UNIT 3 METAL FINISHING PROCESSES

Structure

3.1 INTRODUCTION

Quality of surface is an important factor to decide the performance of a manufactured product. Surface quality affect product performance like assembly fit, aesthetic appeal that a potential customer might have for the product. A surface is defined as the exterior boundary of an object with its surroundings, which may be any other object, a fluid or space or combination of these. The surface encloses the object's bulk mechanical and physical properties.

A surface is what we touch, when we held a manufactured object. Normally dimensions of the object are specified in its drawing relating the various surfaces to each other. These nominal surfaces, representing the intended surface contour of the manufactured part, are defined by line in the drawing (machine). The nominal surfaces of the object are represented by perfect straight lines, perfect circles, round holes, absolute perpendicularity and straightness. A variety of processes are used to make the designed parts. In totality the manufacturing result is wide variations in surface characteristics. It is important to know the technology of surface generation. Only then the root causes of deviations can be determined and fixed to get the good results.

Objectives

After studying this unit, you should be able to

- meaning of metal finishing and surface preparation,
- surface roughness,
- different process of surface finish,
- super finishing operations, and
- machine-tool used in surface finishing operations.

3.2 DEFINITIONS

Some important definitions are being described here which determine the quality of a generated surfaces. The surface parameters described here are not only responsible for aesthetic point of view but also their correctness and accuracy influence performance of the object correctly.

Angularity

The extent to which a part feature such as a surface or axis is at a specified angle relative to a reference surface. If angle is maintained exactly at 90^o it is called *perpendicularity*. If the angle is maintained exactly at 0^o it is called *parallelism*.

Circularity

For a surface of revaluation such as cylinder, circular hole, or cone, circulating is the degree to which all points on the intersection of the surface and plane perpendicular to axis of revaluation are equidistant from the axis. For a sphere, circulating is the degree to which all points on the intersection of the surface and a plane centre. Same is also called roundness.

Concentricity

The degree to which any two or more part features such as a cylindrical surface and a circular hole have a common axis.

Cylindricity

The degree to which all points on a surface of revaluation such as a cylinder are equidistant from the axis of revaluation.

Flatness

The extent to which all points on a surface lie in a single plane.

Straightness

The degree to which a part feature such as a line or axis is a straight line.

3.3 OBJECTIVES OF SURFACE PREPARATION

Surfaces are very important due to various commercial and technological reasons. These reasons may be different depending on different applications of the product. The main objectives are described below.

(a) All smooth surfaces which are free from scratches and blemishes provide good aesthetic appearance. This all add value to product and give a favourable impression to the customers.

(b) Smooth surfaces free from scratches and sharp corners and edges give safety to users.

(c) Friction and wear also decided by surface conditions. In case of mating parts, the mating surfaces should be perfectly finished to avoid wear and energy loss due to friction.

(d) Good quality surfaces improve mechanical and physical properties. Any surface flow can act as a point of stress concentration.

(e) A slightly rough surface having uniform and constantly maintained value of surface roughness provides anti-glazed property to the same.

(f) Smooth surfaces improve capability to make good electrical contacts.

3.4 CHARACTERISTICS OF SURFACES

Characteristics of surfaces includes surface texture, surface integrity, it also takes care of relationship between manufacturing processes and characteristics of generated surfaces. A surface is generally examined by a magnified cross-section of the surface of the part produced.

The bulk of the part referred to as substrate has a grain structure that depends on previous processing of the metal. The exterior of the machine part is called surface whose topography is pre-decided. The surface may have roughness, waviness and flaws. It may also have some pattern or directional pattern depending on the process used. All these are described as surface texture. The elements of surface texture are defined below and shown in Figure 3.1.

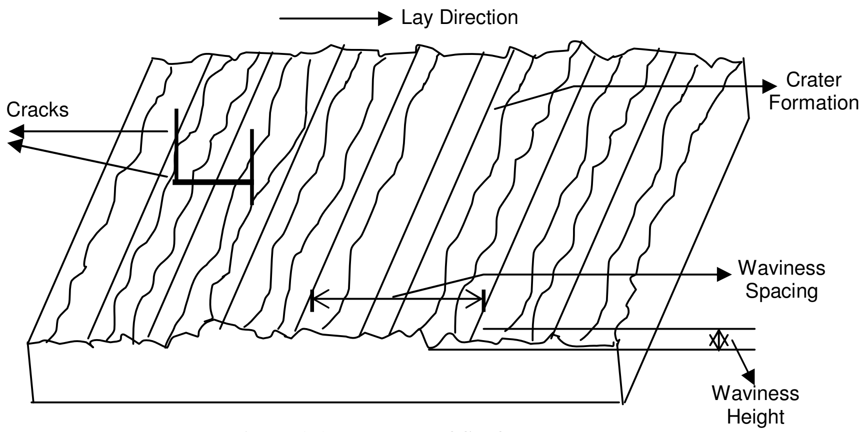

Figure 3.1 : Features of Surface Texture

Surface Roughness

It refers to small, finely spaced deviations from nominal surface that are determined by the material characteristics and the process used.

Waviness

It is defined as the deviations of much larger spacing occurring due to work deflection, vibration, heat treatment and other similar factors. Roughness is generally superimposed on the waviness.

Lay

Lay is the predominant direction or pattern of the surface texture. It is the result of and determined by the manufacturing method employed to generated the surface.

Flaws

Flaws are irregularities that occur sometimes on the surface. Flaws are not the characteristics of the process but these are the faults. Examples of flaws are cracks, scratches, inclusions, etc.

Surface Roughness/Surface Finish

Surface roughness and surface finish are opposite to each other, these are quantitative parameters. Surface roughness can be expressed in units of length after its measurement.

"Measurement of finely spaced deviations of actual surface from nominal surface (datum) in the units of length (μm) are the measurement of surface roughness. Lesser the value of surface roughness better the surface finish is said. There are two popular methods of expressing measured value of surface roughness. According to "AA" method surface roughness is the average of vertical deviations from the nominal surface over a specified surface length.

$$\text{Average Roughness (AA)} = \int_0^{lm} \frac{(Y)}{L_m}\, dx$$

where, Y = Vertical deviations from nominal surface, and

L_m = Specified length on surface.

According to root mean square method, "Value of surface roughness is square root of the mean of the squared deviations from nominal surface over the measuring length (sampling length)" RMS value is always observed more than the arithmetic average because larger deviations play more prominent role.

$$R_{rms} = \int_0^{lm} \sqrt{\frac{|Y|^2}{L_m}\, dx}$$

All the notations have the same meanings above.

3.5 SURFACE FINISHING PROCESSES

Manufacturing process employed determines surface finish level. Some processes are inherently capable of producing better surfaces than others. The processes recognized for good surface finish are honing, lapping, polishing and surface finishing. Tolerance and range of surface roughness produced by different processes are given below.

Process	Tolerance (mm)	Roughness (μm)
Grinding	± 0.008	5 to 75
Lapping	± 0.005	2 to 15
Honing	± 0.005	4 to 30
Super Finishing	± 0.003	1 to 10

Different surface finishing processes are described below.

Honing

Honing is a surface finishing operation based on abrasive action performed by a set of bonded abrasive sticks. It is generally used to finish bores of cylinders of IC engine, hydraulic cylinders, gas barrels, bearings, etc. It can reduce the level of surface roughness below 32 μm. It produces a characteristics surface pattern as cross hatched which is a fit case to retain lubrication layer to facilitate motion to moving parts, their best example is IC engine. The honing tool used to finish internal surface is shown in Figure 3.2. The honing tool consists of a set of bonded abrasive sticks. The number of sticks mounted on a tool depends on its circumferential area. Number of sticks may be more than a dozen.

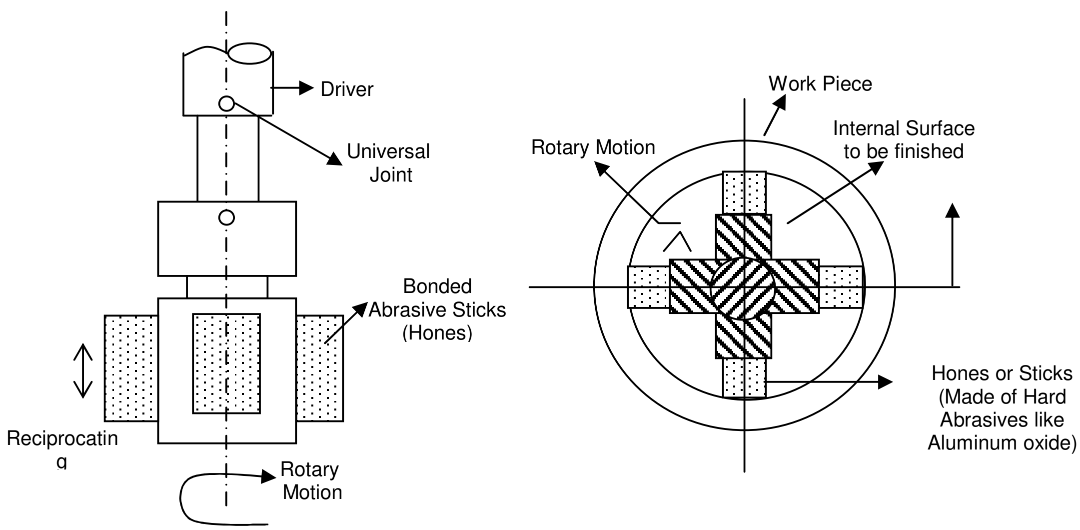

Figure 3.2 : Honing Tool and its Operation

The motion of a honing tool a combination of rotation and reciprocation (linear). The motion is managed in such a way that *a given point on the abrasive stick does not trace the same path repeatedly*. The honing speed may be kept upto 10 cms per sec. Lower speeds are recommended for better surface finish. Manufacturing defects like slight eccentricity a way surface, light tapper, less of circulating can also be corrected by honing process.

The process of honing is always supported by flow of coolants. It flashes away the small chips and maintains a low and uniform temperature of tool and work.

Honing Machines

Honing machines resembles with vertical drilling machines in their construction. Reciprocating motion of spindle is obtained by hydraulic means. The rotary motion may be by hydraulic motor or by a gear train. Depending upon the movement of spindle or hones a machine may be vertical honing machine or horizontal honing machine. Generally honing vertical honing machines are used. Horizontal honing machines are recommended for finishing internal of long gun barrels.

Lapping

Lapping is also one of the abrasive processes used to produce finished (smoothly accurate) surfaces. It gives a very high degree of accuracy and smoothness so it is used in production of optical lenses, metallic bearing surfaces, measuring gauges, surface plates and other measuring instruments. All the metal parts that are subjected to fatigue loading or those surfaces that must be used to establish a seal with a mating part are often lapped. The process of lapping uses a bonded abrasive tool and a fluid suspension having very small sized abrasive particles vibrating between the workpiece and the lapping tool. The process of lapping is shown in Figure 3.3. The fluid with abrasive particles is referred as lapping compound. It appears as a chalky paste. Normally the fluid used in lapping compound is oil or kerosene. The fluid should have slightly lubricating properties to make the action of abrasive mild in nature. Abrasives used in lapping compound are aluminium oxide and silicon carbide. Their girt size is kept 300 to 600 μm. It is hypothesized that two alternative cutting mechanisms are working in the process of lapping.

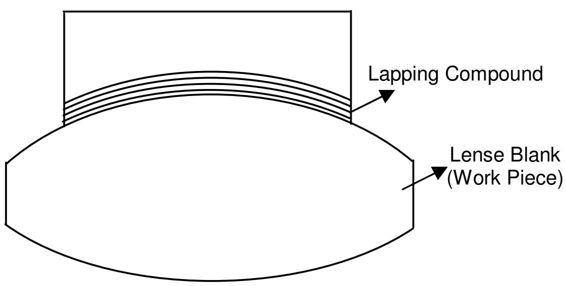

Figure 3.3 : Lapping Process

In first mechanism the abrasive particles roll and slide between the lapping tool and workpiece. These particles produce small cuts on both surfaces. Another mechanism suppose to work in lapping is that the abrasives become imbedded in the lap surface to give cutting action like in case of grinding. It is assumed that lapping is due to the combination of these two above mentioned mechanism. Lapping can be done manually but use of lapping machine makes the process accurate, consistent and efficient.

Machine Lapping

Machine lapping is recognized as fast lapping process. Gudgeon pins with 25 mm diameter and 75 mm long can be lapped at the rate of 500 units per hour. Mechanical lapping machines have vertical construction with the work holder mounted on the lower table which is given oscillatory motion. The upper lap is stationery and floating while lower one revolves at 60 rpm. Some special purpose lapping machines are available for lapping of small parts such as piston pins ball bearing races, etc. in machine lapping a pressure upto 0.02 N/mm^2 for soft material and 0.5 N/mm^2 for hard material is applied.

Lapping Applications

Materials processed by lapping range from steel, cast iron to non-ferrous metal like copper, brass and lead. Wooden parts, made of hard wood, can also be finished using wood laps. Lapping removes material at a very slow rate. So lapping is generally followed by accurate machining of workpieces. Lapping is a costlier process so its applications are justified only when very high grade of surface finishing is required. Lapped surfaces are well resistant to corrosion and wear, used in manufacturing of high precision parts.

Polishing and Buffing

Polishing and buffering are similar surface finishing operations. Polishing is used to remove scratches and burrs from a machined surface. It develops a very smooth surface by means of abrasive grains embedded to a polishing wheel rotating at high rpm. Rotating speed is equivalent to 2300 meter per minutes. The rotating wheels are made of softer materials like canvas, leather or paper. Thus, the wheels are enough flexible to finish the cavities and internal of intricate shapes.

Polishing

Polishing is carried out with the help of above mentioned polishing wheels. Abrasive grains are bonded by gluing to the outside periphery of the wheel. After the abrasives have been worn down and used up, the wheel is replenished with new girts. Depending on the girt size polishing is divided into three categories.

(a) **Rough Polishing :** Girt size is maintained 20 to 80.

(b) **Finish Polishing :** Girt size is kept 80 to 120.

(c) **Fine Finish :** For polishing to give very fine finishing abrasive girt size is maintained to above 120. In case of fine finishing process oil, tallow or beeswax is used as lubricating agent.

There is a limitation of polishing process that the parts with irregular shapes, sharp corners, deep recesses and sharp projections are difficult to polish.

Polishing Tool

Polishing can be done by hand, but for mass production work, specially designed semi-automatic and automatic polishing machines are available. Abrasive particles are Al_2O_3 or diamond. Carrier of abrasive particles has already been discussed. Polished surfaces may be buffed to obtain an even finer surface. Polishing does not improve dimensionless accuracy as done by lapping.

Different between Lapping and Polishing

Lapping and polishing differ in the following manner, polishing produce a shiny surface but lapping does not produce bright shiny surface. Lapping removes metal from the surface to be finished, however, polishing removes negligible amount of metal. Lapping involves cutting action but polishing consists of producing a kind of plastic flow of the surface crystals so that the high spots are made to fill the low spots.

Buffing

Buffing is similar to polishing in appearance, but its function is different. Buffing is used to provide attractive surfaces with high luster. Buffing is like a polishing operation in which the workpiece is brought in contact with a revolving cloth buffing wheel that usually has been charged with a very find abrasive as shown in Figure 3.4. Buffing status is some where in between polishing and lapping. A minor cutting action with microchip is done in case of buffing.

Buffing wheels are made of discs of liners, cotton, broad cloth and canvas. These are made more or less firm by the amount of stitching used to fasten the layers of the cloth together. Buffing tools are enough flexible to polish upto interior of intricate cavities. The buffing tools are named as BUFFING ROUGES. There are semi-automatic buffing machines available consisting of a series of individually drivers buffing wheel which can be adjusted to the desired position so as to buff different positions of the workpiece. The workpieces are held in fixtures on a suitable rotating worktable so as to move the buffing wheels.

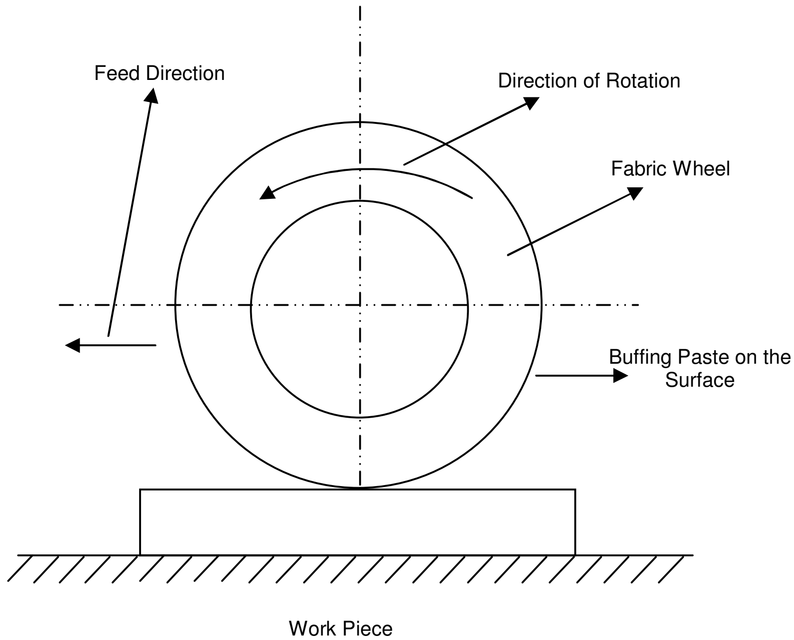

Figure 3.4 : Buffing Wheel Performing Buffing Operation

Application of buffing produces mirror like finish. It is used for finishing of automobile parts, boats, bicycles, sport items, tools, furniture, fixtures, commercial and residential hardware, house hold utensils and home appliances, etc.

Super Finishing

Super finishing is an alternative process similar to honing. This also uses bonded abrasive stick moved with a reciprocating motion and pressed against the surface to be finished. The relative motion between the abrasive stick and the workpiece is varied so that individual grains do not retrace the same path. Cutting fluid is used in the process for cooling of tool workpiece interface. Coolant also washes away the tiny chips produced in the process. The time needed for super finishing is very small. Workpiece may be super finished to a roughness of the order of 0.075 µm within 50 seconds. Sometimes the process of super finishing can be continued upto 3 minutes for very fine quality of finish. Super finishing can be differentiated from honing in the following ways :

(a) Super finishing stroke length is comparatively shorter but frequency is larger. It is upto 1500 stokes/minute.

(b) It requires low pressure application as compared to honing process.

(c) During the process fed is given to workpiece, the fed rate in case of super finishing operation is smaller than honing.

(d) Grit size of abrasive used in case of super finishing is smaller than that is used with hones.

Major applications of super finishing are finishing of computer memory drums, sewing machine parts, automotive cylinders, brake drums, bearing components, pistons piston rods, pins, axles, shafts, clutch plates, guide pins, etc.

3.6 LATHE ATTACHMENTS USED FOR SUPER FINISHING

Super finishing can also be carried out lathe machine. Some attachments of centre lathe along with their capabilities and uses are listed below.

Automatic Plunge Centreless Micro-finishing Machine

It is used for finishing of piston pins, cam followers, rollers, piston rods, etc. The surface finish can be obtained upto 0.2 μ (Ra) value.

Centreless Micro-finishing Machine with Roller Support and Auxiliary Drivers

The dimensions of the job that can be processed by this attachment is diameter 25 to 150 mm and job length upto 2000 mm. It is capable to finish the surface of roughness of 0.3 μ (Ra) to 0.025 μ (Ra). It is used for surface finish of hydraulic cylinder piston rods; shock absorber front fork tubes, IC engine parts, etc.

Attachment for Finishing of Engines and Gearbox Parts

It can be used for surface finishing of IC engine parts and gears, shafts, etc.

Most of the attachments designed and developed for lathe machine meant for some specific purpose. With all the attachment lathe provides the following facilities :

(a) Base to work with the workpiece.

(b) Check to hold the workpiece/tool.

(c) Tool post to hold any processing tool.

(d) It provides motive power or a controlled relative motion between the workpiece and tool. However, there is no end of lathe attachments used for super finishing operation. Any attachment utilizing the above mentioned lathe facilities can be designed and developed.

3.7 SUMMARY

The unit is focused on metal finishing operations. Different types of finishing operations starting from coarse finishing to super finishing are described here. Procedure to work and the machine tool required to execute the processes are described in the unit. Advantages, disadvantages and commercial applications of the processes are also have detailed description.