Module
6
Superfinishing processes

Lesson 30

Superfinishing processes, Honing, Lapping and Superfinishing

Instructional Objectives

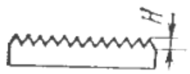
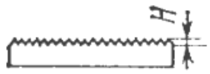
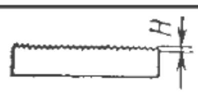
At the end of this lesson the students would be able to

(i) understand the significance of superfinishing process
(ii) state various applications of the superfinishing process
(iii) illustrate various techniques of superfinishing process

To ensure reliable performance and prolonged service life of modern machinery, its components require to be manufactured not only with high dimensional and geometrical accuracy but also with high surface finish. The surface finish has a vital role in influencing functional characteristics like wear resistance, fatigue strength, corrosion resistance and power loss due to friction. Unfortunately, normal machining methods like turning, milling or even classical grinding can not meet this stringent requirement.

Table 30.1 illustrates gradual improvement of surface roughness produced by various processes ranging from precision turning to superfinishing including lapping and honing.

Table 30.1

Process	Diagram of resulting surface	Height of micro irregularity (μm)
Precision Turning		1.25-12.50
Grinding		0.90-5.00
Honing		0.13-1.25
Lapping		0.08-0.25
Super Finishing		0.01-0.25

Therefore, superfinishing processes like lapping, honing, polishing, burnishing are being employed to achieve and improve the above-mentioned functional properties in the machine component.

30.1 Lapping

Lapping is regarded as the oldest 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. Figure 30.1 schematically represents the lapping process. Material removal in lapping usually ranges from .003 to .03 mm but many reach 0.08 to 0.1mm in certain cases.

Characteristics of lapping process:

- ✦ Use of loose abrasive between lap and the workpiece
- ✦ Usually lap and workpiece are not positively driven but are guided in contact with each other
- ✦ Relative motion between the lap and the work should change continuously so that path of the abrasive grains of the lap is not repeated on the workpiece.

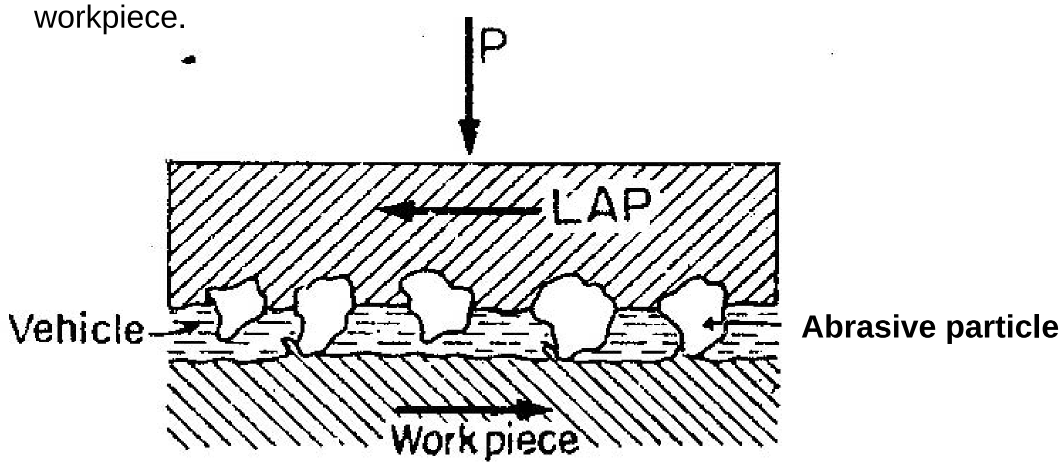


Fig. 30.1 *Scheme of lapping process*

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 are:

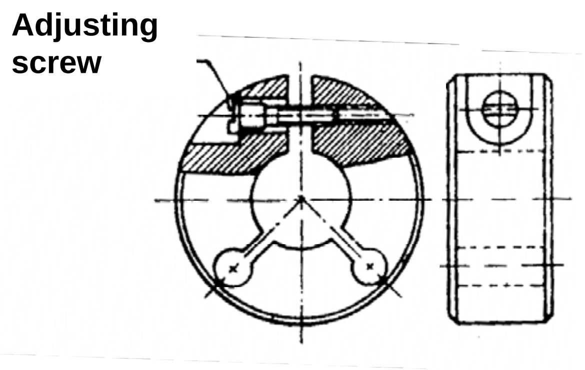
- unit pressure
- the grain size of abrasive
- concentration of abrasive in the vehicle
- lapping speed

Lapping is performed either manually or by machine. Hand lapping is done with abrasive powder as lapping medium, whereas machine lapping is done either with abrasive powder or with bonded abrasive wheel.

30.1.1 Hand lapping

Hand lapping of flat surface is carried out by rubbing the component over accurately finished flat surface of master lap usually made of a thick soft close-grained cast iron block. Abrading action is accomplished by very fine abrasive powder held in a vehicle. Manual lapping requires high personal skill because the lapping pressure and speed have to be controlled manually.

Laps in the form of ring made of closed grain cast iron are used for manual lapping of external cylindrical surface. The bore of the ring is very close to size of the workpiece however, precision adjustment in size is possible with the use of a set screw as illustrated in Fig.30.2(a). To increase range of working, a single holder with interchangeable ring laps can also be used. Ring lapping is recommended for finishing plug gauges and machine spindles requiring high precision. External threads can be also lapped following this technique. In this case the lap is in the form of a bush having internal thread.



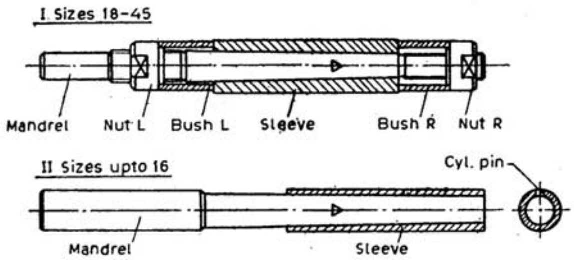


Fig. 30.2 *Manual Ring lapping of external cylindrical surface*

Fig. 30.2 *(b) Manual Lapping of internal cylindrical surfaces*

Solid or adjustable laps, which are ground straight and round, are used for lapping holes. For manual lapping, the lap is made to rotate either in a lathe or honing machine, while the workpiece is reciprocated over it by hand. Large size laps are made of cast iron, while those of small size are made of steel or brass. This process finds extensive use in finishing ring gauges.

30.1.2 Lapping Machine

Machine lapping is meant for economic lapping of batch qualities. In machine lapping, where high accuracy is demanded, metal laps and abrasive powder held in suitable vehicles are used. Bonded abrasives in the form wheel are chosen for commercial lapping. Machine lapping can also employ abrasive paper or abrasive cloth as the lapping medium. Production lapping of both flat and cylindrical surfaces are illustrated in Fig. 30.3 (a) and (b). In this case cast iron plate with loose abrasive carried in a vehicle can be used. Alternatively, bonded abrasive plates may also be used. Centreless roll lapping uses two cast iron rolls, one of which serves as the lapping roller twice in diameter than the other one known as the regulating roller. During lapping the abrasive compound is applied to the rolls rotating in the same direction while the workpiece is fed across the rolls. This process is suitable for lapping a single piece at a time and mostly used for lapping plug gauges, measuring wires and similar straight or tapered cylindrical parts.

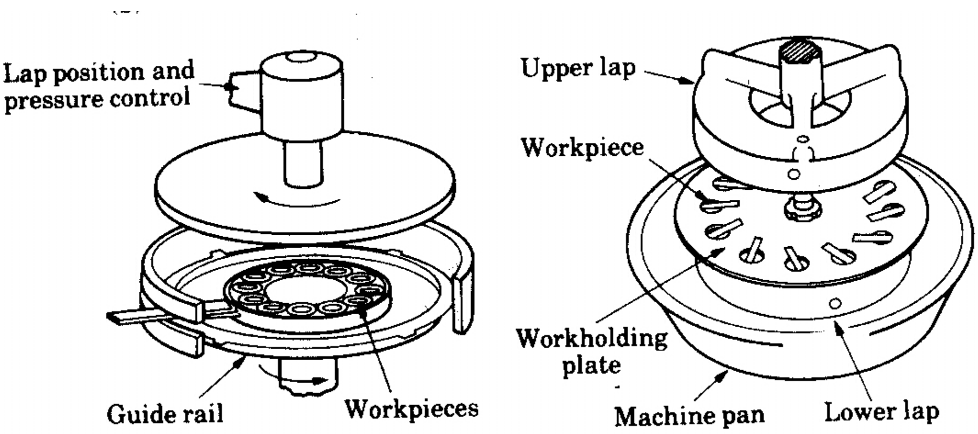


Fig.30.3 *Production lapping on (a) flat surface (b) cylindrical surface*

Centreless lapping is carried out in the same principle as that of centreless grinding. The bonded abrasive lapping wheel as well as the regulating wheel are much wider than those used in centreless grinding. This technique is used to produce high roundness accuracy and fine finish, the workpiece requires multi-pass lapping each with progressively finer lapping wheel. This is a high production operation and suitable for small amount of rectification on shape of workpiece. Therefore, parts are to be pre-ground to obtain substantial straightness and roundness. The process finds use in lapping piston rings, shafts and bearing races.

Machines used for lapping internal cylindrical surfaces resembles honing machines used with power stroke. These machines in addition to the rotation of the lap also provide reciprocation to the workpiece or to the lap. The lap made usually of cast iron either solid or adjustable type can be conveniently used.

Figure 30.4 shows that to maximize the MRR (material removal rate) an optimum lapping pressure and abrasive concentration in the vehicle have to be chosen.

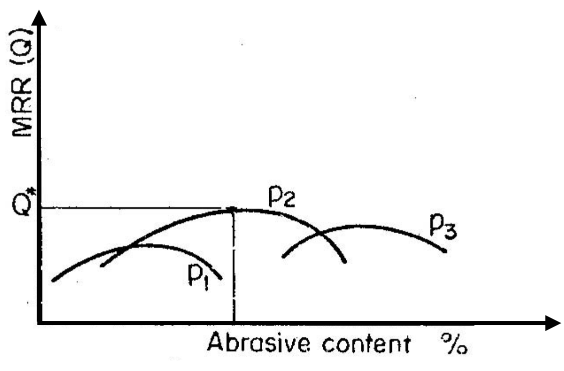


Fig. 30.4 *Effect of abrasive content on MRR*

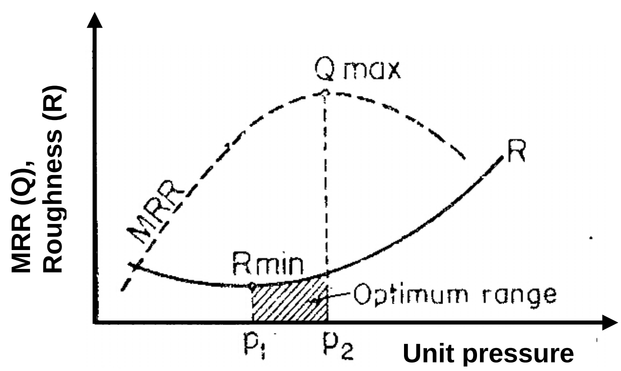


Fig. 30.5 *Effect of lapping pressure on surface roughness and MRR*

The effect of unit pressure on MRR and surface roughness is shown in Fig. 30.5. It is shown in the same figure that unit pressure in the range of p_1-p_2 gives the best values for MRR and roughness of the lapped surface.

The variation in MRR and surface roughness with grain size of abrasive are shown in Fig.30.6. It appears that grain size corresponding to permissible surface roughness and maximum MRR may be different. Primary consideration is made on the permissible surface roughness in selecting abrasive grain size.

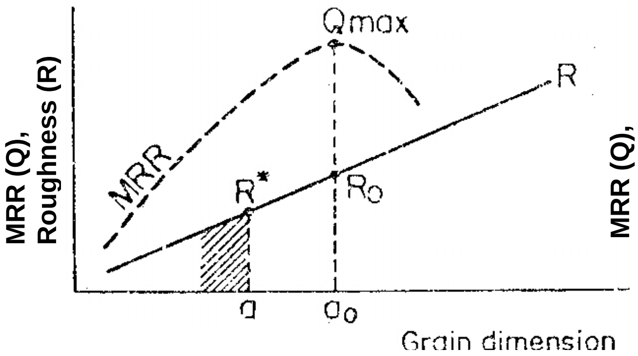


Fig. 30.6 *Effect of abrasive grain size on surface roughness and MRR*

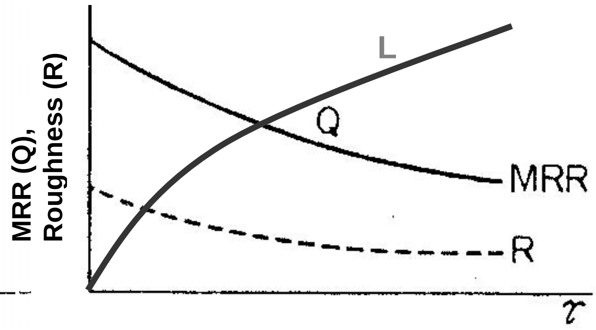


Fig. 30.7 *Effect of lapping time on surface roughness and MRR*

The dependence of MRR, surface roughness and linear loss (L) of workpiece dimension is shown in fig. 30.7. Lapping conditions are so chosen that designed surface finish is obtained with the permissible limit of linear loss of workpiece dimension as shown in Fig. 30.8.

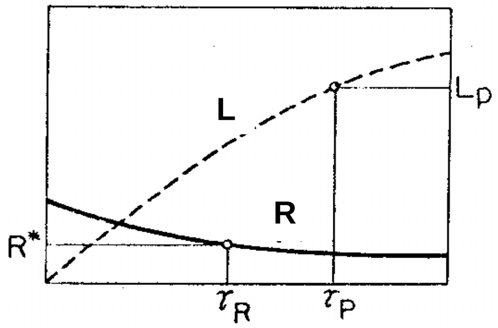


Fig. 30.8 *Criteria for choosing lapping time*

30.2 Honing

Honing is a finishing process, in which a tool called hone carries out a combined rotary and reciprocating motion while the workpiece does not perform any working motion. Most honing is done on internal cylindrical surface, such as automobile cylindrical walls. The honing stones are held against the workpiece with controlled light pressure. The honing head is not guided externally but, instead, floats in the hole, being guided by the work surface (Fig. 30.9). It is desired that

1. honing stones should not leave the work surface
2. stroke length must cover the entire work length.

In honing rotary and oscillatory motions are combined to produce a cross hatched lay pattern as illustrated in Fig. 30.10

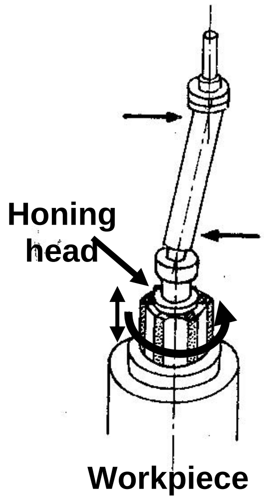


Fig. 30.9 *Honing tool*

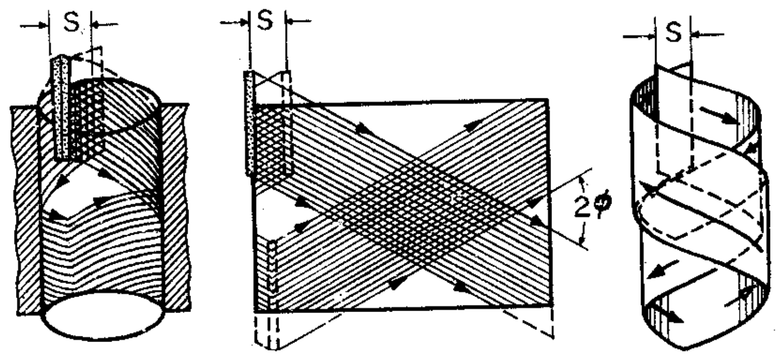


Fig. 30.10 *Lay pattern produced by combination of rotary and oscillatory motion*

The honing stones are given a complex motion so as to prevent every single grit from repeating its path over the work surface. The critical process parameters are:

1. rotation speed
2. oscillation speed
3. length and position of the stroke
4. honing stick pressure

With conventional abrasive honing stick, several strokes are necessary to obtain the desired finish on the work piece. However, with introduction of high performance diamond and cBN grits it is now possible to perform the honing operation in just one complete stroke. Advent of precisely engineered microcrystalline cBN grit has enhanced the capability further. Honing stick with microcrystalline cBN grit can maintain sharp cutting condition with consistent results over long duration.

Superabrasive honing stick with monolayer configuration (Fig. 30.11), where a layer of cBN grits are attached to stick by a galvanically deposited metal layer, is typically found in single stroke honing application.

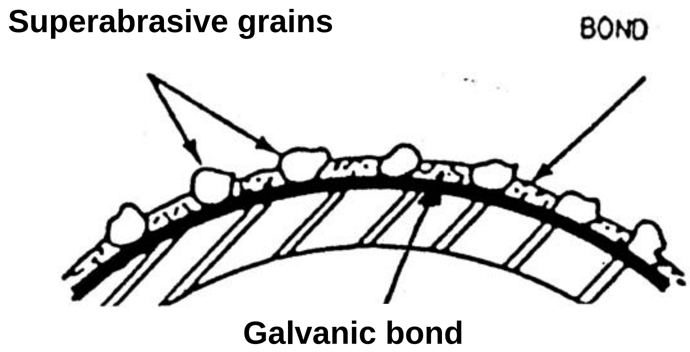


Fig.30.11 *Superabrasive honing stick with single layer configuration*

With the advent of precision brazing technique, efforts can be made to manufacture honing stick with single layer configuration with a brazed metal bond. Like brazed grinding wheel such single layer brazed honing stick are expected to provide controlled grit density, larger grit protrusion leading to higher material removal rate and longer life compared to what can be obtained with a galvanically bonded counterpart.

The important parameters that affect material removal rate (MRR) and surface roughness (R) are:

(i) unit pressure, p
(ii) peripheral honing speed, Vc
(iii) honing time, T

The variation of MRR (Q) and R with unit pressure is shown in Fig. 30.12. It is evident from the graph that the unit pressure should be selected so as to get minimum surface roughness with highest possible MRR.

Fig. 30.12*: Effect of honing pressure on MRR and surface finish*

Figure 30.13 shows that an increase of peripheral honing speed leads to enhancement of material removal rate and decrease in surface roughness.

Figure 30.14 shows that with honing time T, MRR decreases. On the other hand, surface roughness decreases and after attaining a minimum value again rises. The selection of honing time depends very much on the permissible surface roughness.

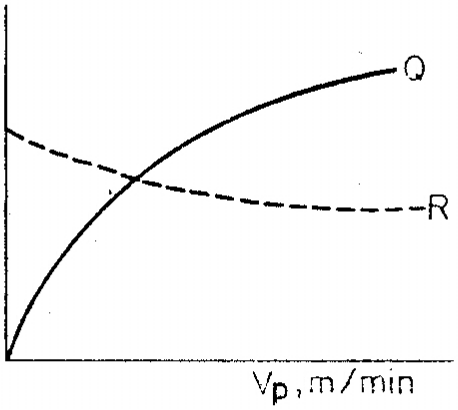


Fig. 30.13 *Effect of peripheral honing speed*

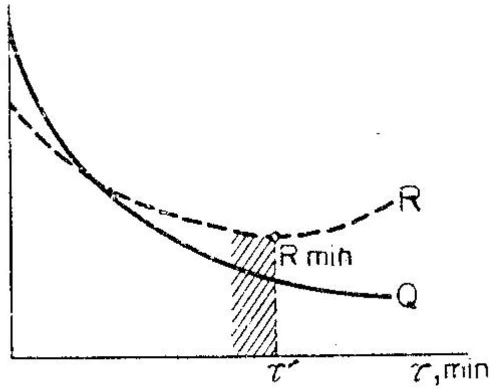


Fig. 30.14 *Effect of honing time on material removal rate and surface roughness*

30.3 Superfinishing

Figure 30.15 illustrates superfinishing end-face of a cylindrical workpiece. In this both feeding and oscillation of the superfinishing stone is given in the radial direction.

Figure 30.16 shows the superfinishing operation in plunge mode. In this case the abrasive stone covers the section of the workpiece requiring superfinish. The abrasive stone is slowly fed in radial direction while its oscillation is imparted in the axial direction.

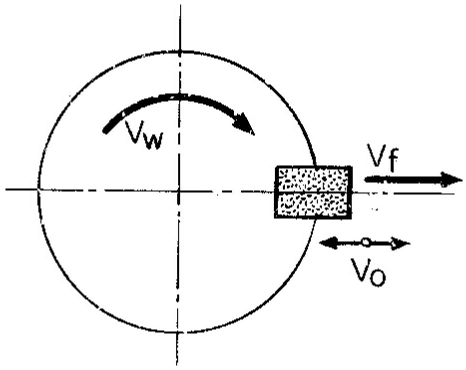


Fig. 30.15 *superfinishing of end face of a cylindrical work piece in radial mode*

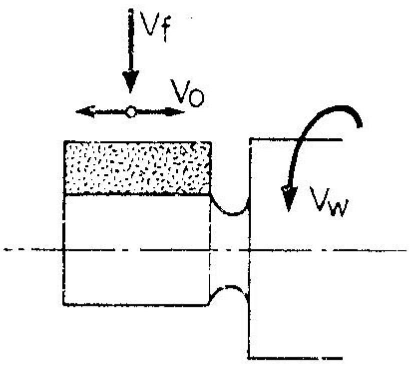


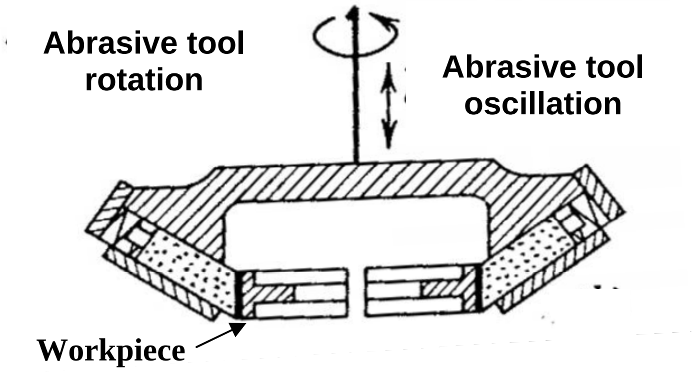
Fig. 30.16 *superfinishing operation in plunge mode*

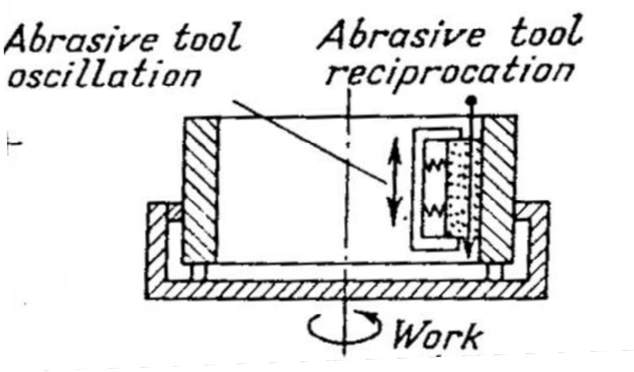
Superfinishing can be effectively done on a stationary workpiece as shown in Fig. 30.17. In this the abrasive stones are held in a disc which oscillates and rotates about the axis of the workpiece.

Fig. 30.18 shows that internal cylindrical surfaces can also be superfinished by axially oscillating and reciprocating the stones on a rotating workpiece.

Abrasive tool oscillation

Abrasive tool reciprocation





Abrasive tool oscillation

Workpiece

Fig. 30.17 *Abrasive tool rotating and oscillating about a stationary workpiece*

Fig. 30.18 *Superfinishing of internal surface*

30.3.1 Burnishing

The burnishing process consists of pressing hardened steel rolls or balls into the surface of the workpiece and imparting a feed motion to the same. Ball burnishing of a cylindrical surface is illustrated in Fig. 30.19.

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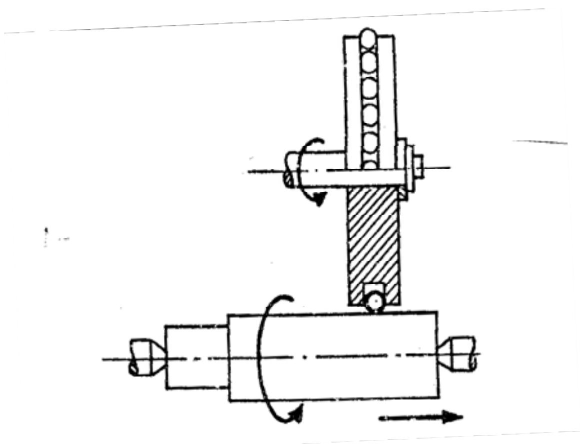

Fig. 30.19 *Scheme of ball burnishing*

During burnishing considerable residual compressive stress is induced in the surface of the workpiece and thereby fatigue strength and wear resistance of the surface layer increase.

30.3.2 Magnetic float polishing

Magnetic float polishing (Fig.30.20) finds use in precision polishing of ceramic balls. A magnetic fluid is used for this purpose. The fluid is composed of water or kerosene carrying fine ferro-magnetic particles along with the abrasive grains. Ceramic balls are confined between a rotating shaft and a floating platform. Abrasive grains ceramic ball and the floating platform can remain in suspension under the action of magnetic force. The balls are pressed against the rotating shaft by the float and are polished by their abrasive action. Fine polishing action can be made possible through precise control of the force exerted by the abrasive particles on the ceramic ball.

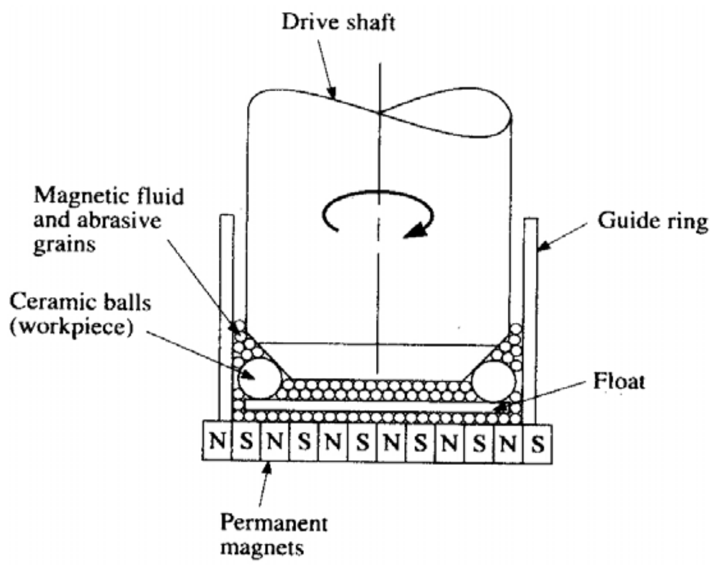

Fig. 30.20 *Scheme of magnetic float polishing*

30.3.3 Magnetic field assisted polishing

Magnetic field assisted polishing is particularly suitable for polishing of steel or ceramic roller. The process is illustrated schematically in Fig. 30.21. A ceramic or a steel roller is mounted on a rotating spindle. Magnetic poles are subjected to oscillation, thereby, introducing a vibratory motion to the magnetic fluid containing this magnetic and abrasive particles. This action causes polishing of the cylindrical roller surface. In this technique, the material removal rate increases with the field strength, rotational speed of the shaft and mesh number of the abrasive. But the surface finish decreases with the increase of material removal rate.

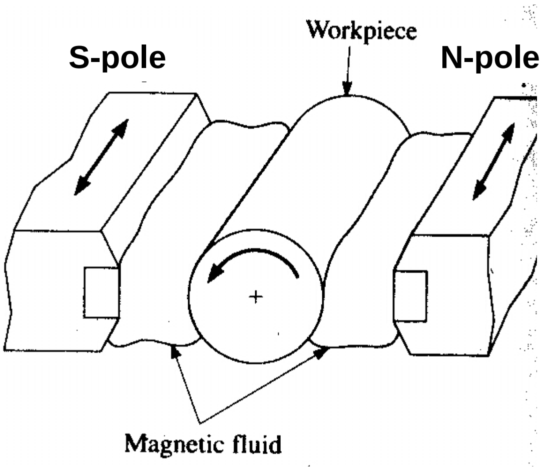

Fig. 30.21 *scheme of magnetic field assisted polishing*

30.3.4 Electropolishing

Electropolishing is the reverse of electroplating. Here, the workpiece acts as anode and the material is removed from the workpiece by electrochemical dissolution. The process is particularly suitable for polishing irregular surface since there is no mechanical contact between workpiece and polishing medium. The electrolyte electrochemically etches projections on the workpiece surface at a faster rate than the rest, thus producing a smooth surface. This process is also suitable for deburring operation.

Exercise 30

Q1: How is the size of the abrasive grain chosen?

Q2: Can cBN be used in honing stick in single layer configuration?

Q3: How does superfinishing differ from honing?

Q4: State the advantage of electro polishing over mechanical polishing.

Q5: How is the surface quality improved in ball burnishing?

Ans1:
Size of the abrasive grain is chosen keeping in view, the permissible roughness of the workpiece and maximum material removal rate attainable.

Ans2:
cBN grits in single layer configuration embedded in galvanic bond can be effectively used as honing stick. Such honing stick is preferred in production honing with just a single stroke operation.

Ans3:
Superfinishing, in a way, is similar to honing but with very low cutting pressure and different kinematic tool-work interactions like

- oscillatory motion of the abrasive stick with short stroke but with high frequency.
- rotation of workpiece is usually kept low.
- feed motion of the tool or the work piece.

Ans4:
Electropolishing has clear advantage in polishing irregular surfaces. The electrolyte attacks high points at a faster rate than rest of the surface resulting in production of a smooth surface.

Ans5:
In this process, a hardened steel ball presses the workpiece surface. The surface finish is markedly improved. In addition, a residual compressive stress is developed on the surface, which in turn improves the fatigue resistance. The work hardening effect, as a result of burnishing, also enhances wear resistance of the surface. Therefore, by ball burnishing the overall quality of the workpiece surface is significantly improved.