4.4. MAGNETIC ABRASIVE FINISHING

4.4.1. INTRODUCTION

Magnetic abrasive finishing process was developed in US, USSR, Bulgaria and Japan. This process is mainly used in finishing radiusing and deburring of various flat surfaces and cylindrical surfaces.

4.4.2. PRINCIPLE

In magnetic abrasive finishing process, the magnetic particles are joined to each other magnetically between magnetic poles along the lines of magnetic force forming a flexible abrasive brush. This magnetic abrasive brush is used to perform surface and edge finishing operation.

4.4.3. CONSTRUCTION AND WORKING OF MAF

- The schematic arrangement of magnetic abrasive finishing is shown in figure 4.11.
- MAF process consists of magnetic abrasive particles, flexible magnetic abrasive brush and workpieces.

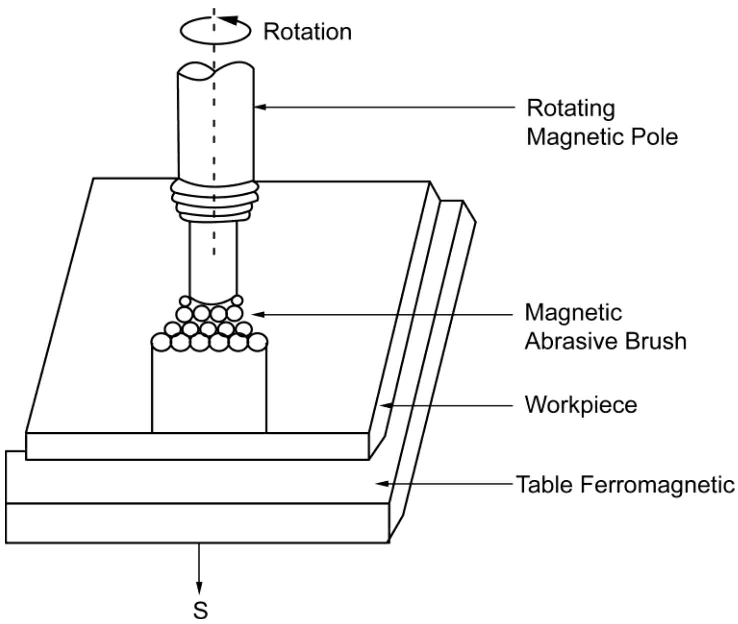

Fig. 4.11. Magnetic abrasive finishing

Magnetic Abrasive Particles

- The rotating magnetic poles consist of granular magnetic abrasives composed of ferromagnetic particles and abrasives as shown in figure 4.9.

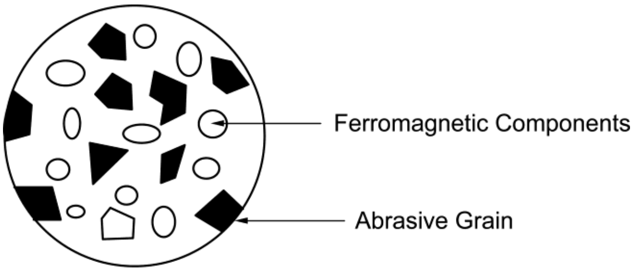

Fig. 4.12. Magnetic Abrasive Particle

- The abrasives used in this process may be silicon carbide, Aluminium oxide and diamond grits.

- These particles acts as the multiple cutting tool.

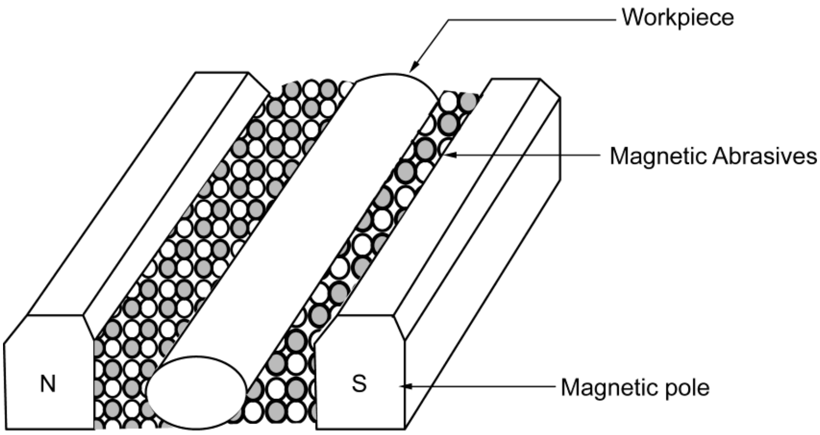

Fig. 4.13. Magnetic abrasive finishing-cylindrical surface

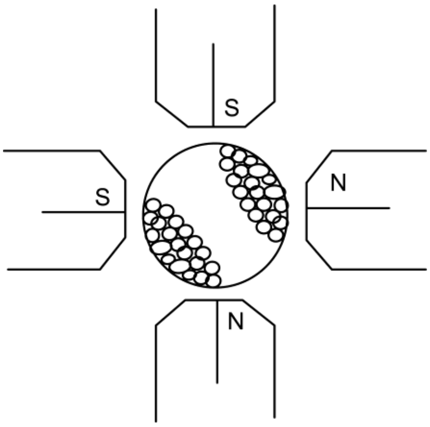

Fig. 4.14. Magnetic abrasive finishing – internal surface

Flexible Magnetic Abrasive Brush

- When electromagnets generates the magnetic field, the ferromagnetic abrasives join with each other under the influence of magnetic field.
- The ferromagnetic abrasive particles join together to produce a flexible magnetic abrasive brush. This brush acts as the cutting tool.
- The magnetic field generated by the electro magnets applies essential finishing pressure on the brush.

- The cutting force essential for metal or workpiece finishing is provide by the magnetic field.

Workpiece

- The workpiece used in MAF process is ferromagnetic or non ferromagnetic materials.
- The workpiece is placed between the poles of magnet.
- The workpiece may be flat surface, internal and external surface of cylindrical objects for finishing.

Working

- When the electromagnets generates the magnetic field. This magnetic field influence the abrasive particles.
- In presence of magnetic field, the magnetic abrasive particles join with each other to magnetic abrasive brush.
- The magnetic field produced generates the essential pressure require to move the abrasive brush.
- The magnetic field also controls and regulates the essential cutting force required to abrade the peaks on the surface of the workpiece.
- The magnetic flux density produced will rotate, vibrates and produce axial movement on the workpiece surface.
- The flexible magnetic brush receives the actions due to magnetic flux density and produces sharing action on workpiece.
- The force acting on the workpiece is exerted by the magnetic flux density through the flexible magnetic abrasive brush.
- The force acting on the workpiece are of two types (*i*) Normal force (*ii*) Tangential force.
- The normal force acting in "F" which is responsible for actuating the abrasive particles along the magnetic force, it is mainly responsible for cutting action or penetration in the workpiece. The tangential force acting in "F_x" which is responsible for enhancing the surface finish of the workpiece and removes the material in the surface of workpiece.
- It also improves the surface finish of the workpiece and removes thematerial in the surface of workpiece.

- It also improves the surface integrity by introducing the compressive residual stresses.
- The normal and tangential force are expressed as

$$F_y = \frac{\pi D^3}{6} kH \left(\frac{\partial H}{\partial y}\right)$$

$$F_x = \frac{\pi D^3}{6} kH \left(\frac{\partial H}{\partial x}\right)$$

where D - diameter of abrasive particles

k - susceptibility of magnetic abrasive particle

H - magnetic field strength

- The force required to remove material is

$$F_{req} = \tau_s A_p$$

where τ_s - shear strength of workpiece

A_p - projected area of penetration

$F_{req} = F_t \Rightarrow$ equilibrium condition

$F_{req} < F_t \Rightarrow$ material removal exchanging

$F_{req} > F_t \Rightarrow$ non cutting condition

- The variables of MAF process are type and size of magnetic abrasives, mixing ratio of abrasive grains with ferromagnetic particles, working clearance, rotational speed, vibration, property of workpiece material magnetic flux density and relative speed of magnetic abrasive to work surface.
- These variables affects the material removal rate, machined depth, surface finish and surface integrity.
- In plane finishing process, the magnetic force on the work surface depends on rigidity of the brush and grain size of the magnetic abrasives.
- The finishing efficiency of the brush depends on the size of abrasiveparticles mixed. If small size diamond abrasives of irregular shape ismixed in the brush, the finishing efficiency is good.
- The surface finish or surface roughness value produced is around 0.5 μm.

- ❖ Based on bonded or unbounded magnetic particles, the material removal rate is determine.

For unbounded – 55 mg/min and bonded = 10 mg/min

4.4.4. FACTORS AFFECTING PROCESS PARAMETERS

1. Pressure
2. Type and size of grains
3. Finishing efficiency
4. Bonded and unbounded magnetic abrasive
5. Magnetic flux density.

1. Pressure

- ❖ When the pressure exerted by the magnetic abrasive in decreased, the clearance between the magnetic pole and the workpiece is increased.

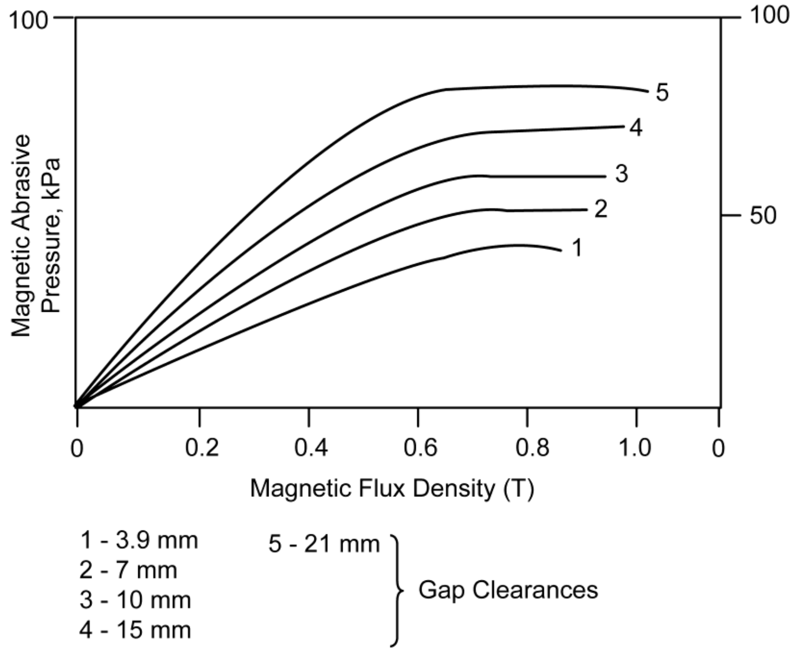

Fig. 4.15.

- ❖ When the magnetic abrasive pressure increases with increase in magnetic flux density, the gap clearance reduces from 21 mm to 3.9 mm.

- ❖ It is clear from the graph 4.15 that as magnetic flux density increases the magnetic abrasive pressure also increases linearly.

2. Types and Size of Grains

- ❖ From the graph 4.16, it is clear that as finishing time increases the surface roughness is reduced or improved.
- ❖ The magnetic force of magnetic abrasive brush are governed by the grain

size of magnetic abrasives.

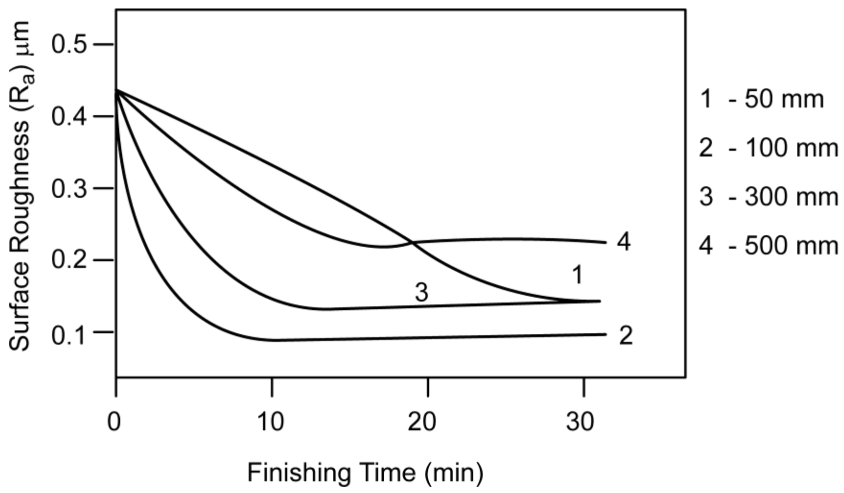

Fig. 4.16.

- ❖ If finish is in the larger is the particle size, then the material removal is higher and the surface finish is poor.
- ❖ If finer is the particle size, then the stock removal is less and the surface finish is good.

3. Finish Efficiency

- ❖ Finishing efficiency can be improved by adding small size of diamond abrasives with larger size ferromagnetic particles.
- ❖ Both the size and mixing proportion of ferromagnetic particles influence the characteristics of the finished surface.
- ❖ Optimum value of mixing weight percentage of particles form best surface finish and largest machining depth.

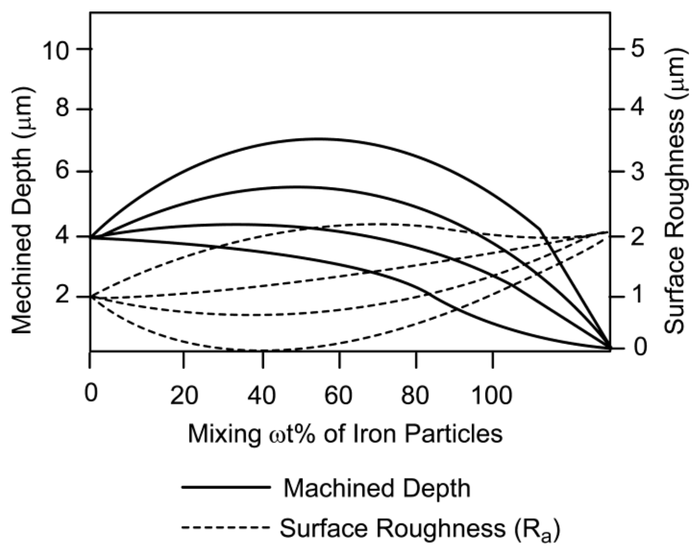

Fig. 4.17.

4. Bonded and Unbonded Magnetic Abrasives

- From the graph 4.18 it is clear that bonded magnetic abrasives produced better surface finish.
- And unbounded magnetic abrasive produce higher material removal than surface finish.

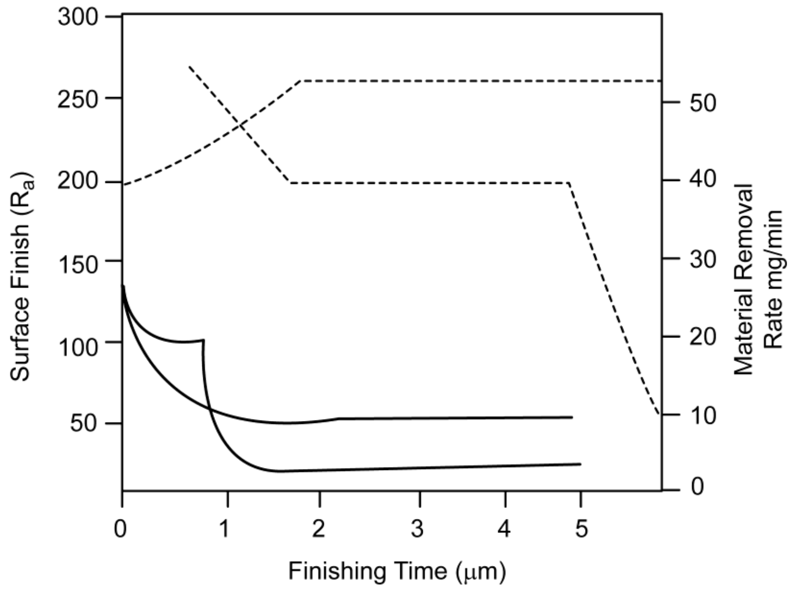

Fig. 4.18.

5. Magnetic Flux Density

- When the magnetic flux density increases the machining depth get increased.
- In plane finishing operation, the surface roughness is improved with the increase in magnetic flux density and finishing time.

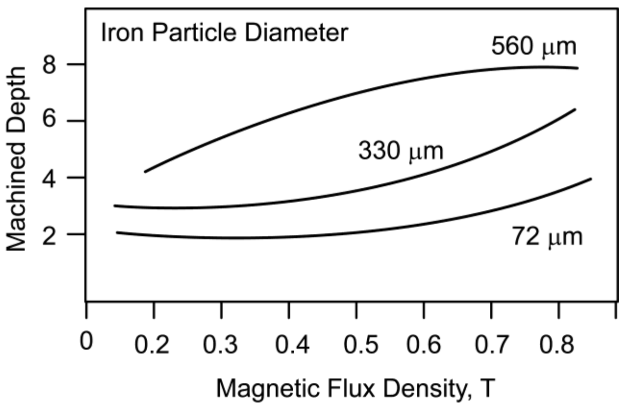

Fig. 4.19.

4.4.5. ADVANTAGES OF MAF

- MAF have self adaptability and easy controllability
- Surface finish is in order of nanometer.
- The device can be easily mounted on other machine without the need of high capital investment.

4.4.6. DISADVANTAGES OF MAF

- ❖ It is difficult to implement MAF in mass production operation.
- ❖ It is a time consuming process.
- ❖ It is not applicable for some ordinary finishing task where conventional finishing technique can be easily implemented.

4.4.7. APPLICATIONS OF MAF

- ❖ It is used in finishing processes such as lapping, buffing, honing and burnishing operation in surface of tubes, bearing and automobile components.
- ❖ Precision deburring can be done on edges of the workpiece.
- ❖ Polishing and removal of thin oxide film from high speed rotating shafts.
- ❖ It is used in finishing operations of cutting tools, turbine blades, air foil optics and sanitary pipes.
- ❖ It is used in medical field in areas of capillary tube, needles and biopsy needles etc.

4.5. MAGNETO RHEOLOGICAL FINISHING

4.5.1. INTRODUCTION

A magneto rheological fluid is a layer of smart fluid in a carrier. It is a type of oil when subjected to a magnetic field, the fluid increases it apparent viscosity to the point that it becomes a viscoelastic solid.

Rheology is a science of flow and deformation study of rheological properties of the medium. The performance of the medium. The performance of the medium is given by its rheological properties.

Flow behavior of the medium is complex in nature as it is a heterogeneousmixture. Each ingredient of the mixture is responsible for its flow behavior.

4.5.2. PRINCIPLE

In magneto rheological finishing process under the influence of magnetic field the MR fluid (Magneto rheological fluid) becomes a viscoelastic solid. This act as the cutting tool to remove the materials from the surface of the workpiece.

4.5.3. CONSTRUCTION AND WORKING OF MRF

The schematic arrangement of magneto rheological polishing is as shown in figure 4.20.

The MRF experimental setup consist of electromagnets, nozzle, suction pipe, pumps and MR fluid conditioner.

Magneto rheological finishing process relies on magneto rheological effect exhibit by carbonyl iron particles along with non magnetic abrasives in the carrier medium.

MR fluids are suspension of non colloidal magnetically soft particles in organic or aqueous liquid.

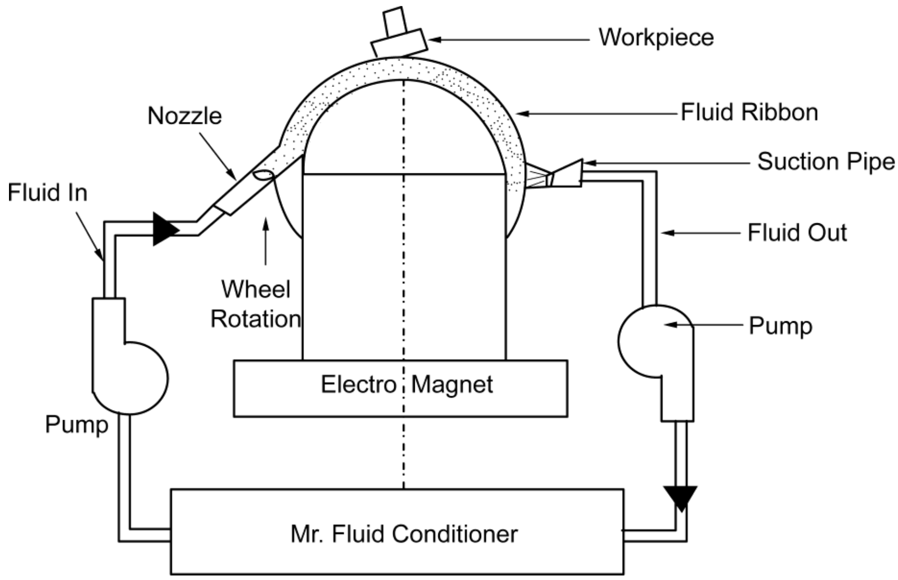

Fig. 4.20. Magneto rheological finishing process

The basic components in MR fluid are

1. Magnetic dispersed phase
2. Abrasive particles
3. Stabilizers
4. Carrier fluid

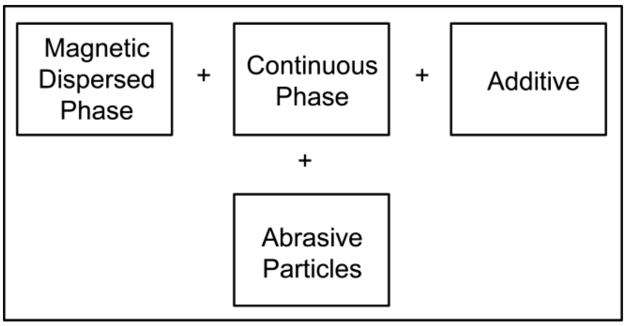

Fig. 4.21.

Magnetic Dispersed Phase

- ❖ It is a base carrier fluid which is non magnetic in nature. The metalparticles are suspended with water, hydrocarbon oils, mineral oils, silicon oils and glycols.

- MR fluids are suspension of micron sized magnetizable particles (0.05 – 10 μm) in a non magnetic carrier base fluid surfactants and anticorrosive additives.
- Magnetizable metal particles such as carboyl iron powder and iron cobalt alloy powder are used.

Characteristic of Base Carrier Fluid

- Optimum concentration of magnetic particles and abrasives
- High yield stress under magnetic field
- Low off state visciocity
- Resistance to corrosion
- High polishing efficiency

Abrasive Particles

- Abrasive particles are non magnetic particles in MR fluid
- The important property of abrasives are granularity and hardness
- The abrasives used are Aluminium oxide, silicon carbide, cerium oxide and diamond powder
- Polishing abrasives such as Alumina and diamond power is used in polishing optical materials.

Carrier Fluid

- The function of carrier fluid is it acts as a medium in which solid particles, CIP‟s abrasives are suspended.
- Off state viscosity of MR fluid should be as low as possible as it can flow and reach each and every corner of the area.
- The important properties of carrier fluid are
    - Should be non corrosive with magnetic particles and abrasives.
    - Should have high boiling temperature and low freezing point.
    - Should not show any significant variation in viscosity with temperature.
- The types of carrier fluid used are (*i*) Oil based (*ii*) Water based
- Oil based carrier fluid has high viscosity, MR fluid have good performance in stability and sedimentation
- Water based MR fluid have high yield stress. Water has hydroxylation to glass for improving finishing efficiency.
- In addition, the water also cools the workpiece during finishing.

Stabilizers

- ❖ The main function of stabilizers is used to disperse the magnetic particles and abrasives uniformly in suspension
- ❖ It is used to retard oxidation of the magnetic particles and percent agglomeration
- ❖ The types of stabilizers used are (*i*) glycerol and grease
- ❖ The main function of stabilizers is that it creates a coating on the particles so that MR fluid can easily re-disperse
- ❖ It helps to present the dense magnetic particles from setting too fast and reduce the formation of hard sediment which in difficult to remix.

Workpiece

The workpiece material used in MRF in optical lenses, glasses and ceramic.

Nozzle

Nozzle in the opening connected by the pump from the MR fluid conditioner.

Nozzle is used to deliver the MR fluid over the surface of the electromagnetic rotating wheel.

Suction

- ❖ It is a point at which the MR fluid is sucked after finishing the polishing process.
- ❖ It is sucked by this pipe and pumped into the MR fluid conditioner again.

Working

- ❖ An electromagnet is placed below the moving roller which generates the magnetic field in the area around hemispherical region of the rotating wheel is as shown in figure 4.22.

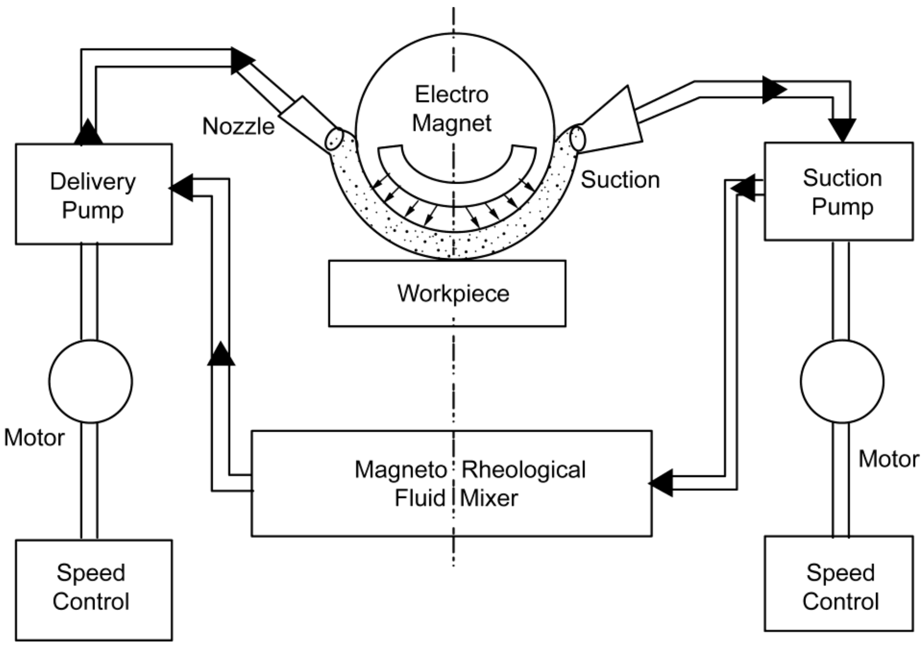

Fig. 4.22. Magneto rheological fluid circulation system

- Magneto rheological fluid is delivered to the moving roller just above the electromagnetic pole through the nozzle.
- This fluid is influenced by the magnetic field. In presence of the magnetic field, the fluid becomes a thin polishing ribbon.
- This polishing ribbon contains the CI particle closed to magnetic fluid and abrasives above the CIP chain which touch the surface of workpiece to be polished. It acquire a plastic Bingham‟s property.
- MR fluid is extruded into the rotating wheel form a thin ribbon that will contact the optical surface of the workpiece.
- Electromagnets below the rotating wheel creates a strong local magnetic field gradient.
- The strength of magnetic field gradient influences the stiffness of MR fluid and pulls it. The MR fluid produces dynamic field strength of 50-100 kPa. The controlled zone magnetized fluid becomes the polishing tool.
- The ribbon is pulled against the moving wall by magnetic field gradient. It is dragged through the gap resulting in material removed in the surface of the workpieces.

- Material removal takes place due to shear stress. The workpiece is positioned above the abrasive involved in finishing operation. There are two types of forces acting on the roller. 1. Normal force and 2. Tangential force.
- The normal force represent as „F_n‟ this force penetrates the abrasive inside the workpiece. Under magnetic force, the particle squeezes in the converging gap.
- The other force is the tangential force „F_{xy}‟ which helps in removal of material in form of micro- nano chips. This is done by shear flow of MR fluid which pushes the abrasives forward. The resultant force "F_r" moves the chip from the workpieces.
- In absence of magnetic field the abrasive ribbon changes the viscoelastic nature into fluid. This fluid is sucked by the suction pipe.

Carbonyl iron particles in columnar and structure in presence of magnetic field get aligned along the lines of magnetic force. The abrasive floats on the outer layer of the magnetic field which is in contact with the workpieces.

When the ribbon have relative motion due to magnetic flux gradient with respect to work surface, the surface of the work[piece get abraded due to shearing plastic deformation at the tips. Thus finishing or polishing operation is carried out. MR fluid is efficient process for high precision finishing of optics. It is also used for free from shapes.

The merits of using MR polishing fluid lap are

- It is adjustable with respect to magnetic field.
- It carry away the heat and debris from the polishing zone.

- ❖ It does not produce any pressure like of grinding wheel.
- ❖ It does not lodes, it sharpness as it is self deformable.

The accuracy produced by computer controlled MRF process is in the order of 10-100 nm.

4.5.4. FACTORS AFFECTING PROCESS PARAMETERS

The factor affecting process parameters are

1. Concentration of CIP"s abrasives
2. Working gap
3. Wheel speed

Concentration of CIP's and Abrasive

From the graph 4.23 it is clear that, as force increases it pushes CIP"s and the concentration get increases. Thus the working gap decreases and polishing operation is good.

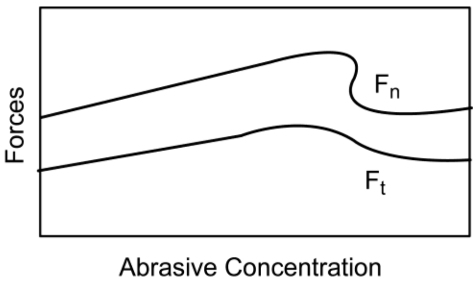

Fig. 4.23.

When both forces increase there is an increase in abrasive concentration upto 3.5%, but after that they decrease with further increase in abrasives particle concentration.

Working Gap

- ❖ When normal as well as tangential forces decrease with increasing working gap.
- ❖ When both forces increases there is a increase in CIP concentration and gap is reduced.

Wheel Speed

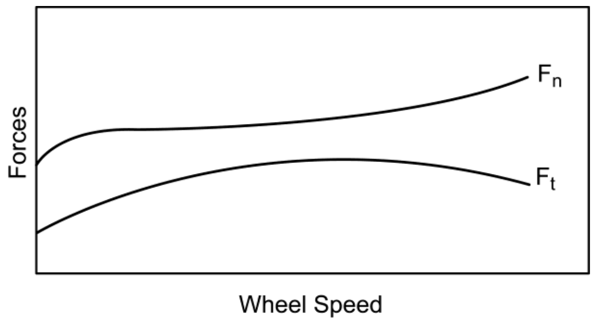

Fig. 4.24.

The normal force increases with increase in wheel speed but tangential force increases upto certain limit of wheel speed beyond which it starts decreasing.

Effect of wheel speed ion the normal force “F_n” and tangential force “F_t”CIP = 40%, abrasive 45% and working gap = 1 mm.

4.5.5. ADVANTAGES OF MRF

- High accuracy
- Enhances product quality and repeatability
- Increases production rate, productivity yield and cost effectiveness.
- Manufacture of precision optics.
- Optical glasses with roughness of less than 10 angstrom can be machined.
- Polishing tool can be easily adjusted and confines perfectly to the workpiece surface.
- Obtain high precision surfaces without any damage
- Surface finish upto nanometer level is achieved without sub surface damage.

4.5.6. LIMITATIONS OF MRF

- High quality fluids are expensive.
- Fluids are subject to thickening after prolonged used and need replacement.
- Settling of ferromagnetic particles can be a problem for some application
- This process is not suitable for finishing of internal and external surface of cylindrical components.

4.5.7. APPLICATIONS OF MRF

- Use in lens manufacturing
- Optical glasses, single crystals, calcium fluorides silicon ceramic are machined.
- Square and rectangular aperture surface such as prism, cylinder and photo blank substrates are machined
- The nano diamond doped MR fluid removes edge chips, cracks and scratches in sapphire bend bars
- Polishing of high aspect ratio optics and thin film filling and semiconductor wafers
- It is also used machining materials like glass, copper and tantalum
- It is used in automobile, electrical and manufacturing fields.

4.6. MAGNETO RHEOLOGICAL ABRASIVE FLOW FINISHING

This process is the combination of two finishing processes. They are abrasive flow machining and magneto rheological finishing. This process eliminates the limitations in AFM and MRF.

The limitations in AFM are lacks to control its properties like viscosity and wall shear stress and also difficult to mix the abrasive particles which made to think of better alternatives.

The limitations of MRF is, it is ineffective polishing hard metals and it is used for machining flat, spherical and external surfaces.

After studying these processes, it was planned to eliminate the limitations of both the processes and combine its advantages.

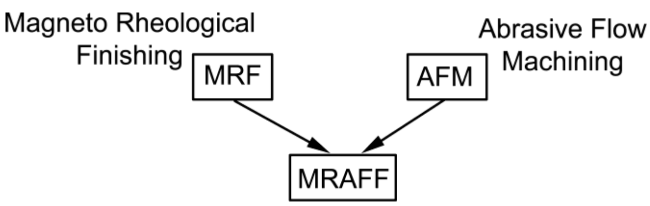

Fig. 4.25.

On combining the process, the abrasive medium in magneto rheological abrasive flow finishing can be manipulated and controlled in real time and also it helps in deterministically and selectively abrade the workpiece surfaces.

The machining setup is similar to AFM will remove the shape limitation in workpiece surface.

Magneto rheological polishing fluid comprises of carbonyl iron powder andsilicon carbide, abrasive dispersed in the viscoplastic base of grease and mineral oil.

When external magnetic field is applied these fluid exhibit change in rheological behavior. These fluids behaves smartly and does the finishing operation precisely.

4.6.1. CONSTRUCTION AND WORKING OF MRAFF

The schematic arrangement of MRAFF is as shown in figure 4.26.

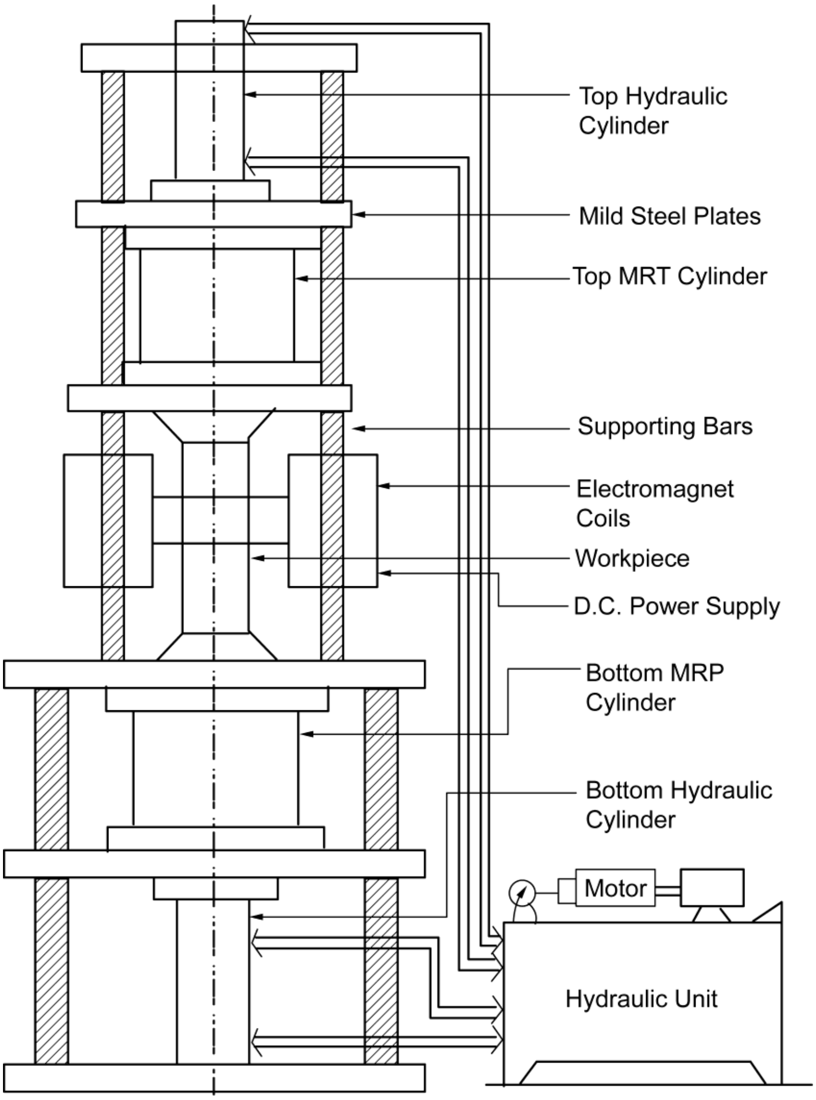

Fig. 4.26. Magneto rheological abrasuive flow finishing

Magneto rheological abrasive flow finishing arrangement consists of hydraulic cylinders, MR fluid cylinder with piston, workpiece and workpiece fixtures, electromagnets.

Electromagnets

The electromagnets are placed on either side of the workpiece fixture. It consists of 2000 turns of 17 SWG copper wire.

Workpiece and Workpiece Fixtures

The workpieces are inserted in the workpiece fixtures, which are placed in between the two cylinders.

The workpiece material is metal and metal alloys.

MR Polishing Fluid or Medium

The magneto rheological polishing fluid consists of magnetic dispersed phase, continuous phases and additives along with abrasive particles.

Magneto rheological polishing fluid consists of magnetic dispersed phase, continuous phases and additives along with abrasive particles.

Magneto rheological fluid or MR fluid are suspension of micro sized, magnetizable carbonyl iron particles in non magnetic carrier base fluid with abrasives.

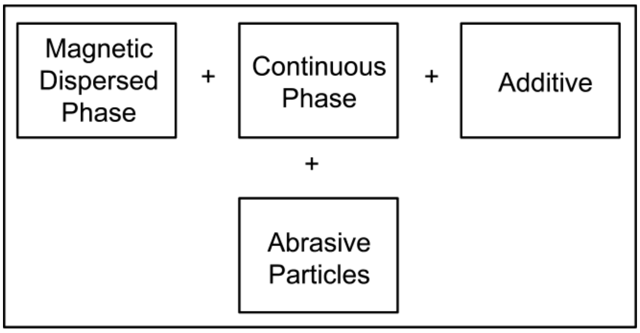

Fig. 4.27.

Magnetic Dispersed Phase

The CI particles in presence of magnetic field forms a chain along the magnetic line of force and holds the abrasives in between them.

CIP"s contains high purity nearly 99.9% of iron powder. The concentration of these particles are 30-50% by volume. The particles sizes are around 10-30 μm.

The other materials that can be used as CIP"s are FeCO alloys – Ferromagnetic materials like Mn Zn ferrite and NiZn ferrite.

Continuous Phase

Organic fluids are used as continuous phase for MR fluids. The other type of fluids are silicone oils, kerosene, mineral oil and glycol.

Additives

It is used to achieve stability against settling and enhance dispensability repeatedly.

Common additives such as silica, fibrous carbon and surfactants such as oleic acid.

It"s main function to avoid settling down of iron particles.

MR fluid is mixture of 26.6 vol% of electrolytes, 99.5% of Fe powder, 13.4 vol% of silicon carbide abrasive with 4.8% paraffin oil and 12% AP_3 grease.

The suspension is prepared by mixing solid particle into continuous phase and stirring with the help of specially designed mixer for an hour.

Hydraulic Cylinders

Hydraulic cylinders with actuators and housing frames are placed on the top and bottom of the experimental setup. This enables to push the MR fluids to and forth of the setup.

These actuators clamp the MR fluid cylinder and workpiece sand witched between them.

The frames and housing are used to hold the experimental setup in accurate position during polishing.

The top and bottom double acting cylinders are connected in series to operate regardless to the difference in magnitude of load resistance. Fluid from the top cylinder is used to pour during the downward stroke and vice versa.

The connecting rods of hydraulic cylinders are coupled with Aluminium piston with Teflon rings upside MRF cylinder. With helps of the hydraulic cylinders, MR fluids is pushed into the fixture through Teflon pistons.

Characteristic of Magneto Rheological Fluids

- Faster response time
- High dynamic yield stress
- Low off- state viscosity
- Resistance to setting
- Easy remixing
- Excellent wear and abrasive resistance

Mechanism of Magneto Rheological Abrasive Flow Finishing

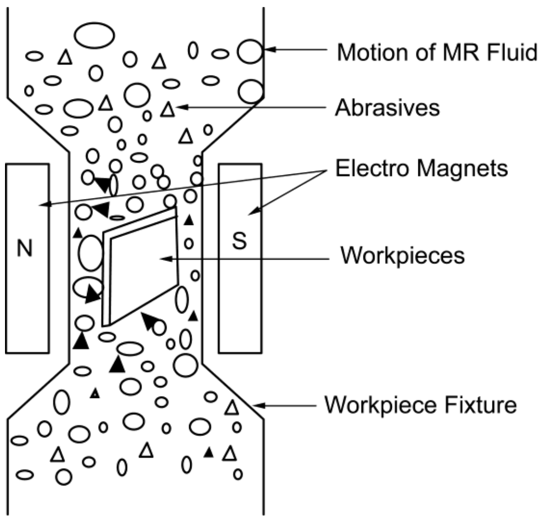

Fig. 4.28.

Working

- Hydraulic ram alternatively undergoes compression and extrusion in the medium cylinder and moves the MR fluid from the bottom media cylinder to the top through the workpiece.
- Appropriate pressure is applied to the hydraulic cylinder for movement of the MR fluid medium.
- The MR fluids with the CI particles abrasive and additives are mixed mechanically in semisolid state before placing in the medium cylinder.
- When pressure is applied by the hydraulic actuators the media cylinder

pushes the MR fluid to move upwards through the workpiece.

- When the MR fluid reaches the workpiece it is influenced by the localized magnetic field using the electro magnets.
- It develops maximum magnetic field gradient of 0.1 tesla in which the MR fluid behaves smartly and passes across the workpiece in a gap of 30 mm, the CI particles lies closer to magnetic field and abrasive particles entrap in them and lies outwards as shown in figure . 4.28.
- The abrasives on the MR fluid is squeezed under high pressure and viscosity around the workpiece. Thus the workpiece surface get abraded and material removal takes place.
- This compression and extrusion of the MR fluids result in finishing operation. The MR fluid media cylinder is moved from bottom to top or viceversa.
- The finishing efficiency of the MR fluids relies mainly on the rheological properties of fluid.
- The rheological properties such as yield stress and viscosity are characterized based on the specific applications.
- The property of the MR fluid is responsible for binding/bonding strength of abrasive particles surrounding CI particles or CIP chain.
- MR fluid‟s composition and volume ratio have an impact on rheological property and stability.
- Rheometer with magneto rheological devices is used to find the property analysis and temperature distribution of the fluid.

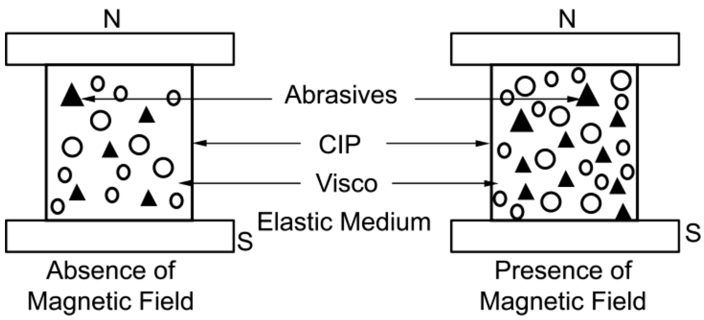

Fig. 4.29. Microscopic image of MR fluid

- The microscopic image of MR fluid is presence or absence of magnetic field is shown in figure. 4.29.
- In absence of magnetic field, the CIP abrasives in the carrier fluid are randomly distributed without any order.
- And also the MR fluid along with the abrasives moves around the peaks on the workpiece. But there is no effective removal of material as shown in figure. 4.30.

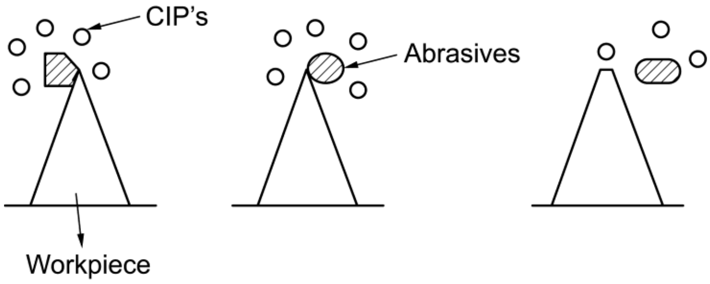

Fig. 4.30. Absence of magnetic fluid

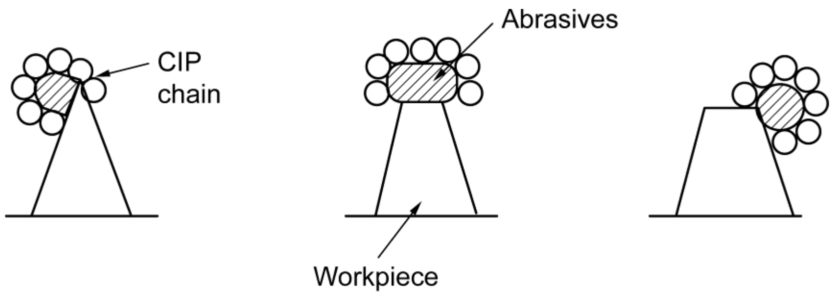

Fig. 4.31. In presence of magnetic fluid

In presence of magnetic field, the MR fluid acts smartly, CIP forms a chain and holds the abrasives in between them as shown in figure 4.31.

This smart fluid on compression follows a controlled path and effectively strikes on the peals of the workpieces. Thus material abrades.

The forces acting on MRAFF process are normal and tangential force which is responsible for penetration of abrasives into the workpiece and removal of materials from the workpiece.

The movement of the MR fluid is linear in direction along the magnetic field of the workpieces.

At extrusion hydraulic pressure of 3.75 MPa, maximum improvement in surface finish is observed due to optimum concentration of magnetic field.

The best surface finish is obtained at stainless steel workpieces was 30 mm at optimum finishing condition of N-400 cycles, P = 3.75 MPa , B – 0.668 Tesla.

The maximum surface finish obtained in 0.10μm at around 2000 finishing cycles.

4.6.2. FACTOR AFFECTING PROCESS PARAMETER

- ❖ The main factor which influences the surface finishing process in number of cycles and magnetic flux density.
- ❖ When the number of cycles is around 200, the quality of surface increases and then decreases.
- ❖ When the number of cycles increases beyond 400, the finishing rate get increased as shown in figure. 4.32.

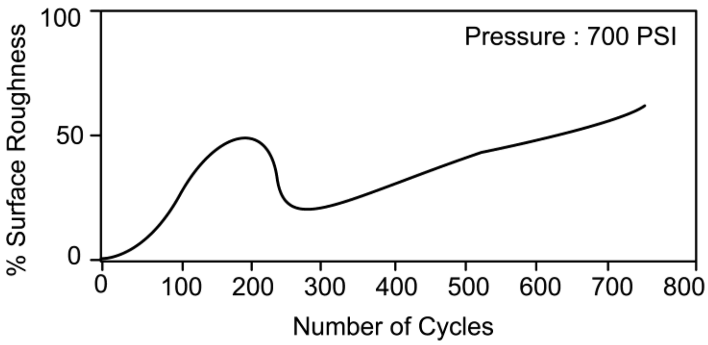

Fig. 4.32.

4.6.3. ADVANTAGES OF MRAFF

- ❖ The viscosity of abrasives in MRAFF can be controlled in real time and also it helps in finishing the workpieces determistically.
- ❖ Complex structures can be easily machined.
- ❖ Localized finishing is possible
- ❖ Thermal distortion is negligible
- ❖ High machining versatility.

4.6.4. LIMITATIONS OF MRAFF

- ❖ Low finishing rate

- Non uniform magnetic field produces non uniform surface finish
- Required a closed environment.

4.6.5. APPLICATIONS OF MRAFF

- Used in investment cast milled parts, airfoil, cast aluminum automobileturbo components
- Complex piping for values, fittings, tubes and flow meter
- Finishing of automotive gears in a single pass, heart values, exhaustmanifold and high pressure holes.
- Used in finishing of heart valves, exhaust manifold and high pressureholes.