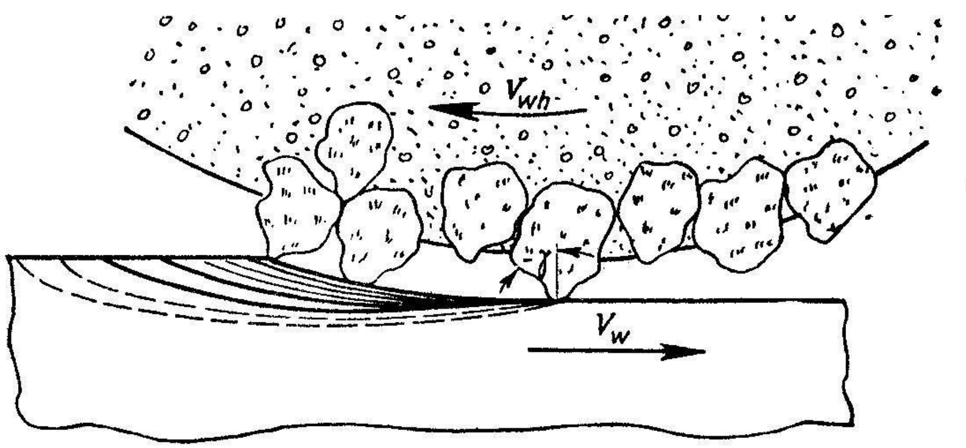


Fig.5. Cutting action of abrasive

grain Conventional grinding machines can be broadly classified

as:

- Surface grinding machine
- Cylindrical grinding machine

- Internal grinding machine
- Tool and cutter grinding machine

Advantages

A grinding wheel requires two types of specification

- dimensional accuracy
- good surface finish
- good form and locational accuracy
- applicable to both hardened and unhardened material

Applications

* surface finishing
* slitting and parting
* descaling, deburring
* stock removal (abrasive milling) finishing of flat as well as cylindrical surface
- grinding of tools and cutters and re sharpening of the same.

Conventionally grinding is characterized as low material removal process capable of providing both high accuracy and high finish. However, advent of advanced grinding machines and grinding wheels has elevated the status of grinding to abrasive machining where high accuracy and surface finishas well as high material removal rate can be achieved even on an unhardened material

Broaching

Broaching is a machining process for removal of a layer of material of desired width and depth usually in one stroke by a slender rod or bar type cutter having a series of cutting edges with gradually increased protrusion as indicated in Figure. The difference in broaching and shaping, is that broaching enables remove the whole material in one stroke only by the gradually rising teeth of the cutter called broach where as shaping requires a number of strokes to remove the material in thin layers step by step by gradually infeeding the single point tool. Machining by broaching is preferably used for making straight through holes of various forms and sizes of section, internal and external through straight or helical slots or grooves, external surfaces of different shapes, teeth of external and internal splines and small spur gears etc.

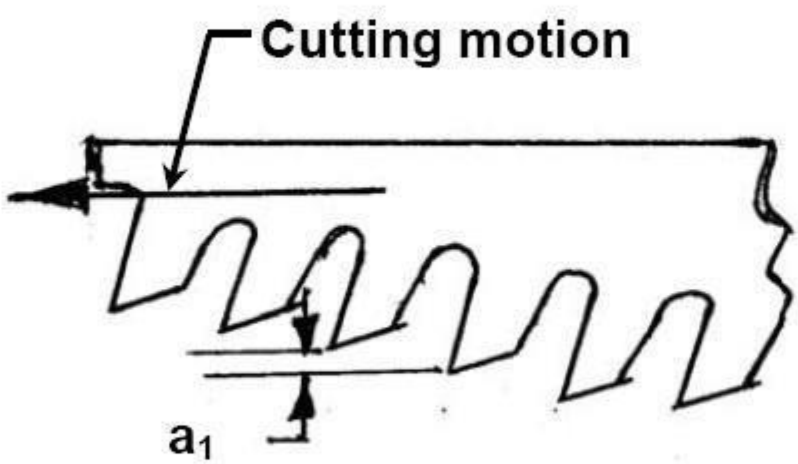
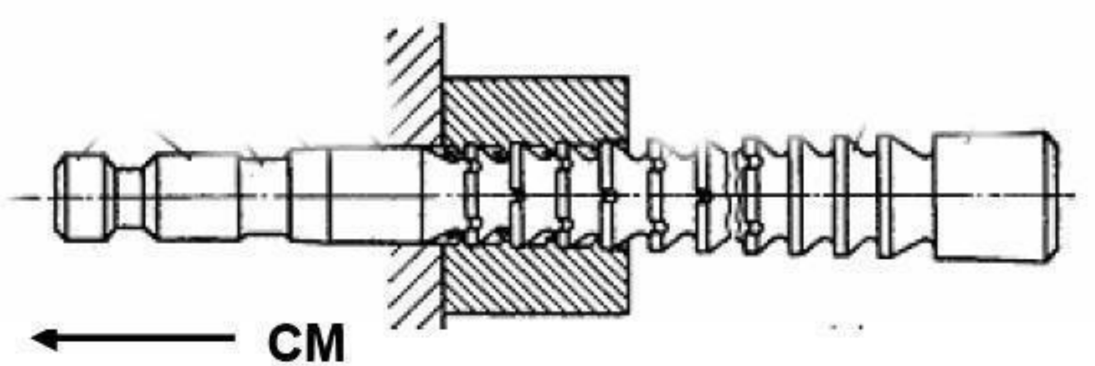


Fig.6. Principle of Broaching

Figure shows how a through hole is enlarged and finished by

broaching.

Fig7. Horizontal pull type Finishing hole by broaching



Construction of broaching tools

Construction of any cutting tool is characterized mainly by

* Configuration
* Material
* Cutting edge geometry

Both pull and push type broaches are made in the form of slender rods or bars of varying section having along its length one or more rows of cutting teeth with increasing height (and width occasionally). Push type broaches are subjected to compressive load and hence are made shorter in length to avoid buckling.

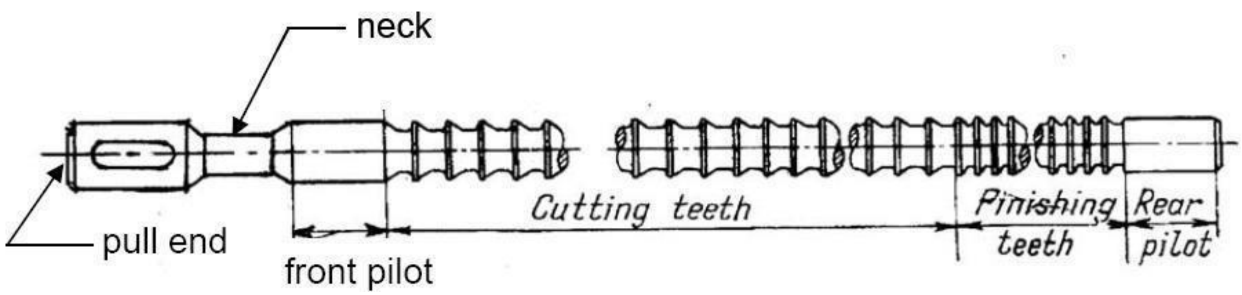


Fig. 9. Pull type

broach tool The essential elements of the broach are :

* Pull end for engaging the broach in the machine
* Neck of shorter diameter and length, where the broach is allowed to fail, if at all, under overloading
* Front pilot for initial locating the broach in the hole
* Roughing and finishing teeth for metal removal
* Finishing and burnishing teeth
* Rear pilot and follower rest or retriever

Advantages of broaching:

- It is the fastest way of finishing an operation with a single stroke.
- Very little skill is required from the operator.
- It is simple since only a single reciprocating motion is required for cutting.
- Final cost of the machining is one of the lowest for mass production.
- Any type of surface, internal or external can be generated with broaching.
- Good surface finish and fine dimensional tolerance can be achieved.

Limitations of broaching:

- Custom made broaches are very expensive and hence generally used for very large volume production.
- The lead time for manufacturing is more for custom designed broaches.
- A broach can be designed and used for a specific application.
- As it is a very heavy metal removal operation, it requires that work-piece is rigid and capable of withstanding the large forces.

It can only be carried out on the work-piece whose geometry is such that there is no inference for broach movement for the cutting

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Super finishing processes

The surface finish has an important role in influencing functional characteristics like wear resistance, fatigue strength, corrosion resistance and power loss due to frictional properties. As normal machining methods like turning, milling or even classical grinding cannot meet these requirements, therefore in order to improve the performance and increase the prolong service life of modern machinery, the components required to be manufactured with high dimensional accuracy and high surface finish. Lapping, honing, polishing, burnishing are some of the super finishing processes that are employed to achieve above properties.

Lapping

Lapping is the method of obtaining a fine finish. Lapping is basically an abrasive process in which loose abrasives function as cutting points finding momentary support from the laps. Following Figure represents the lapping process. Material removal in lapping usually ranges from .003 to .03 mm but many reaches 0.08 to 0.1mm in certain cases.

Characteristics of lapping process:

- Use of loose abrasive between lap and the work piece.
- Usually lap and work piece are not positively driven but are guided in contact with each other.
- In order to avoid the repetitive path of the abrasive grains of the lap on the work piece, relative motion between the lap and the work should change continuously

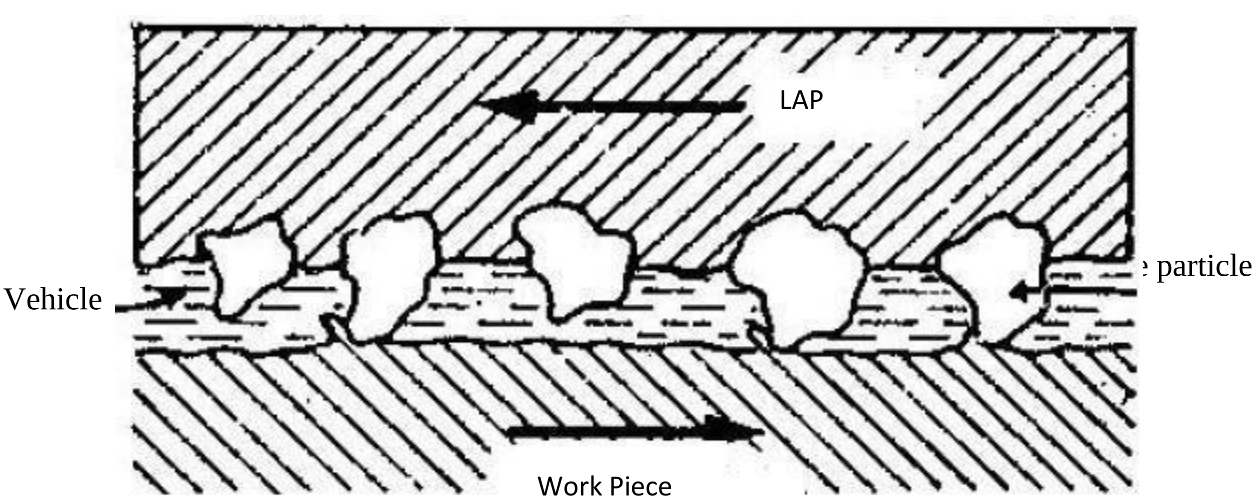

Fig.10. Lapping process

Cast iron is the mostly used lap material. However, soft steel, copper, brass, hardwood as well as hardened steel and glass are also used.

Abrasives of lapping

- Al_2O_3 and SiC, grain size 5~100µm
- Cr_2O_3, grain size 1~2 µm
- B_4C_3, grain size 5-60 µm
- Diamond, grain size 0.5~5 V

Vehicle materials for lapping

- Machine oil
- Rape oil
- grease

Technical parameters affecting lapping processes

- unit pressure
- grain size of abrasive
- concentration of abrasive in the vehicle
- lapping speed

Honing

Honing is a finishing process, in which a tool called hone carries out a combined rotary and reciprocating motion while the work piece does not perform any working motion. The honing stones are held against the work piece with controlled light pressure. Honing is generally done on internal cylindrical surface, such as automobile cylindrical walls.

Following assumptions are considered during honing processes.

- Honing stones should not leave the work surface.
- Stroke length must cover the entire work length.

Burnishing

Burnishing process carries a pressing hardened steel rolls or balls into the surface of the work piece that imparting a feed motion to the work piece.

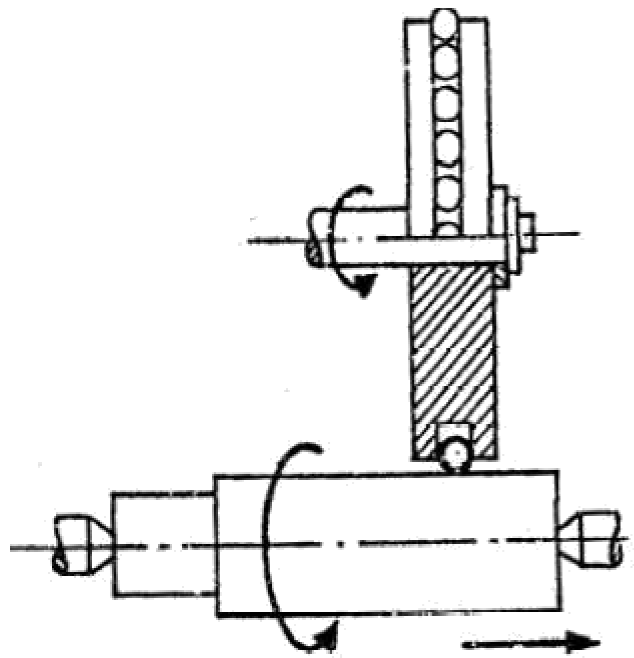

Fig.11. Ball burnishing

During the process, compressive stress is induced on the workpiece Electro polishing Electro polishing is the reverse of electroplating. In this process, the work piece acts as anode and the material is removed from the work piece by electrochemical dissolution. The process is particularly suitable for polishing irregular surface since there is no mechanical contact between work piece and polishing medium.. This process is also suitable for deburring operation.

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Casting is a manufacturing process by which a liquid material is usually poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mold to complete the process. Casting materials are usually metals or various cold setting materials that cure after mixing two or more components together; examples are epoxy, concrete, plaster and clay. Casting is most often used for making complex shapes that would be otherwise difficult or uneconomical to make by other methods.

Types

Metal casting is one of the most common casting processes. Casting involves pouring a liquid metal into a mold, which contains a hollow cavity of the desired shape, and then is allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mold to complete the process. Casting is most often used for making complex shapes that would be difficult or uneconomical to make by other methods.

The casting process is subdivided into two main categories: expendable and non-expendable casting. It is further broken down by the mold material, such as sand or metal, and pouring method, such as gravity, vacuum, or low pressure.

a) Permanent mold casting

b) Die casting

c) Semi-solid metal casting

d) Centrifugal casting

Fig 1 Casting Process

MOULDING PROCESS

This technique includes at least four different methods: permanent, die, centrifugal, and continuous casting.

Permanent mold casting

Permanent mold casting is metal casting process that employs reusable molds ("permanent molds"), usually made from metal. The most common process uses gravity to fill the mold, however gas pressure or a vacuum are also used. A variation on the typical gravity casting process, called slush casting, produces hollow castings. Common casting metals are aluminum, magnesium, and copper alloys. Other materials include tin, zinc, and lead alloys and iron and steel are also cast in graphite molds. Permanent molds, while lasting more than one casting still have a limited life before wearing out.

Die casting

The die casting process forces molten metal under high pressure into mold cavities (which are machined into dies). Most die castings are made from nonferrous metals, specifically zinc, copper, and aluminium based alloys, but ferrous metal die castings are possible. The die casting method is especially suited for applications where many small to medium sized parts are needed with good detail, a fine surface quality and dimensional consistency.

Semi-solid metal casting

Semi-solid metal (SSM) casting is a modified die casting process that reduces or eliminates the residual porosity present in most die castings. Rather than using liquid metal as the feed material, SSM casting uses a higher viscosity feed material that is partially solid and partially liquid. A modified die casting machine is used to inject the semi-solid slurry into re-usable hardened steel dies. The high viscosity of the semi-solid metal, along with the use of controlled die filling conditions, ensures that the semi-solid metal fills the die in a non-turbulent manner so that harmful porosity can be essentially eliminated.

Used commercially mainly for aluminium and magnesium alloys, SSM castings can be heat treated to the T4, T5 or T6 tempers. The combination of heat treatment, fast cooling rates (from using un-coated steel dies) and minimal porosity provides excellent combinations of strength and ductility. Other advantages of SSM casting include the ability to produce complex shaped parts net shape, pressure tightness, tight dimensional tolerances and the ability to cast thin walls.

Centrifugal casting

Centrifugal casting is both gravity- and pressure-independent since it creates its own force feed using a temporary sand mold held in a spinning chamber at up to 900 N. Lead time varies with the application. Semi- and true-centrifugal processing permit 30-50 pieces/hr-mold to be produced, with a practical limit for batch processing of approximately 9000 kg total mass with a typical per-item limit of 2.3-4.5 kg. Industrially, the centrifugal casting of railway wheels was an early application of the method developed by German industrial company Krupp and this capability enabled the rapid growth of the enterprise. Small art pieces such as jewelry are often cast by this method using the lost wax process, as the forces enable the rather viscous liquid metals to flow through very small passages and into fine details such as leaves and petals. This effect is similar to the benefits from vacuum casting, also applied to jewelry casting.

Continuous casting

Continuous casting is a refinement of the casting process for the continuous, high-volume production of metal sections with a constant cross-section. Molten metal is poured into an open-ended, water- cooled copper mold, which allows a 'skin' of solid metal to form over the still-liquid centre. The strand, as it is now called, is withdrawn from the mold and passed into a chamber of rollers and water sprays; the rollers support the thin skin of the strand while the sprays remove heat from the strand, gradually solidifying the strand from the outside in. After solidification, predetermined lengths of the strand are cut off by either mechanical shears or travelling oxyacetylene torches and transferred to further forming processes, or to a stockpile. Cast sizes can range from strip (a few millimetres thick by about five metres wide) to billets (90 to 160 mm square) to slabs (1.25 m wide by 230 mm thick). Sometimes, the strand may undergo an initial hot rolling process before being cut.

Continuous casting is used due to the lower costs associated with continuous production of a standard product, and also increases the quality of the final product. Metals such as steel, copper and aluminium are continuously cast, with steel being the metal with the greatest tonnages cast using this method.

Plaster, concrete, or plastic resin

Plaster itself may be cast, as can other chemical setting materials such as concrete or plastic resin - either using single-use waste molds as noted above or multiple-use 'piece' molds, or molds made of small ridged pieces or of flexible material such as latex rubber (which is in turn supported by an exterior mold). When casting plaster or concrete, the finished product is, unlike marble, unattractive, lacking in transparency, and so it is usually painted, often in ways that give the appearance of metal or stone. Alternatively, the first layers cast may contain colored sand so as to give an appearance of stone. By casting concrete, rather than plaster, it is possible to create sculptures, fountains, or seating for outdoor use. A simulation of high-quality marble may be made using certain chemically-set plastic resins (for example epoxy or polyester) with powdered stone added for coloration, often with multiple colors worked in. The latter is a common means of making attractive washstands, washstand tops and shower stalls, with the skilled working of multiple colors resulting in simulated staining patterns as is often found in natural marble or travertine.

Fig 2 RESIN

Patterns

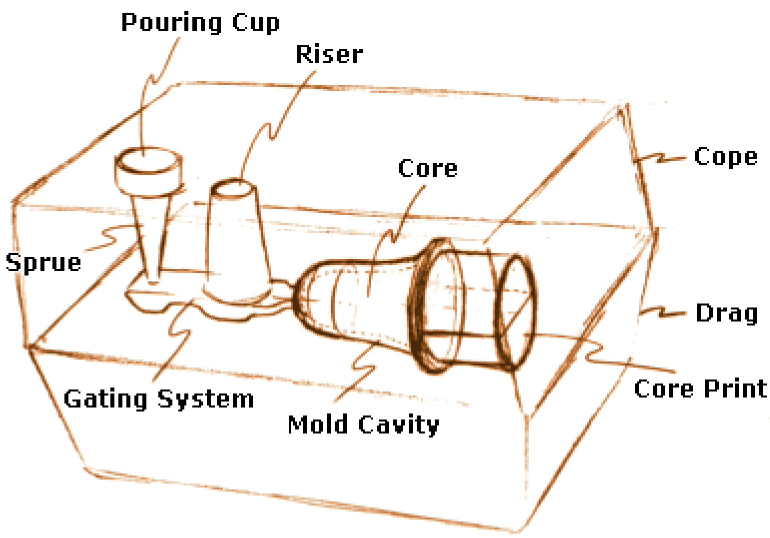


Fig 3 Patterns

The cavity in the sand is formed by using a pattern (an approximate duplicate of the real part), which are typically made out of wood, sometimes metal. The cavity is contained in an aggregate housed in a box called the flask. Core is a sand shape inserted into the mold to produce the internal features of the part such as holes or internal passages. Cores are placed in the cavity to form holes of the desired shapes. Core print is the region added to the pattern, core, or mold that is used to locate and support the core within the mold. A riser is an extra void created in the mold to contain excessive molten material. The purpose of this is feed the molten metal to the mold cavity as the molten metal solidifies and shrinks, and thereby prevents voids in the main casting.

Typical Components of a Two-part Sand Casting Mold.

In a two-part mold, which is typical of sand castings, the upper half, including the top half of the pattern, flask, and core is called cope and the lower half is called drag. The parting line or the parting surface is line or surface that separates the cope and drag. The drag is first filled partially with sand, and the core print, the cores, and the gating system are placed near the parting line. The cope is then assembled to the drag, and the sand is poured on the cope half, covering the pattern, core and the gating system. The sand is compacted by vibration and mechanical means. Next, the cope is removed from the drag, and the pattern is carefully removed. The object is to remove the pattern withoutbreaking the mold cavity. This is facilitated by designing a draft, a slight angular offset from the vertical to the vertical surfaces of the pattern. This is usually a minimum of 1° or 1.5 mm (0.060 in), whichever is greater. The rougher the surface of the pattern, the more the draft to be provided.

Sprues and Runners

The molten material is poured in the pouring cup, which is part of the gating system that supplies the molten material to the mold cavity. The vertical part of the gating system connected to the pouring cup is the sprue, and the horizontal portion is called the runners and finally to the multiple points where it is introduced to the mold cavity called the gates. Additionally there are extensions to the gating system called vents that provide the path for the built up gases and the displaced air to vent to the atmosphere.The cavity is usually made oversize to allow for the metal contraction as it cools down to room temperature. This is achieved by making the pattern oversize. To account for shrinking, the pattern must be made oversize by these factors, on the average. These are linear factors and apply in each direction. These shrinkage allowance are only approximate, because the exact allowance is determined the shape and size of the casting. In addition, different parts of the casting might require a different shrinkage allowance. Sand castings generally have a rough surface sometimes with surface impurities, and surface variations. A machining (finish) allowance is made for this type of defect.

Joining processes: Introduction

According to the classification made by the American Welding Society, joining processes fall into three major categories:

- Welding
- Adhesive bonding
- Mechanical fastening

A variety of welding methods exist, including arc and gas welding, as well as brazing and soldering. Generally welding processes can be classified into three basic categories:

- Fusion welding
- Solid-state welding
- Brazing and soldering

In welding, two or more metal parts are joined to form a single piece when one-part fabrication is expensive or inconvenient.

- Both similar and dissimilar metals may be welded.
- The joining bond is metallurgical (involving some diffusion) rather than just mechanical, as with riveting and bolting.
- During arc and gas welding, the workpieces to be joined and the filler material are heated to a sufficiently high temperature to cause both to melt; upon solidification, the filler material forms a fusion joint between the workpieces.

Main advantages of welding

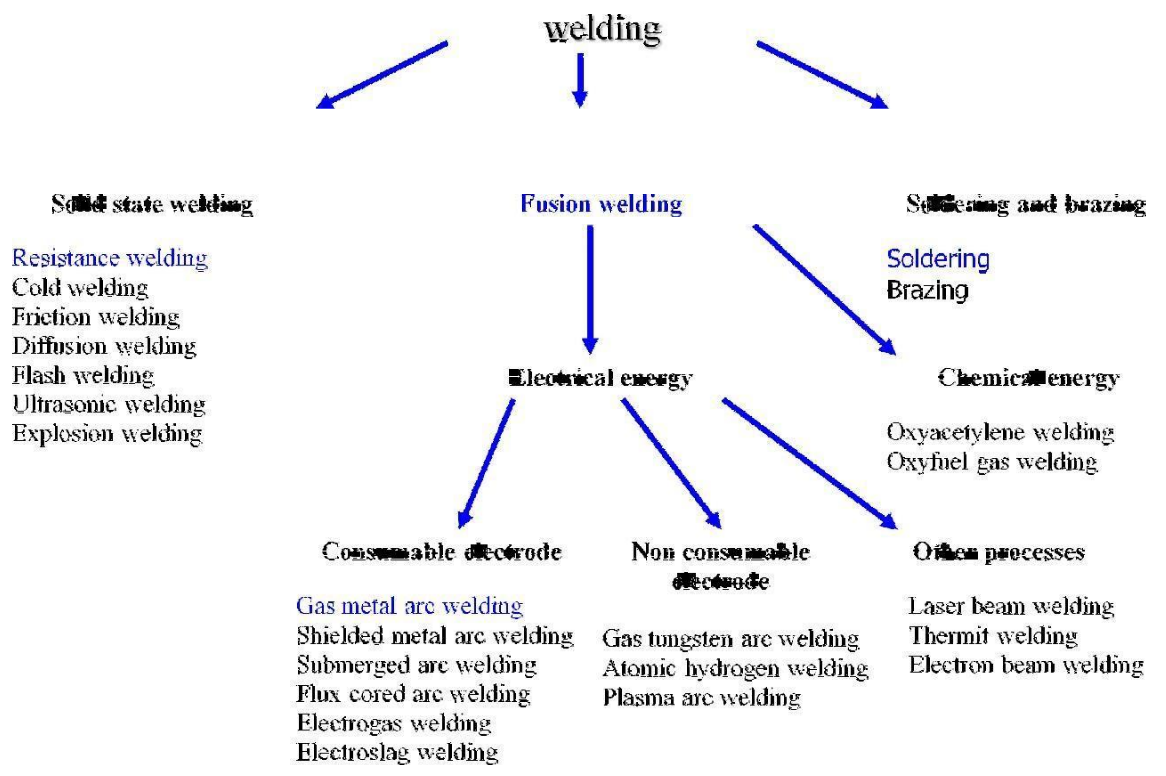
- Welding has replaced riveting in many applications including: steel structures, boilers tanks, and motor car chassis
- Cost effectiveness
- Strong and tight joining

- Simplicity of welded structure design
- Welding process can be mechanised and automated

Some disadvantages of welding

- Internal stresses, distortions and changes of structures in the weld region
- HAZ is formed
- Harmful effects: light, ultra violate radiation, fumes, high temperature
- Permanent joint

Classification of welding processes



As seen from the Figure 1, the welding processes fall under larger categories. We will describe main methods in detail in the following sections.

Oxy-fuel gas welding

- OFW is a general term used to describe any welding processes that uses a fuel gas combined with oxygen to produce a flame.
- This flame is the source of the heat that is used to melt the materials at the joint.
- The most common gas welding processes uses acetylene, is known as oxy-acetylene gas welding (OAW).
- OAW is used typically for structural-sheet metal fabrication, automotive bodies and various repair works.

Type of flames on OAW

Different types of flames obtained from oxyacetylene welding are shown in Figure 2.

- ***Neutral flame***: Acetylene and oxygen mix at the ratio of 1:1.
- ***Oxidizing flame***: A flame with excess oxygen is known as oxidising flame
- ***Reducing flame***: If oxygen is insufficient for full combustion, the flame is known as a reducing or carburising flame

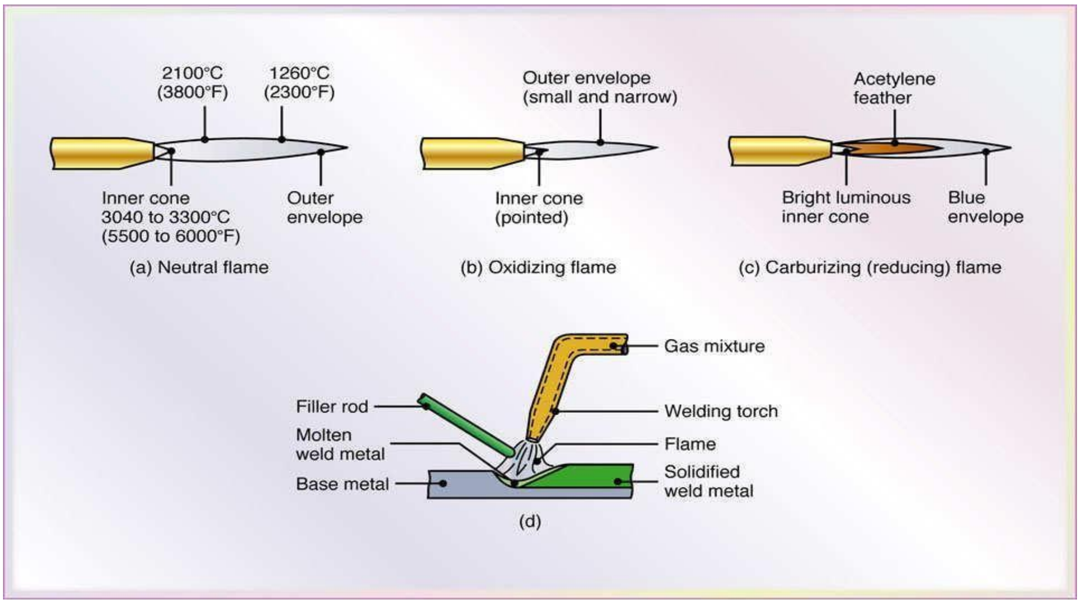


Figure 4: Schematic illustration of three basic oxyacetylene flames

Oxy-acetylene welding practice and equipment

- Prepare the edges to be joined and establish and maintain their proper position by using clamps and fixtures
- Open main valves
  Adjust pressure
- Crack open acetylene needle valve.
  Ignite,
- Adjust flame.
- Crack open oxygen needle valve.
- Adjust flame. Hold the torch at 45^{o} and filler rod at about $30\text{-}40^{o}$ and control its movement
- Shut down in reverse order; finally, open needle valves to bleed off gases.

Oxy-fuel gas cutting

- The cutting takes place mainly by the oxidation (burning) of the steel; some melting also takes place. This process generates a kerf. With oxy-acetylene gas, 300 – 600 mm and thickness 1.5 to 10 mm.
- OFC is similar to oxyfuel welding, but the heat source now is used to remove a narrow zone from a metal plate or sheet. In this process, the metal is preheated with fuel gas, and oxygen is introduced later.
- The higher the carbon content of the steel, the higher the preheating temperature required

Arc welding

Arc welding processes fall under a larger category labeled as fusion welding, with an electrical energy source (Figure 1).

General characteristics of arc welding processes

- These processes are associated with molten metal
- Arc welding processes use an electric arc as a heat source to melt metal. The arc is struck between an electrode and the workpiece to be joined. The electrode can consist of consumable wire or rod, or may be a non-consumable tungsten electrode.
- The process can be manual, mechanized, or automated. The electrode can move along the work or remain stationary while the workpiece itself is moved. A flux or shielding gas is employed to protect the molten metal from atmosphere.
- If no filler metal is added, the melted weld is referred to as autogenous. If the filler metal matches the base metal, it is referred to as homogenous. If the filler metal is different from the base metal, it is referred to as heterogeneous.

The common arc welding processes used to weld metals are: shielded metal arc welding or SMAW, gas metal arc welding GMAW, sometimes called MIG welding; flux cored arc welding FCAW; submerged arc welding SAW; and gas tungsten arc welding GTAW, sometimes called TIG welding.

- Shielded Metal Arc Welding (SMAW)
- Gas Metal Arc Welding (GMAW)
- Flux Cored Arc Welding (FCAW)
- Submerged Arc Welding (SAW)
- Gas Tungsten Arc Welding (GTAW)

Shielded metal arc welding (SMAW)

- Arc is developed between electrode and the component
- Flux creates a gas shield and the metal slag prevents oxidation of the underlying metal.
- Typical uses: Pressure vessels, structural steel, and in general engineering Economics: Versatile and low cost (easy to transport) but can't be automated.
- SMAW is the most widely used welding process for joining metal parts because of its versatility, its less complex, more portable and less costly equipment

Metals commonly welded by SMAW

- Carbon and low alloy steels
- Stainless steels and heat resistance steels
- DCEN (Direct Current Electrode Negative) (reverse polarity) can be used of all steels. Melting and deposition rates are higher than with DCEP (Direct Current Electrode Positive) (straight polarity).
- The multiple-pass approach requires that the slag be cleaned after each weld bed. 3-20 mm thick

A schematic illustration of SMAW is shown in Figure 3. This is typically a manual welding process where the heat source is an electric arc which is formed between a consumable electrode and the base material. The electrode is covered by a coating, which is extruded on the surface of the electrode. During welding, the electrode coating decomposes and melts, providing the protective atmosphere around the weld area and forming a protective slag over the weld pool.

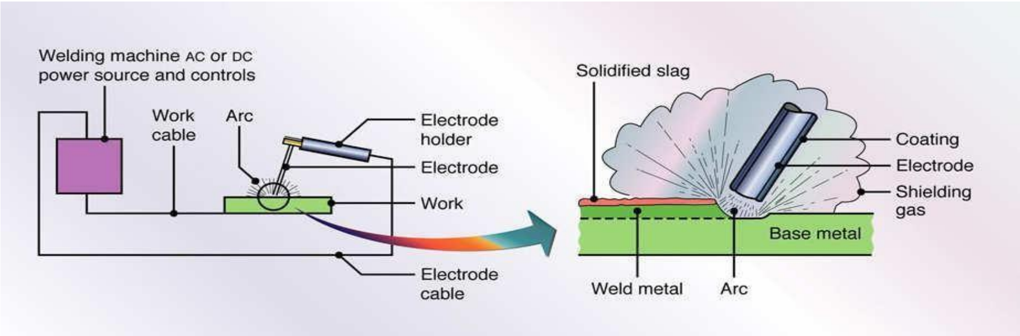


Figure 5: Schematic illustration of shielded metal arc welding

Advantages of SMAW

- Equipment relatively easy to use, inexpensive, portable
- Filler metal and means for protecting the weld puddle are provided by the covered electrode
- Less sensitive to drafts, dirty parts, poor fit-up
- Can be used on carbon steels, low alloy steels, stainless steels, cast irons, copper, nickel, aluminum

Disadvantages of SMAW

Discontinuities associated with manual welding process that utilise flux for pool shielding

Slag inclusions

- Lack of fusion

Other possible effects on quality are porosity, and hydrogen cracking. These points would be discussed separately in the welding defects section.

Limitations of SMAW

SMAW has a low weld metal deposition rate compared to other processes. This is because each welding rod contains a finite amount of metal. As each electrode is used, welding must be stopped and a new rod inserted into the holder. A 12-inch electrode may be able to deposit a bead 6-8 inches long.

The overall productivity of the process is affected by:

- Frequent changing of electrodes,
- Inter pass cleaning (grinding, brushing, etc.),
- Grinding of arc initiation points and stopping points,
- Slag inclusions which require removal of the defect and re-welding of the defective area.

The heat of the welding arc is too high for some lower melting metals. And the shielding of metals that react aggressively with the atmosphere is inadequate.

Gas metal arc welding (GMAW)

In GMAW, formerly known as metal inert-gas (MIG) welding is an arc welding process in which the heat for welding is generated by an arc between a consumable electrode and the work metal. The consumable bare wire is fed automatically through a nozzle into the weld arc by a wire-feed drive motor. In GMAW, the weld area is shielded by an effectively inert atmosphere of argon, helium, carbon dioxide or various other gas mixtures. Schematic illustration of GMAW is illustrated in Figure 4.

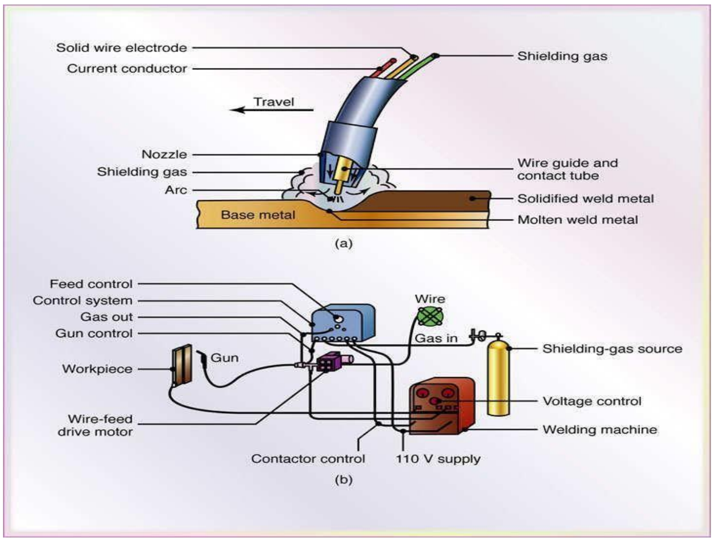


Figure 6: Schematic illustration of GMAW (Source: Manufacturing Engineering and Technology, Fifth Edition, by Serope Kalpakjian and Steven Schmid. ISBN 0-13-148965-8.

2006 Pearson Education, Inc. PP 951

Advantages if GMAW

- Can weld almost all metals and alloys, aluminum and aluminum alloys, stainless steel
- All positions of welding
- DCEP which provides stable arc, smooth metal transfer, relatively low spatter and good weld bed characteristics
- Due to automatic feeding of the filling wire (electrode) the process is referred to as a semi-automatic. The operator controls only the torch positioning and speed.
- No slag produced
- High level of operator skill is not required.

Further advantages of GMAW

- High productivity
- All positions of welding and reliability
- Wide area applications
- All ferrous and nonferrous can be welded

Limitations of GMAW

- Expensive and non-portable equipment
- Less skilled workers can operate this process, however this can lead to poor setup of the welding parameters, in turn this can lead to defects in the finished weld such as lack of fusion and porosity.
- More heat is generated in MIG than TIG; this will mean that the HAZ is larger around a weld of this type.

Flux- cored arc welding (FCAW)

Flux Cored Arc Welding (FCAW) (Figure 5) uses a tubular wire that is filled with a flux. FCAW is similar to GMAW, except the electrode is tubular in shape and filled with flux (hence the term flux-cored). The arc is initiated between the continuous wire electrode and the workpiece. The flux, which is contained within the core of the tubular electrode, melts during welding and shields the weld pool from the atmosphere. Direct current, electrode positive (DCEP) is commonly employed as in the FCAW process. Cored electrode produces a more stable arc, improve weld contour, and produce a better mechanical properties of the weld metal.

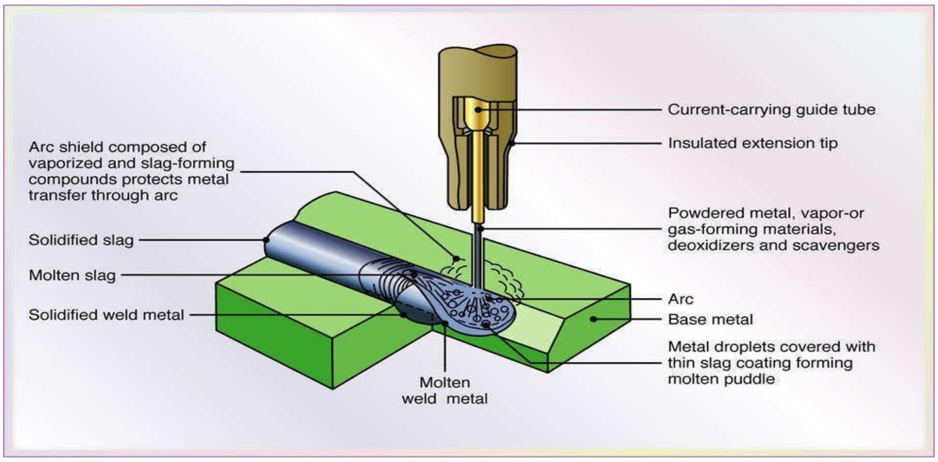


Figure 7: Schematic illustration of the flux-cored arc-welding proces

The FCAW process combines the versatility of SMAW with the continuous and automatic electrode-feeding feature of GMAW. A schematic illustration of FCAW is shown in Figure 6.

Advantages of FCAW

- Specific weld-metal chemistries can be developed
- By adding alloying elements to the flux core, all alloy composition can be produced
- Easy to automate and readily adaptable to flexible manufacturing and robotics

Disadvantages of FCAW

- The slag formed during welding must be removed between passes on multipass welds. This can reduce the productivity and result in possible slag inclusion discontinuities. For gas shielded FCAW, porosity can occur as a result of insufficient gas coverage.
- Large amounts of fume are produced by the FCAW process due to the high currents, voltages, and the flux inherent with the process. Increased costs could be incurred through the need for ventilation equipment for proper health and safety.
- FCAW is more complex and more expensive than SMAW because it requires a wire feeder and welding gun. The complexity of the equipment also makes the process less portable than SMAW.

Submerged-arc welding (SAW)

In SAW, the weld arc is shielded by a granular flux consisting of lime, silica, manganese oxide, calcium fluoride, and other compounds. A schematic illustration of submerged-arc welding process is shown in Figure 6.

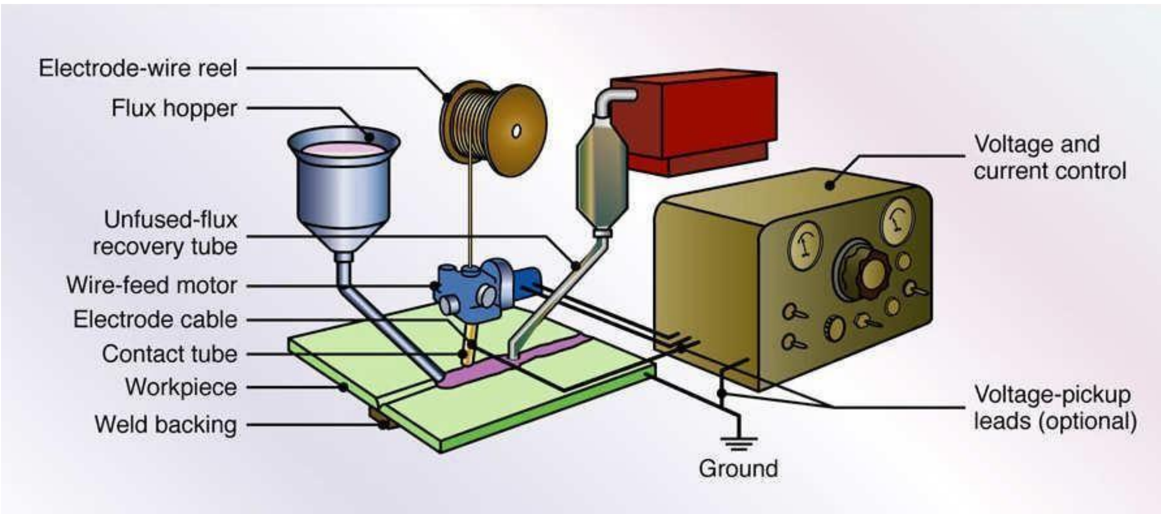


Figure 8: Schematic illustration of submerged-arc-welding (Source: Manufacturing Engineering and Technology, Fifth Edition, by Serope Kalpakjian and Steven Schmid. ISBN 0-13-148965-8. 2006 Pearson Education, Inc. PP 950)

Characteristics of submerged-arc welding

- The flux is fed into the weld zone from a hopper by gravity through a nozzle:
- The functions of the flux:
- Prevents spatter and sparks;
- Suppresses the intense ultraviolet radiation and fumes characteristics of the SMAW.
- It acts as a thermal insulator by promoting deep penetration of heat into the workpiece.
- The unused flux can be recovered, treated and reused.

The filler metal is a continuously-fed wire electrode like GMAW and FCAW. However, higher deposition rates can be achieved using SAW by using larger diameter electrodes and higher currents (650-1500 Amperes). Since the process is almost fully mechanized, several variants of the process can be utilized such as multiple torches and narrow gap welding.

- Because of the flux is gravity fed, the SAW process is limited largely to welds in flat or horizontal position
- This process can be automated and use to weld a variety of carbon and alloy steel and stainless steel sheets or plates as high as 5m/min.
- The quality of weld is very high, provides high productivity in ship building and for pressure vessels.

Advantages of submerged welding (SAW)

- This process can be automated and use to weld a variety of carbon and alloy steel and stainless steel sheets or plates as high as 5m/min.
- The quality of weld is very high, provides high productivity in ship building and for pressure vessels.
- High deposition rates
- No arc flash or glare
- Minimal smoke and fumes
- Flux and wire added separately - extra dimension of control
- Easily automated
- Joints can be prepared with narrow grooves
- Can be used to weld carbon steels, low alloy steels, stainless steels, chromium-molybdenum steels, nickel base alloys
- SAW has the highest deposition rate of the entire deep penetrating arc welding processes making it ideal for thick section and multi-pass welding. Variations of the process can utilize dual arc welding, twin arc welding, multiple torches, and narrow groove welding to increase productivity.
- Since the arc is completely submerged in the flux, there is no arc radiation. Screens or light filtering lenses are not needed. Additionally, the smoke and fumes are trapped within the flux and thus minimizing smoke and fumes.

- Since the process is simple to mechanize and easily automated, it is extremely consistent once a procedure is qualified. And it can be used on a wide variety of materials.

Limitations of submerged welding (SAW)

- Because of the flux is gravity fed, the SAW process is limited largely to welds in flat or horizontal position
- The flux which shields the arc and weld pool in SAW also obstruct the operator's view of the joint and molten weld pool. This makes observation of the pool and joint impossible during welding; thus, correction of problems during welding can be very difficult.
- Because of the high current levels common to this process, it is normally not suited for thinner materials.
- Due to the presence of a granulated flux, submerged arc welding is limited to the flat and horizontal positions. As with SMAW and FCAW, SAW produces a slag which must be completely removed after each pass.
- Finally, additional flux handling equipment is required.

Gas tungsten arc welding (GTAW)

In gas tungsten arc welding (GTAW), formerly known as TIG welding (for "tungsten inert gas"), the filler metal is supplied from a filler w ire as shown in Figure 7. In non-consumable-electrode welding process, the electrode is typically a tungsten electrode.

- An externally supplied shielding gas is necessary because of the high temperatures involved in order to prevent oxidisation of the weld zone.
- Typically direct current is used, and its polarity is important.

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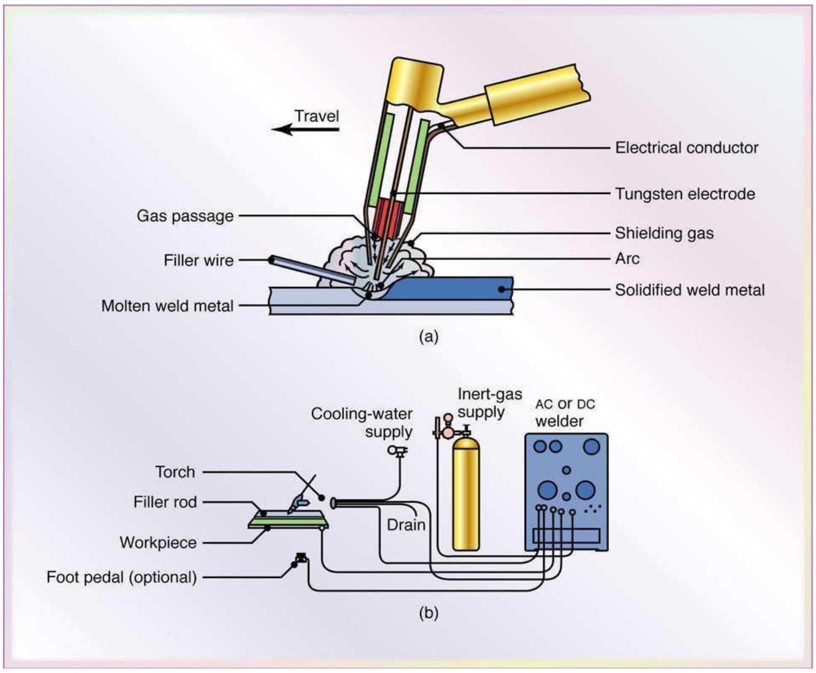

Figure 9: Schematic illustration of GTAW

- TIG is an arc welding process in which the heat is produced between a non-consumable electrode and the work metal.
- Because the tungsten electrode is not consumed in this operation, a constant and stable arc gap is maintained at a constant current level.
- The filler metals are similar to the metals to be welded, and flux is not used.
- The shielding gas is usually argon or helium (or a mixture of the two).
- TIG welding process is used for a wide variety of metals and applications.
- Metals that can be welded by TIG are aluminum, magnesium, titanium and copper and its alloy.

Applications of GTAW welding

TIG welding process is used for a variety of metals and applications in all industrial sectors. TIG is especially for welding aluminum, magnesium, titanium, and refractory metals. It is suitable for welding thin metals. The cost of the inert gas makes this process makes more expensive than SMAW but provides welds with very high quality and surface finish.

Advantages of GTAW

- Uses a lower temperature than either MIG or gas welding (Finch, 1997) subsequently this will produce a smaller HAZ (Heat Affected Zone) within which defects and weakness can occur.
- Produces very high quality welds of satisfactory quality for even the rigorous standards set by the aerospace industry. (Pritchard, 1996)
- Suitable for welding thin materials due to the lower temperature and the precise nature of the process.
- The equipment used is smaller than that of MIG and is subsequently more portable and thus more versatile. Also can weld in any position i.e. flat, horizontal, or overhead.

Limitations of GTAW

- The process is manual and requires a highly skilled operator, of which there is a shortage in the work force (Smith, 1986).
- TIG cannot be automated and is significantly slower than MIG welding and therefore less suitable for mass production.

Electrodes for arc welding

Electrodes for consumable arc-welding processes are classified according to:

Strength of the deposited weld metal

- Current (AC or DC)
- Type of coating

Friction Stir Welding (FSW)

FSW is a relatively new process developed and patented in England by The Welding Institute of Cambridge (TWI UK). The process works by lowering the pin of a shouldered tool into the gap between the two materials to be welded at a high rotational speed and under significant down force (see Figure 8). This creates friction between the tool and work, generating enough heat for the metal to change to a plasticised state. Subsequently the plasticised shaft of metal around the pin is stirred together to create a forged bond, or weld, between the materials (NASA Technology Applications Team, 2001).

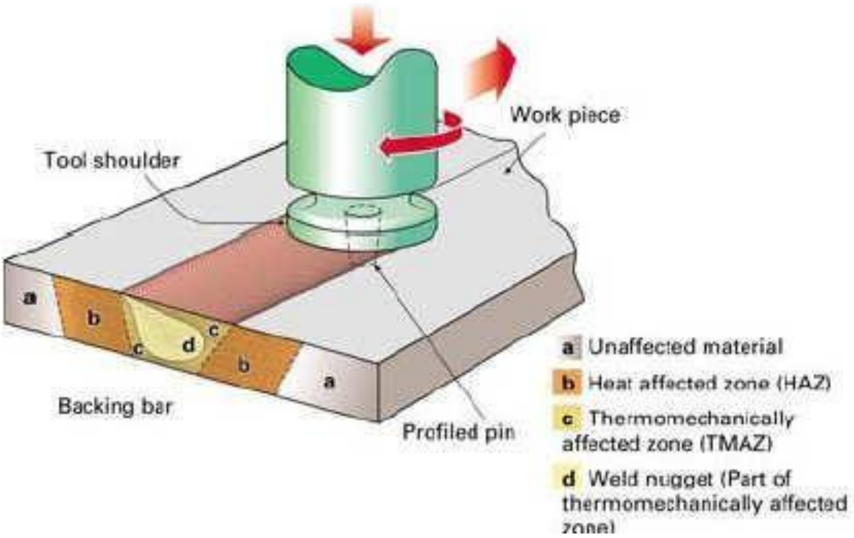

Figure 10: Schematic diagram of FSW (Nicholas et al 2002)

Advantages of FSW

Since gravity has no influence on the solid-phase welding process, it can be used in all positions, viz:

- Horizontal
- Vertical
- Overhead
- Orbital

The process advantages result from the fact that the FSW process (as all friction welding of metals) takes place in the solid phase below the melting point of the materials to be joined. The benefits therefore include the ability to join materials which are difficult to fusion weld, for example 2000 and 7000 aluminium alloys. Friction stir welding can use purpose-designed

equipment or modified existing machine tool technology. The process is also suitable for automation and adaptable for robot use.

Main characteristics/advantages of FSW

- The FSW process works below the melting temperature of the weld material in the solid state phase (Nicholas et al, 2002). This means that the work has a significantly smaller heat affected zone (HAZ) than conventional fusion welding techniques where weld defects can occur.
- In tests by TWI UK, the fatigue performance of butt welds in aluminium alloys has been found to be comparable to that of the parent material (Nicholas et al, 2002).
- Post-process natural ageing of 7000 series aluminium also led to FSW welds having an average of 95% of the tensile strength of the parent material (Nicholas et al,
- 2002). FSW creates a very strong bond between materials. In shear tests done by USC Research in the USA riveted panels failed at a load of approximately 32,300lbs, whereas the equivalent FSW panels failed at an average of 35,100lbs (USC Research and Health Sciences). FSW can weld alloys that were previously very difficult to weld using the established welding techniques of the time.
- FSW can be easily automated and subsequently can be programmed to perform complex shape welds (NASA Technology Applications Team, 2001). This also means that FSW is not as dependent on highly skilled operators.
- Defects such as solidification cracking and gas porosity caused by absorption of hydrogen during welding do not occur in FSW, although they are common in fusion welding processes (Leal et al, 2004)

Limitations of FSW

Two drawbacks to the FSW procedure are the requirement for different length pin tools when using the process on materials which vary in thickness, and the fact that a keyhole is left at the end of the weld where the welding tool is removed. This is particularly a problem when welding cylindrical items such as pipe which require a continuous weld. However, NASA Marshall have developed a retractable pin tool which removes the pin at the end of the weld, leaving no keyhole (NASA Technology Applications Team, 2001). The workpiece in FSW also requires to be clamped rigidly. If metal deposition is required, this process is not good.

Electron-Beam Welding (EBW)

In EBW, developed in 1960s, the heat used for welding the two materials is generated by high velocity narrow-beam (concentrated) electrons is fired through the work, this transfers kinetic energy to the particles of metal causing them to heat up and melt to form a weld. A schematic illustration of EBW is shown in Figure 9. EBW process requires special equipment to focus the beam on the workpiece, typically in a vacuum. The higher the vacuum, the more the beam penetrates, and the greater the depth-to-width ratio can be achieved. There are three methods in EBW as far as vacuum is concerned:

- EBW-HV (for high vacuum)
  EBW-MV (medium vacuum)
- EBW-NV (no vacuum)

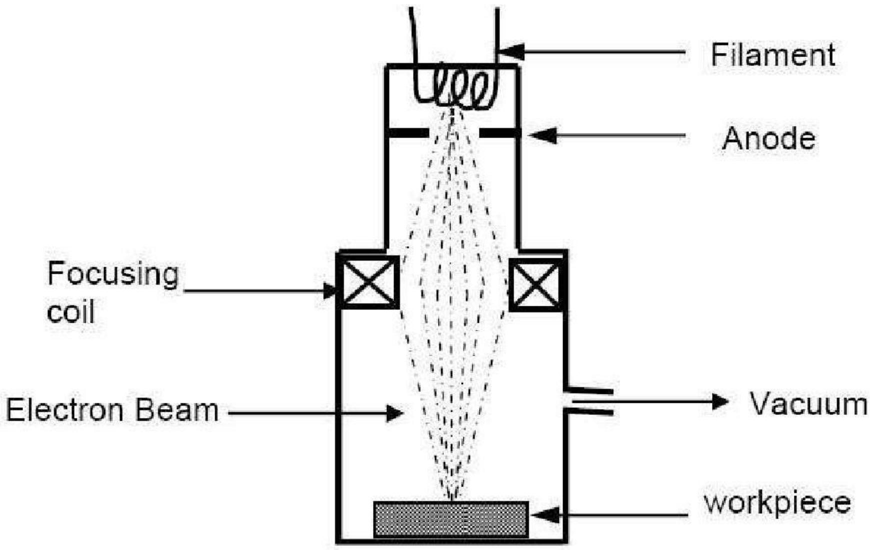

Figure 11: Schematic illustration of Electron Beam Welding (EBW) (Source: MAS 2007)

Some characteristics of EBW

- In aircraft industry alloy grade Ti is used. Electron Beam Welding (EBW) is extensively employed. TIG welding is adopted only in a few cases.

- Much better joints can be obtained by EBW of alloy grade Ti. By welding in a vacuum chamber, gas absorption is prevented.
- The HAZ is very narrow and influence of welding on structure is
- minimal. Complicated work-pieces can be welded without distortion.
- Components with large wall thickness as well as thin walled components can also be successfully welded.

Advantages of EBW

- Narrow welds can be made on thicker sections with deeper penetration with minimal thermal disturbances.
- This makes the process suitable for welding in titanium, niobium, tungsten, tantalum, beryllium, nickel alloys and magnesium, mostly in aerospace and space research sectors.
- Because welding is performed in a vacuum, there is no atmospheric contamination; accurate control of welding parameters is possible by controlling the electron beam power and accurate beam focus.
- Excellent welds can be made even on more reactive metals.
- Lack of thermal disturbance in the process means that there is minimum shrinkage and distortion.

EBW is suitable for welding many materials which are either complicated or impossible to weld using fusion welding techniques such as titanium, magnesium, tungsten, and aluminium alloys (MAS, 2007).

Laser Beam Welding (LBW)

LBW utilizes a high-power laser beam as the source of heat, to produce a fusion weld. Because the beam can be focused on to a very small area, it has high energy density and deep-penetrating capability. A schematic illustration of laser welding of titanium allows is shown in Figure 11.

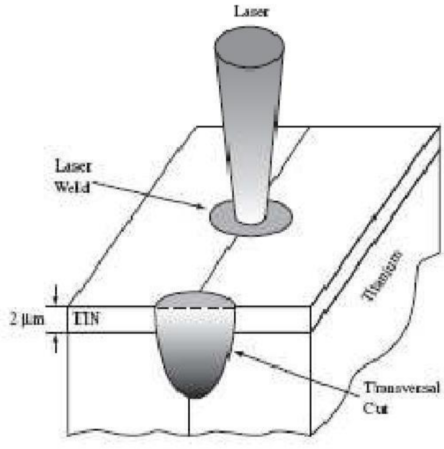

Figure 12: Schematic illustration of laser welding (Sergio and Lima 2005)

Advantages of LBW

- LBW produces welds of good quality with minimum shrinkage and distortion
- Laser welds have good strength, generally low hardness (ductile) and free of porosity The process can be automated
-
- Narrow welding seam
- Low energy input per seam length
- Reduced heat affected zone (HAZ)
- Very high welding speed (ranges from 2.5 m/min to as high as 80 m/min)

Resistance welding (RW)

Resistance Welding is a welding process in which work pieces are welded due to a combination of a pressure applied to them and a localized heat generated by a high electric current flowing through the contact area of the weld.

Different metals and alloys such as low carbon steels, aluminium alloys, alloy steels, medium carbon and high carbon steels can be welded by resistance welding. However, for high carbon contained steels, the weld bed can be harder (less brittle).

Resistance Welding (RW) is used for joining vehicle body parts, fuel tanks, domestic radiators, pipes of gas oil and water pipelines, wire ends, turbine blades, railway tracks.

The most popular methods of Resistance Welding are:

- Spot welding
- Flash welding
- Resistance butt welding
- Seam welding

Advantages of resistance welding

- High welding rates;
- Low fumes;
- Cost effectiveness;
- Easy automation;
- No filler materials are required;
- Low distortions.

Disadvantages of resistance welding

- High equipment cost;
- Low strength discontinuous welds;

- Thickness of welded sheets is limited - up to 6 mm.

Spot welding

Spot Welding is a Resistance Welding process, in which two or more overlapped metal sheets are joined by spot welds. The method uses pointed copper electrodes providing passage of electric current. The electrodes also transmit pressure required for formation of strong weld. Diameter of the weld spot is in the range 3 - 12 mm. Spot welding is widely used in automotive industry for joining vehicle body parts.

Flash welding

Flash Welding is a Resistance welding process, in which ends of rods (tubes, sheets) are heated and fused by an arc struck between them and then (brought into a contact under a pressure) producing a weld. The welded parts are held in electrode clamps, one of which is stationary and the second is movable.

Flash Welding method permits fast (about 1 min.) joining of large and complex parts. Welded parts are often annealed for improvement of toughness of the weld. Steels, Aluminium, Copper alloys, Magnesium alloys and Nickel alloys may be welded by flash welding. Thick pipes, ends of band saws, frames, and aircraft landing gears are produced by Flash Welding.

Resistance butt welding

Resistance Butt Welding is a Resistance Welding process, in which ends of wires or rods are held under a pressure and heated by an electric current passing through the contact area and producing a weld. The process is similar to Flash Welding however in Butt Welding pressure and electric current are applied simultaneously in contrast to Flash Welding where electric current is followed by forging pressure application.

Resistance seam welding

Seam welding is a Resistance Welding process of continuous joining of overlapping sheets by passing them between two rotating electrode wheels. Heat generated by the electric current flowing through the contact area and pressure provided by the wheels are sufficient to produce a leak-tight weld.

Friction welding

Friction welding uses pressure and frictional heat caused by mechanical rubbing, usually by rotation. In this process, the parts are rotated at high speed and brought together. The heat generated on contact causes the parts to fuse together. Typical use: Automotive components, agriculture equipment, joining high speed steel ends and twist drills. Process can be automated. Economics: Capital costs are high but tooling costs are low.

Incomplete fusion and penetration

Incomplete fusion is termed as fusion which does not occur over the entire base metal surfaces intended for welding and between adjoining weld beads. Incomplete fusion can result from insufficient heat input or the improper manipulation of the welding electrode. While it is a discontinuity more commonly associated with weld technique, it could also be caused by the presence of contaminants on the surface being welded. Incomplete penetration occurs when the depth of welded joint is insufficient. A schematic illustration of various discontinuities in fusion welds is shown in Figure 13.

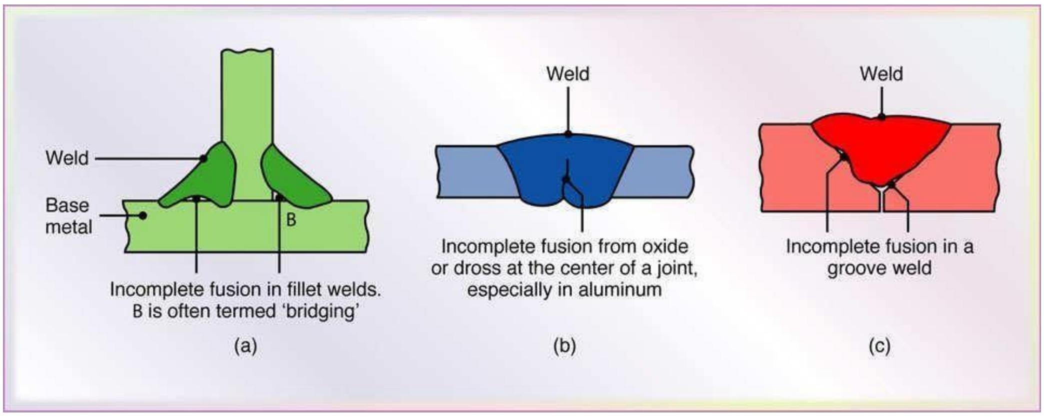

Figure 13: Examples of various discontinuities in fusion welding (Source: Manufacturing Engineering and Technology, Fifth Edition, by Serope Kalpakjian and Steven Schmid. ISBN 0-13-148965-8. 2006 Pearson Education, Inc. PP 963)

Incomplete fusion and penetration can be improved by: By raising the temperature

- Cleaning the weld area before welding
- Modifying the weld design
- Providing sufficient shielding gases
- Reducing the travel speed during the welding

Cracks

Cracks in welding occur is various locations and directions in the weld area as a result from hot tearing or cold cracking.

- Hot tearing or hot cracks (solidification crack) occurs when shrinkage during solidification tears mushy (liquid – solid) weld – physical constraints against shrinkage may exacerbate the problem. Hot cracking results from internal stress developed on cooling following solidification. This defect occurs at a temperature above the solidus of an alloy.
- Cold cracking or hydrogen cracking typically occurs after weld freezes, and residual stresses are sufficient to cause cracks – hours/day s later.

Cause of crack formation

- by welding fixtures that do not permit contraction of the weld during cooling,
- by narrow joints with large depth-to-width ratios,
- by poor ductility of the deposited weld metal,
- or by a high coefficient of thermal expansion coupled with low-heat conductivity in the parent metal

Methods to minimize hot cracking

- Maintenance of adequate manganese-to-sulfur ratio
- Reduction of sulfur, phosphorus, carbon and niobium to minimal amounts Reduction of the tensile restraint exerted on the weld

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School of Mechanical
Department of Aeronautical Engineering

UNIT – V- SAEA1302 - AIRCRAFT PRODUCTION TECHNIQUES

INTRODUCTION

Surface finishing may be defined as any process that alters the surface of a material for aesthetic or functional purposes.

The basis material (whose surface is being altered) can be a metal, a plastic, concrete, a ceramic; ie any material used for engineering or decorative purposes.

20 years ago, if you asked the layman to define surface finishing the answer would probably have been –chrome plating‖. The same question today could elicit the answer, ―powder coating‖, the in coating of the nineties.

Surface finishing can hide any number of faults in a casting, but there are limits.
Surface finishing can improve the aesthetic appeal of a casting by changing its gloss, shininess and colour, can improve corrosion resistance and tailor surface properties.

SURFACE FINISHING TECHNIQUES

The five major processes that make up surface finishing are:

(iii) abrasive blast cleaning and protective coating.
(iv) anodising
(v) electroplating and electroless plating
(vi) hot dip galvanizing and tinning
(vii) powder coating

There are a score of minor niche finishes for specific purposes. Some of which are relevant to casting.

(xiv) mechanical preparation
(xv) metal polishing
(xvi) plastics coating, eg nylon, polythene
(xvii) weld surfacing

USEFULNESS OF SURFACE FINISHING TO OUR LIFESTYLE

It is fair to say that humans would not have developed to our lifestyle without a surface finishing industry, right from the beginning. Stone Age man produced cutting edges and spear points by splintering stone. Finishing consisted of rubbing two pieces of stone together to improve the cutting edge.

Today, not one activity can be undertaken by mankind that does not include surface finishing.

When one awakes to the clock radio or similar it is the surface finishing industry that has made possible the design of the unit and the decoration on it. Look up and you see a light fitting. If it is made from metal, then surface finishing provided the lustre or colour of the fitting; if made from plastic the mould into which the fitting was formed had to be surface finished so that the plastic would flow evenly and provide the required surface profile on the component. The filament of the incandescent lamp is made of metal, drawn through surface finished dies. The contact between the light bulb and the electrical wiring (often lead) was surface finished. The electricity which passes through the filament and makes it glow to produce light is generated in power stations where surface finishes including electroplating, galvanizing, powder coating, abrasive blasting and industrial coatings are essential for a continuous and non interrupted supply.

And we haven't even got out of bed yet.

MAJOR SURFACE FINISHING ACTIVITIES-BY VOLUME OF OUTPUT

There are five main surface finishing activities, in alphabetical order:

•Abrasive blast cleaning and industrial painting

•Anodising

•Electroplating and electroless
  plating Decorative
  Functional

•Galvanizing

•Powder Coating

Abrasive Blasting

Abrasive blasting is the major method used to prepare large structures for painting. Abrasive grit is sprayed at the surface to be cleaned removing all manners of soils, oxides, scale, etc. The grit can be mineral sands such as garnet and ilmenite; copper slag and zinc slag; crushed glass or glass beads; crushed nut shells such as walnut shells; dry ice pellets, crushed limestone; steel shot or steel round.

Abrasive blasting will not necessarily remove oils and greases.

In the foundry industry, abrasive blasting can be used to remove impregnated sand from cast metal surfaces, to ―hide‖ minor defects such as fine porosity, minor cracks, etc. The danger with this practice is that a following finishing operation such as electroplating or powder coating will blister at these imperfections.

The term painting is normally used to mean the application of an organic coating from a liquid, eg house paints etc. Paints of this type have been in use for many years.

Industrial coatings

These are heavy-duty paints designed specifically for the purpose of imparting very good corrosion resistance to surfaces. Everyone is familiar with paint. It is used in the home to paint plaster, timber, metal, etc. In industry specially formulated paints are used to coat white goods, automobiles, trucks, ships, chemical tanks, industrial buildings, etc. Foundries use paints to colour items for identification or as a protective coating prior to another operation.

Anodising

Anodising is the process by which the natural film on aluminium is greatly increased in thickness. Aluminium metal is on the anodic side of the galvanic series. Its position is similar to zinc and magnesium, ie it is readily oxidised. The oxide on aluminium is naturally corrosion resistant, very hard, abrasion resistant, an insulator and very tenacious. In its natural form the oxide film on aluminium is less than 0.50 microns thick

Because the naturally occurring film is very thin and attached to a soft ductile metal, it is easily damaged. Building up this coating provides very useful properties for the aluminium surface.

Preparation

The basis of every good coating is preparation. In anodising, good preparation is essential. Oils and greases are removed in weak alkali solutions and the surface is etched to remove heavy oxides. After rinsing, the aluminium is dipped into a desmut solution to remove the insoluble components of the aluminium which remain on the surface after etching, rinsed and presented for anodising.

How is it done?

Anodizing is electroplating in reverse. During anodizing the part is made the anode (positi electrode) in an Electrolytic cell.

A DC (direct current) electric current is passed between the aluminium that is made the anode (positive terminal), the electrolyte and a cathode (often lead).

When the current is applied, the water in the electrolyte breaks down and oxygen is deposited at the anode. This oxygen combines with the aluminium to form oxide and thus builds on the oxide film always present on the surface. The acid in the electrolyte tries to dissolve this oxide and produces a porous oxide film on the aluminium surface. Coating thickness up to 25 micron are recommended for external use. The oxide grains are hexagonal in shape and each grain contains a hexagonal hole within it.

Once the required thickness of anodic film is obtained, the aluminium is removed from the electrolyte and rinsed thoroughly to remove the acids from the pores in the film.

The anodic film thus produced is quite porous and will accept or trap any material into its pores, either advantageous or disadvantageous to its properties. To prevent this occurring these pores are closed or the coating is―sealed‖. This is done by adding water to the oxide (hydrolysing). The oxide swells and in so doing the pores close-up. The resultant film is now smooth, hard, homogenous and transparent. The sealing process may be carried out in boiling water, or in chemically enriched water at room temperature.

How is colour introduced?

Surface dyes or pigments:

The clear anodised aluminium with its unsealed porous film is immersed in a bath containing organic dyes or inorganic pigments. The colorant is absorbed into the pores of the film and subsequently sealed in.

Almost all organic colours are affected by environmental factors such as UV radiation. Colour change is inevitable with exterior use.

A few inorganic pigments are resistant to UV induced colour changes. Unfortunately, many of these are no longer acceptable environmentally and are not used.

This method of colouring films lends itself to silk screening patterns into the surface.

Integral colour

In this process the colours are derived by electro-chemical means. The colour results directly from the alloying elements in the metal, the electrolyte composition, temperature and current density (the amount of current applied per unit of area).

The aluminium is immersed into a special electrolyte under carefully controlled electrical conditions and temperature for various time periods to produce a variety of colours. In some instances special aluminium alloys are required. The colours are due to the colouring of the intermetallic particles that are spread throughout the depth of the anodic film.

Electrolytic Deposition

Naturally stable metals and metallic oxide particles are electrolytically deposited at the base of the porous anodic film. The film is then ‒sealed‖. The colour is generated through the film and is locked within the clear anodic film.

Why anodise?

Anodising produces a high specification metallurgically bonded finish that resists corrosion, abrasion and exposure to industrial, marine and other severe environments. Some bending is possible of anodised aluminium, but this is not recommended, as the film tends to crack.

Aluminium, titanium, zinc, cadmium and magnesium are the usual metals to be anodised. Anodised aluminium is used in the familiar anodised aluminium window frames, commercial building fascias, etc.

Aluminium castings contain high levels of alloying metals such as silicon. The inclusion of these materials reduces the transparency of the anodic film and produces a greyish finish not greatly appreciated for decorative purposes. Aluminium castings are sometimes anodised for engineering purposes to increase surface hardness and abrasion resistance. This process is carried out
at low temperatures (less than 7^{o}C)

Electroplating

Electroplating was first reported almost 200 years ago. It may be defined as the process wherein an electric current is carried across an electrolyte and in which a substance is deposited at one of the electrodes.

Electrolysis is possible because solvents, water in particular, have the ability to ionise substances dissolved in them, that is they split them into components that carry positive and negative charges. These ions are electrically charged and are attracted to oppositely charged electrodes where they are neutralised by the charges on these electrodes. The products of electrolysis appear on the electrodes. The cathodic product is the deposition of metal and the anodic product most often is the dissolution of metal.

Why electroplate?

Electroplating is one of the means available to the surface finisher to apply a metal coating to a metallic or plastic component.

Electroplating is used to deposit a very wide range of pure metals and alloys for use in decorative, functional and jewellery applications.

Nickel/chromium composites (usually called ―chrome‖ plating), copper, brass (an alloy), bronze (an alloy) and zinc are used for decorative applications.

For functional applications zinc, tin, heavy coatings of nickel, –hard‖ chromium, silver and gold are used. Various alloys are deposited for bearing surfaces.

Functional uses include building up worn parts and changing the surface characteristics of a metal such as electrical inductance, or conductivity, or corrosion resistance.

For jewellery applications, gold, silver and rhodium are plated. Gold is often plated on 18-carat and 9- carat solid gold jewellery to obtain colour matches.

Preparation

The basis of any good coating is preparation.

For electroplating, oils and greases are removed in weak to strong alkali solutions (depending on the metal being cleaned and the soils being removed). The surface oxides are removed in acids (strong pickles are used to remove heavy oxides and rust from steel). After rinsing, the parts are presented for electroplating.

How is it done?

Electroplating is carried out in an electrolytic cell. The part to be plated is made the cathode and the metal to be deposited is often made the anode. The electrolyte contains salts of the metal being deposited as well as other compounds.

The parts to be plated are placed on racks (for still plating) or barrels (for barrel plating of small components such as fasteners) and the racks or barrels immersed in the electrolyte. A DC (direct current) electric current is passed between the items (negative terminal), the electrolyte and the anode. The composition of the electrolyte, the temperature and current are all controlled within close limits to give consistent results. In most cases, the electrolyte is filtered continuously to remove solids, which might otherwise stick to the part being plated and so produce rough deposits.

When the current is applied, metal simultaneously deposits from the electrolyte onto the part and dissolves from the anode to replenish the electrolyte. When an insoluble anode is used, such as in chromium plating or gold plating, the metal ions in the electrolyte are replenished by adding chemicals.

After plating the items are rinsed, dried, inspected and packed.

When zinc is plated, the surface of the zinc reacts with the air and tends to stain and corrode. To overcome this tendency the zinc coated parts are dipped in a chromate solution (chromate conversion coating) for a few seconds. This chromate treatment can be clear or blue, or iridescent gold, or iridescent gold/green, or black in colour. The corrosion resistance is least for the clear and blue chromates and highest for the iridescent chromates.

Electroplating is used to coat fasteners, jewellery, engineering components, to build up worn components, and sometimes as an undercoat for powder coating or painting.

Metals also can be deposited from a solution of the metal to be deposited without the use of electric current by a process called electroless (autocatalytic) deposition. Electroless coatings are deposited very evenly, much more evenly than electroplates and so find use to coat close tolerance dies for manufacturing plastic parts and where corrosion resistance is required using thin coatings.

Galvanizing and other hot dip coatings

The first use of hot dip galvanizing on steel was some work reported by the Frenchman P J Malouin in 1742. A French patent was issued to Sorel in 1837 and an English patent to H V Craufurd in the same year. Very little has changed in the process since that time. (see ―The Origins of Galvanizing‖ in Corrosion Management, August 1995 page 3).

Zinc is very successful as a protective coating for steel because in most environments to which steel will be subjected, zinc will act as the anode; ie it will dissolve in preference to the steel. In simplistic terms, while there is zinc on the surface the steel will be protected from corrosion.

Hot dip galvanizing is one of a number of methods available to the surface finisher for applying a zinc coating to an item. Other techniques include electroplating, mechanical plating, sherardising, painting with zinc-rich coatings and zinc spraying or metallising.

In the hot dip galvanizing process, a uniform coating of metallurgically bonded zinc-iron alloy layers and pure zinc is produced.

The life expectancy of zinc coatings is independent on the coating process – an equivalent coating of zinc will provide the same life expectancy regardless of the coating process. Hot dip galvanizing will provide over 80 microns of zinc coating, while zinc electroplates are normally less than 25 micron.

The hot dip galvanizing process is widely used in a number of applications, particularly constructional. Galvanizing is normally carried out to AS1650 **Hot dip galvanized coatings on ferrous article‗**.

The Galvanizing process

Chemically clean items are galvanized by full immersion in molten zinc. The total coating thickness is automatically determined by the mass of the steel being galvanized and the composition of the steel, particularly silicon and phosphorus. In all other zinc coating processes there is no relationship between mass, composition and thickness of coating.

Virtually any article may be coated. Articles ranging in size from small fasteners to structures hundreds of metres high may be protected. Large galvanizing vats, together with modular design techniques of construction and double-end dipping allow almost any sized structure to be galvanized. While there is zinc on the surface of the steel maintenance costs are reduced and service life is extended.

Visual inspection of aged galvanized products shows that items are completely protected.

Preparation of castings for galvanizing

The first requirement is to remove oils and greases and old paint coatings. This is normally done in hot strong alkali solutions. If scale, rust and other surface contaminants are present abrasive blasting may be necessary, otherwise these contaminants are removed by acid cleaning or pickling in sulphuric or hydrochloric acids, followed by rinsing. Hydrochloric acid is preferred because it is more easily reclaimed. Iron and steel castings are usually abrasive blast cleaned followed by a brief acid dip. In some circumstances items may be cleaned electrolytically to remove foundry sand and surface carbon.

Fluxing

Before a component can be offered to the hot zinc bath, all moisture must be dried from the surface and other cavities. The surface of an acid cleaned steel is very active and will oxidise rapidly, more quickly than the surface can be dried. The metallurgical reactions between the molten zinc and the steel surface will not occur if oxides are present on the steel surface.

To prevent this oxidation, the chemically clean, highly active steel surface is immersed in a flux solution, usually 30% zinc ammonium chloride with wetting agents, maintained at about 65^{o}C.

Applying the galvanized coating

The galvanizing reaction takes place at between 445 and 465^{o}C.

When the dried steel part is immersed in the galvanizing bath the steel surface is wetted by the molten zinc and reacts to form a series of zinc-iron alloy layers. The work remains in the bath until its temperature reaches that of the molten zinc, so that all the galvanizing reactions can go to completion. After the surface of the molten zinc is skimmed to remove the dross from the surface, the job is withdrawn from the bath at a controlled rate. When the surplus surface metal has drained off, the item is either air quenched or quenched in water containing

potassium dichromate. The item carries with it an outer layer of molten zinc that solidifies to form the relatively pure outer zinc coating. This shiny pure zinc layer does not always form – in the presence of high levels of silicon in the steel the pure zinc layer does not form and the surface will be a dull grey colour.

The period of immersion in the galvanizing bath varies from several minutes for relatively light articles, up to half an hour or longer for massive castings. This is one of the reasons that hot dip galvanizing is charged by the weight of the item being coated.

The resulting galvanized coating is tough and durable, normally comprising a surface of relatively pure zinc covering zinc-iron alloy layers bonded metallurgically to the underlying steel. This coating completely covers the article and provides excellent resistance to abrasion.

One of the advantages of the hot dip galvanizing process is that a visual inspection can show that the coating is continuous. Defects such as uncoated areas due to incorrect preparation, carry over of dross (dull grey rough deposits) can be found easily.

Quenching

The galvanized zinc surface is highly reactive. It will oxidise rapidly in moist air (a relative humidity above 65% is sufficient to cause the onset of corrosion) and white corrosion products form rapidly when two zinc surfaces are stacked on each other (storage corrosion). To delay this corrosion, galvanizers normally water quench items in a solution of potassium dichromate which applies a chromate film to the zinc surface.

The chromate film formed from this dichromate solution is not suitable for powder coating. If the item is to be powder coated the galvanizer should air quench the item after galvanizing. To prevent the generation of corrosion products before powder coating, it is essential that the powder coating be applied within a few hours of galvanizing. If this is not possible, then a light acid etch, followed with a zinc phosphate or chromate conversion coating is mandatory.

Galvanizing defects

As the item is withdrawn from the galvanizing kettle, zinc drips off the item causing spikes, dags and a rough surface. Tilting the parts as they emerge from the bath reduces the incidence of these defects. Thus, any drips are found at the drip point. These spikes are removed prior to returning the parts to the customer. The lighter the section the quicker the zinc will freeze so that drips and dags are possible on thin sections.

When designing parts that are to be galvanized, it is important to follow a number of design strategies that will result in good draining and venting of closed sections. This action will allow the galvanizer to do a good job safely.

Storage of galvanized parts

Zinc coated parts will sweat in humid environments when stacked closely. The sweating will lead to corrosion and ugly **white corrosion products** will be produced. Beneath each of the locations of white powder, a pit will have been produced and the coating thickness at these locations will have been reduced so that corrosion of the steel will occur prematurely.

Separate galvanized parts during storage so that air can circulate freely between the items. Use spacers to separate flat sheets.

Galvanizing fasteners and small components

Fasteners and small components are loaded into perforated cylindrical steel baskets. They are degreased, acid pickled, pre-fluxed and dried. The dry baskets containing the components are lowered into the galvanizing bath. At the end of the galvanizing treatment, the baskets of galvanized components are raised from the molten zinc and immediately placed into a centrifuge or spinner and rotated at high speed for 15 to 20 seconds. Excess zinc is thrown off. The resultant coating is smooth and uniform.

Metallurgy of galvanizing

The molten zinc in the galvanizing kettle removes the flux so that the zinc wets the steel surface. Immediately, a metallurgical alloy is formed between the zinc and the steel – a thin molecular layer of brittle, hard high-iron zinc alloy (the gamma layer – 21-28% iron). Next a much thicker, hard, brittle alloy (the delta layer 7-12% iron) forms. On top of this the zeta layer forms containing about 6% iron and finally the surface layer is virtually pure zinc (the eta layer).

The silicon and phosphorous content of the steel affect the formation of these layers. If the silicon content is very high, the eta layer may not form and a dull galvanized surface will result.

Each of these layers is metallurgically bonded to each other so that they cannot be separated from each other or from the steel as can a paint coating.

Abrasion resistance of galvanized coatings

Although the outer eta layer is soft and lacks abrasion resistance, the zeta and delta layers are harder and more abrasion resistant than the steel. The outer eta layer may be removed in service. The exposed harder, more abrasion resistant zeta and delta layers gives the galvanized coating outstanding abrasion resistance so that mechanical damage to galvanized coatings is minimised.

∗ Galvanizing (hot dip) is the process of applying zinc to steel by dipping the part in a bath of molten zinc. It is used to protect steel from corrosion (rusting).

Galvanizing is used to protect large steel structural members, roofing material (galvanized iron, ―galvalume‖) etc.

* Tin is also often deposited using the hot dip technique.

Powder Coating

Powder coating is by far the youngest of the surface finishing techniques in common use today. It was first used in Australia about 1967.

Powder coating is the technique of applying dry paint to a part. The final cured coating is the same as a 2-pack wet paint. In normal wet painting such as house paints, the solids are in suspension in a liquid carrier, which must evaporate before the solid paint coating is produced.

In powder coating, the powdered paint is applied to the part, the part is then placed in an oven and the powder particles melt and coalesce to form a continuous film.

There are two main types of powder available to the surface finisher:

•Thermoplastic powders which will remelt when heated, and

•Thermosetting powder which will not remelt upon reheating. During the curing process (in the oven) a chemical cross-linking reaction is triggered at the curing temperature and it is this chemical reaction which gives the powder coating many of its desirable properties.

Preparation

The basis of any good coating is preparation. The vast majority of powder coating failures can be traced to a lack of a suitable preparation.

The preparation treatment is different for different materials.

In general for all applications the preparation treatment for aluminium is as follows:

Clean	Rinse	Etch	Rinse	Chromate or Phosphate	Rinse	Demin Rinse

Oils and greases are removed in weak alkali solutions and the surface is etched to remove heavy oxides. After rinsing, the aluminium is dipped into a chromate or phosphate solution to form a conversion coating on the aluminium. This film is chemically attached to the aluminium. After rinsing, the aluminium is finally rinsed in demineralised water.

The conversion coating has two functions:

- It presents a surface to the powder which favours adhesion more than the oxides which for very readily on aluminium surfaces, and
- It reduces the incidence of under film corrosion, which may occur at holidays in the coating.

The use of demineralised water reduces the chemical salts on the aluminium surface. These salts have been found to cause filiform corrosion in humid conditions.

For steel the preparation for interior applications is:

Clean	Rinse	Derust	Rinse	Iron Phosphate	Rinse	Acidulated Rinse

For exterior applications:

Clean	Rinse	Derust	Rinse	Grain Refine	Zinc Phosphate	Rinse	Acidulated Rinse

The grain refiner is used after acid cleaning of steel before zinc phosphating because otherwise the zinc phosphate produced on acid cleaned steel will be very coarse low adhesion coatings. The powder coating applied to a coarse phosphate will be rough coatings and possess low adhesion.

Preparing galvanized coatings for powder coating

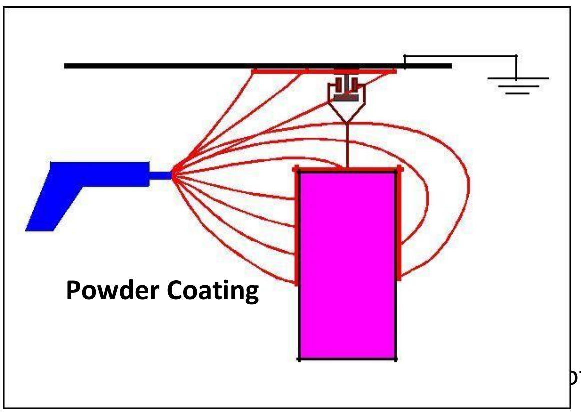
Galvanized coatings are a bright silvery grey colour. In these days of brilliant colours a bright silver finish no longer is sufficient in domestic applications. The coating of choice is a powder coating which eventually will be able to provide almost any colour that the mind can conceive. The powder coating is cathodic to the zinc and if there is an adhesion defect or there is a holiday in the coating, the underlying zinc will corrode under the powder coating film (under film corrosion). The corrosion products will ooze out through and over the powder coating giving an ugly **salt like** appearance to the surface. To reduce the possibility of this occurring it is essential to prepare the corrosion free zinc surface with a conversion coating, either zinc phosphate or chromate. A new Australian Standard is being developed for these types of coatings.

Hot dipped galvanized coatings which have been stored for more than about 4 hours before powder coating the following process is necessary for exterior applications.

Clean	Rinse	Etch	Rinse	Grain Refine	Zinc Phosphate	Rinse	Acidulated Rinse

The etch is required to remove the zinc corrosion products which begin to form almost immediately the zinc is removed from the galvanizing kettle. The grain refiner ensures a fine phosphate is produced.

How is it done - spray coating?



The powder may be applied with an electrostatic spray gun to a part that is at earth potential.

Before the powder is sent to the gun it is fluidised:

•to separate the individual grains of powder and so improve the electrostatic charge that can be applied to the powder and

•so that the powder flows more easily to the gun

Because the powder particles are electrostatically charged the powder wraps around to the back of the part as it passes by towards the air intake system. By

collecting the powder, which passes by the job, and filtering it, the efficiency of the process can be increased to 95% material usage.

The powder will stay attached to the part as long as some of the electrostatic charge remains on the powder. To obtain the final solid, tough, abrasion resistant coating the powder coated items are placed in an oven and heated to temperatures that range from 160 to 210^{o}C (depending on the powder).

Under the influence of heat a thermosetting powder goes through 4 stages to full cure.

MELT, FLOW, GEL, CURE

The powder particles melt, flow together and fuse to produce a continuous film that will vary from high gloss to flat matt depending on the design of the powder by the supplier. During the cure cycle the chemical cross linking reaction, which gives thermosetting powders their unique properties, takes place.

How is it done - dip process

Another method that is commonly used for applying thermoplastic powders is the dip process. In this method the fluidised powder is retained in a pot and the part is either dipped into the powder, or the pot is raised to submerge the part to be coated. The powder may be electrostatically charged or not charged. If the powder is not charged the part is heated prior to being dipped into the powder. If the powder is charged the powder need not be heated prior to coating.

How is colour introduced?

Powder coatings are colour during the manufacturing process, ie before it reaches the powder coater. There is little that can be done to change the colour once the powder leaves the manufacturing plant.

Why powder coat?

Powder coating produces a high specification coating which is relatively hard, abrasion resistant (depending on the specification) and tough. Thin powder coatings can be bent but this is not recommended for exterior applications.

The choice of colours and finishes is almost limitless, if you have the time and money to have the powder produced by the powder manufacturer.

Powder coatings can be applied over a wide range of thickness. The new Australian Standard (not yet numbered) will recommend 25 micron minimum for mild interior applications and up to 60 micron minimum for exterior applications. Care must be exercised when quoting minimum thickness because some powder will not give –coverage‖ below 60 or even 80 micron. ―Coverage‖ is the ability to cover the colour of the metal with the powder. Some of the white colours require about 75 micron to give full ―coverage‖ and one of the orange colours must be applied at 80 micron.

Colour matching is quite acceptable batch to batch.

Powder coatings can be applied to almost any surface (including metals, timber, glass, concrete, rocks, McDonalds buns) if sufficient care is taken and the part will fit into an oven and will not deteriorate at the temperature used to cure the powder.

Powder coating has been used instead of wet paint, electroplating, galvanizing and anodising in such applications as white goods (wet paints), decorative knobs for plumbing fittings, door furniture, etc (electroplating), concrete reinforcing rods, fencing (galvanizing) and window frames (anodising).

INSTALLATIONS AND MAINTENANCE

During installations all coatings should be protected from damage due to abrasion and materials of construction such as mortar and brick cleaning chemicals.

Once installed, maintaining the initial appearance of the surface finish is a simple matter. The soot and grime which builds up on surfaces from time to time contains moisture and salts which will adversely affect the coating and must be removed.

Coatings should be washed down regularly (at least once each 6 months in less severe applications and more often in marine and industrial environments). The coating should be washed down with soapy water – use a neutral detergent - and rinsed off with clean water.

When surface coated items are installed without damage to the powder coating and they are maintained regularly, they should be relatively permanent.

Protective Coatings

Coating materials

The selected coating materials shall be suitable for the intended use and shall be selected after an evaluation of all relevant aspects such as:

- Corrosion protective properties.
- Requirements to health, safety and environment.
- Properties related to application conditions, equipment and personnel.
- Availability and economics of coating materials.

All coating materials and solvents shall be stored in the original container bearing the manufacturer's label and instructions. Each product shall have a batch number showing year and month of manufacture and giving full traceability of production. Shelf life shall be included in the technical data sheet.

Steel materials

Steel subject to surface preparation on site shall as a minimum requirement be in accordance with Rustgrade B according to ISO 8501-1. Shop primer applied by the steel manufacturer shall be regarded as temporary corrosion protection and shall be removed prior to the application of the coating systems herein.

Unpainted surfaces

The following items shall not be coated unless otherwise specified:

- Aluminium, titanium, stainless steel, chrome plated, nickel plated, copper, brass, lead, plastic or similar.

- Jacketing materials on insulated surfaces.

Handling and shipping of coated items
Coated items shall be carefully handled to avoid damage to coated surfaces. No handling shall be performed before the coating system is cured to an acceptable level. Packing, handling and storage facilities shall be of non-metallic type.

Prequalification of products, personnel and procedures

Prequalification requirements as described in clause 10 of this document shall be fulfilled and documented prior to commencement of any work in accordance with this document.

Metal coating

Hot-dip galvanising shall be in accordance with ISO 1461. When hot-dip galvanised items are painted, coating system 6 in this document shall be used.
Metal spraying shall be in accordance with the requirements in this document.

HEALTH, SAFETY AND ENVIRONMENT

The following documentation shall be provided and used when evaluating coating systems:

- Chemical name of organic solvent, OAR number (Occupational Air Requirements) according to Norwegian regulations and VOC content (Volatile Organic Components g/l).

- Percentage of low molecular epoxy (molecular weight < 700).

- Content of hazardous substances. Ref. S-DP-002.
- Specification of hazardous thermal degradation components.
- Combustibility.
- Special handling precautions and personal protection.

All coating products as applied, shall as a minimum, be in accordance with relevant Norwegian regulatory requirements regardless of where the coating operation takes place. Content of quartz and heavy metals in blast cleaning media (ISO 8504-2) shall be given.

SURFACE PREPARATION

Pre-blasting preparations

Sharp edges, fillets, corners and welds shall be rounded or smoothed by grinding (min R = 2 mm).

Hard surface layers, e.g. resulting from flame cutting, shall be removed by grinding prior to blast cleaning.

The surfaces shall be free from any foreign matter such as weld flux, residue, slivers, oil, grease, salt etc. prior to blast cleaning.

Any oil and grease contamination shall be removed by solvent or alkali cleaning prior to blasting operations, ref. SSPC-SP-1.

Any major surface defects, particularly surface laminations or scabs detrimental to the protective coating system, shall be removed by suitable dressing. Where such defects have been revealed during blast cleaning, and dressing has been performed, the dressed area shall be reblasted to the specified standard. All welds shall be inspected and if necessary repaired prior to final blast cleaning of the area.

Blast cleaning

Blasting abrasives shall be dry, clean and free from contaminants which will be detrimental to the performance of the coating.

Size of abrasive particles for blast cleaning shall be such that the prepared surface profile height (anchor pattern profile) is in accordance with the requirements for the applicable coating system. The surface profile shall be graded in accordance with ISO 8503.

The cleanliness of the blast cleaned surface shall be as referred to for each coating system, i.e. Sa 2 1/2 or Sa 3 in accordance with ISO 8501-1.

Final surface condition

The surface to be coated shall be clean, dry, free from oil/grease and have the specified roughness and cleanliness until the first coat is applied.

Dust, blast abrasives etc. shall be removed from the surface after blast cleaning such that the particle quantity and particle size do not exceed rating 2 of ISO 8502-3.

The maximum content of soluble impurities on the blasted surface as sampled using ISO 8502-6 and distilled water, shall not exceed a conductivity corresponding to a NaCl content of 20 mg/m2. Equivalent methods may be used.

PAINT APPLICATION

General

Contrasting colours shall be used for each coat of paint.

The coating manufacturer shall provide a Coating System Data Sheet (CSDS) for each coating system to be used, containing at least the following information for each product:

- Surface pre-treatment requirements.
- Wet film thickness/dry film thickness (max, min. and specified).
- Maximum and minimum recoating intervals at 5 °C, 10 °C and 23 °C.
- Information on thinners to be used (quantities and type).
- Mixing, handling and application requirements/recommendations.
- Hiding power of top coat for specified colours according to ISO 2814. Contrast ratio shall not be less than 94% at the specified top coat thickness.

Application equipment

The method of application shall be governed by the coating manufacturer's recommendation for the particular coating being applied.

Roller application of the first primer coat is not acceptable. When paints are applied by brush, the brush shall be of a style and quality acceptable to the coating manufacturer.

Brush application shall be done so that a smooth coat, as uniform in thickness as possible is obtained.

Application

Prior to the application of each coat, a stripe coat shall be applied by brush to all welds, corners, behind angles, sharp edges of beams etc. and areas not fully reachable by spray in order to obtain the specified coverage and thickness.

Edges of existing coating shall be feathered towards the substrate prior to overcoating.

Each coat shall be applied uniformly over the entire surface. Skips, runs, sags and drips shall be avoided. Each coat shall be free from pinholes, blisters and holidays.

Contamination of painted surfaces between coats shall be avoided. Any contamination shall be removed.

Repairs

All repair of coating shall be conducted in accordance with the original surface preparation and coating application requirements.

THERMALLY SPRAYED METALLIC COATINGS

General

Relevant requirements provided in this Standard are applicable for thermally sprayed metallic coatings. Specific requirements valid for thermally sprayed metallic coatings are provided below.

Coating materials

The materials for metal spraying shall be in accordance with the following standards:

Aluminium: Type Al 99.5 of DIN 8566/2 or equivalent.

Aluminium alloy: Aluminium alloy with 5 % Mg, DIN 8566/2 AlMg5 or equivalent.

All coating metals shall be supplied with product data sheets and quality control certificates, and be marked with coating metal manufacturer's name, manufacturing standard, metal composition, weight and manufacture date.

The materials for sealing the metal coating shall be in accordance with BS 5493 (1977), chapter 11, table 4C. Type CP3-6 shall be used below 60 °C and type CP7 above 60 °C.

Application of thermally sprayed coating

Each coat shall be applied uniformly over the entire surface. The coat shall be applied in multiple layers and shall overlap on each pass of the gun.

Application should follow guidelines given in DIN 32521.

For items that will be welded after spraying, 5-10 cm measured from the bevel area shall be left uncoated.

The coating shall be firmly adherent. The surface after spraying shall be uniform and free of lumps, loosely adherent spattered metal, bubbles, ash formation, defects and uncoated spots. Before application of any further coat, any damage to the previous coat shall be repaired.

Field coating of pipes and coating of infill steel

Before the metal spraying operation starts, the metal coated area 30-40 cm in distance from the weld zone shall be sweepblasted to ensure that all contaminations are removed. The uncoated welding zone shall be blast cleaned as specified for coating system no 2. The metal coating shall be performed according to the requirements above, ref. 9.3. The metal spraying operation shall always start in the weldzone, not on the previously metallised area.

Repairs

All requirements, including adhesion, applicable to metal spraying, shall apply.

The treating and handling of the substrate shall be done in such a manner that the product in its final condition will have a continuous and uniform coating.