ADVANCED FINISHING PROCESSES (AFPs)

TRADITIONAL FINISHING PROCESSES

- **Grinding**
- **Lapping** - uses loose abrasives to finish the surface
- **Honing** - abrasives in the form of stones or sticks carried in an expanding and oscillating mandrel are used to generate random cross-marked surface with good finish

Comparison of surface finish obtainable by different finishing processes

S.No.	Finishing Process	Workpiece	Ra value (nm)
1.	Grinding	-	25 - 6250
2.	Honing	-	25 - 1500
3.	Lapping	-	13 - 750
4.	Abrasive Flow Machining (AFM) with SiC abrasives	Hardened steel	50
5.	Magnetic Abrasive finishing (MAF)	Stainless steel	7.6
6.	Magnetic Float Polishing (MFP) with CeO_2	Si_3N_4	4.0
7.	Magnetorheological Finishing (MRF) with CeO_2	Flat BK7 Glass	0.8
8.	Elastic Emission Machining (EEM) with ZrO_2 abrasives	Silicon	<0.5
9.	Ion Beam Machining (IBM)	Cemented carbide	0.1

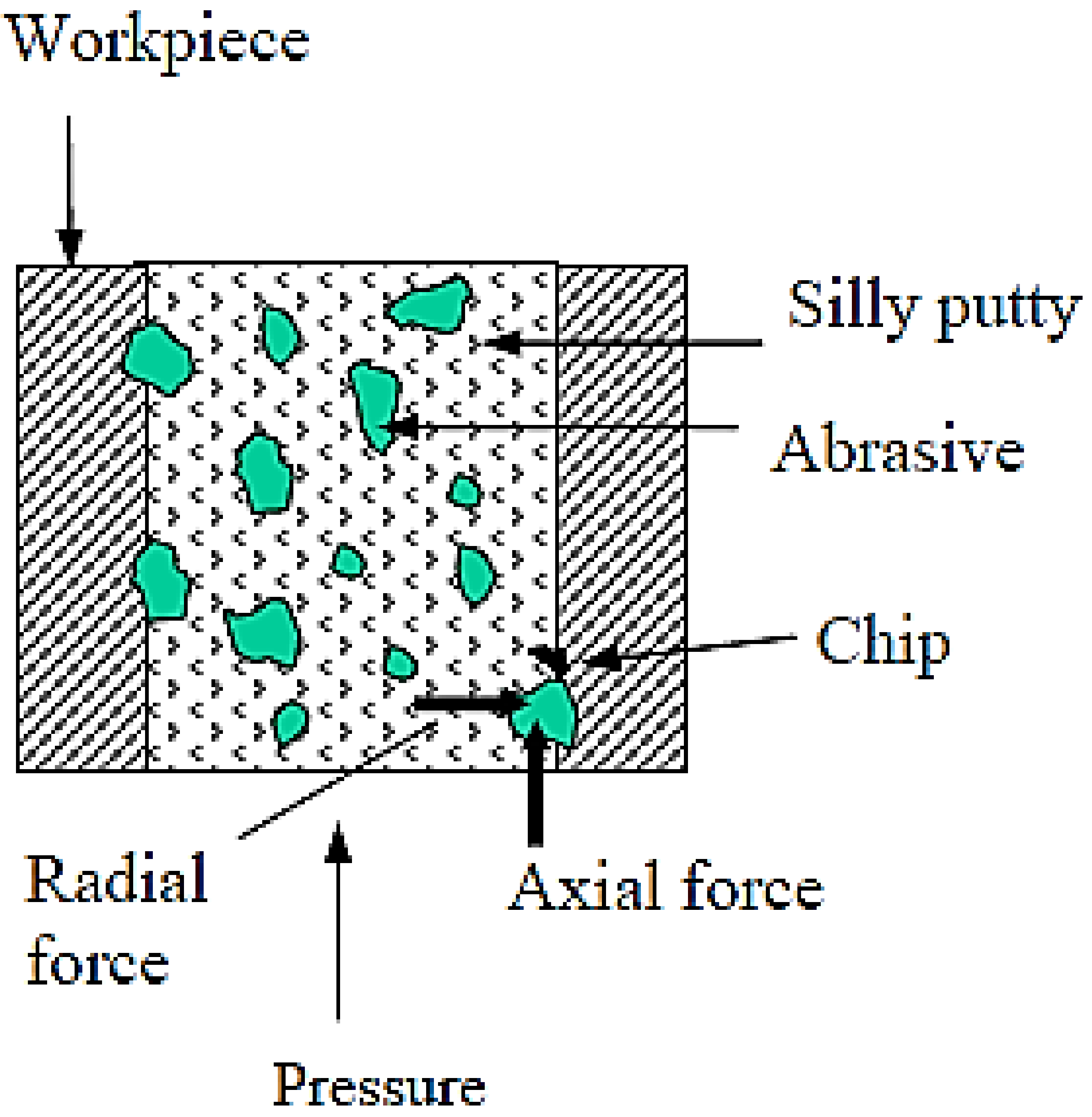
Abrasive Flow Machining (AFM)

- Abrasive Flow Machining (AFM) was identified in 1960s as a method to deburr, polish, and radius difficult to reach surfaces and edges by flowing an abrasive laden visco plastic polymer over them.
- It uses two vertically opposed cylinders, which extrude an abrasive medium back and forth through passage formed by the workpiece and tooling.
- Abrasion occurs wherever the medium passes through the restrictive passages.
- The key components of AFM are the machine, the tooling, types of abrasives, medium composition and process settings.

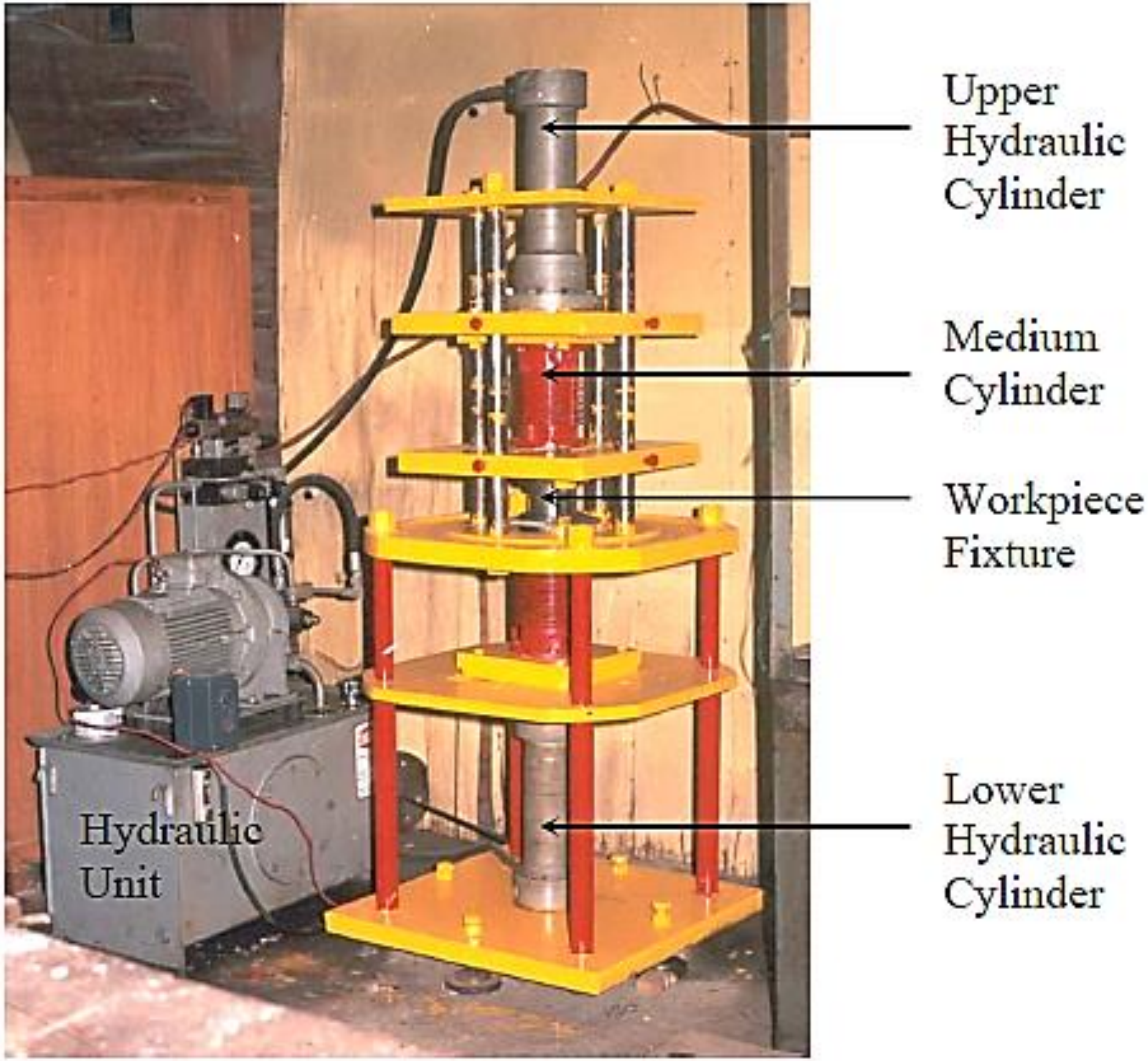
Process parameters

- Extrusion pressure
- Number of cycles
- Grit composition and type
- Fixture design

Forces acting on abrasive particle in AFM process



Experimental setup



- ✓ Abrasive action accelerates by change in the rheological properties of the medium when it enters and passes through the restrictive passages.
- ✓ Viscosity of polymeric medium plays an important role in finishing operation.
- ✓ This allows it to selectively and controllably abrade surfaces that it flows across.
- ✓ Work piece held by fixture is placed between two medium cylinders which are clamped together to seal so that medium does not leak during finishing process.

The three major elements of the process are:

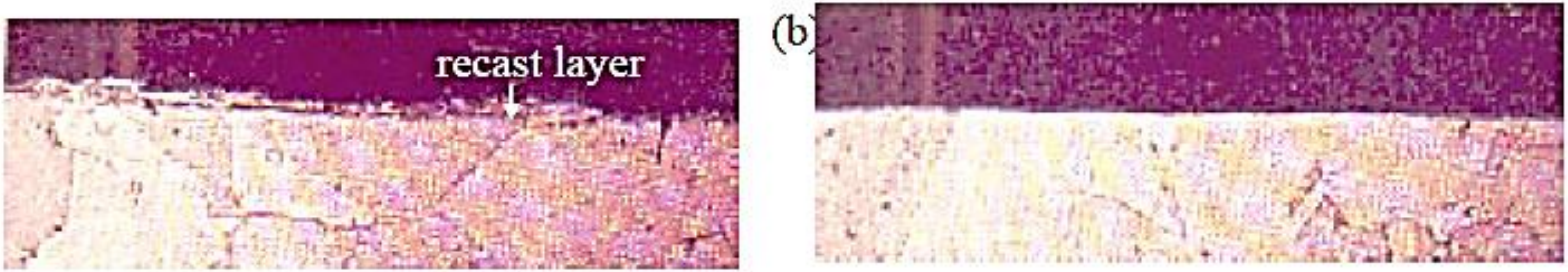
(a) The **Tooling,** which confines and directs the abrasive medium flow to the areas where deburring, radiusing and surface improvements are desired.

(b) The **Machine** to control the process variables like extrusion pressure, medium flow volume, and flow rate.

(c) The abrasive laden **Polymeric Medium** whose rheological properties determine the pattern and aggressiveness of the abrasive action.

To formulate the AFM medium, the abrasive particles are blended into special viscoelastic polymer, which show change in viscosity when forced to flow through restrictive passages.

(a) (b)



500X photomicrograph showing complete removal of EDM recast layer, (a) before AFM, (b) after AFM

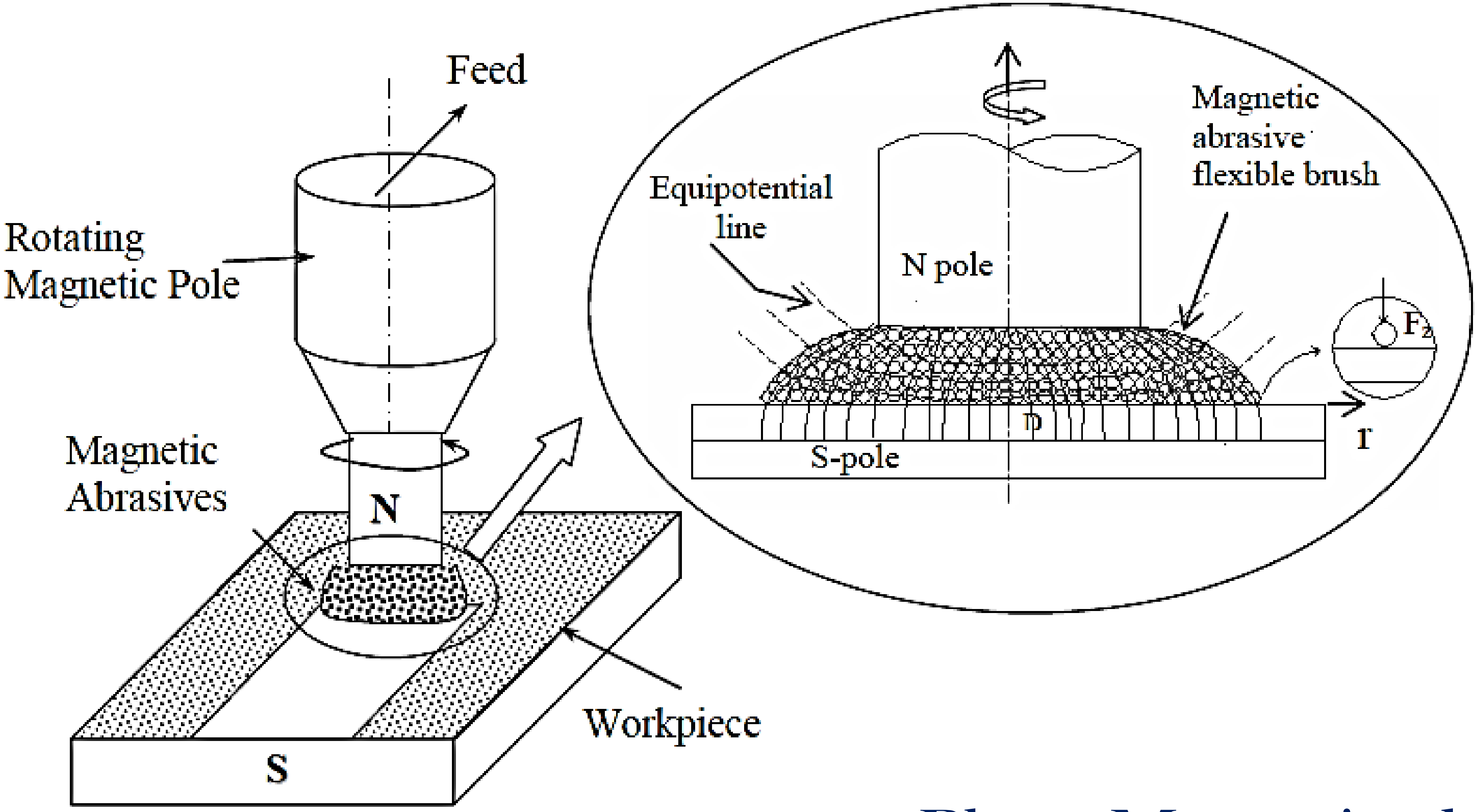
Magnetic Abrasive Finishing (MAF)

- Magnetic Abrasive Finishing is one such unconventional finishing process developed recently to produce efficiently and economically good quality finish on the internal and external surfaces of tubes as well as flat surfaces made of magnetic or non-magnetic materials.

- In this process, usually ferromagnetic particles are sintered with fine abrasive particles (Al_2O_3, SiC, CBN or diamond) and such particles are called ferromagnetic abrasive particles (or magnetic abrasive particles).

- Force due to magnetic field is responsible for normal force causing abrasive penetration inside the workpiece while rotation of the magnetic abrasive brush (i.e. North pole) results in material removal in the form of chips.

Magnetic Abrasive Finishing (MAF)



Plane Magnetic abrasive finishing

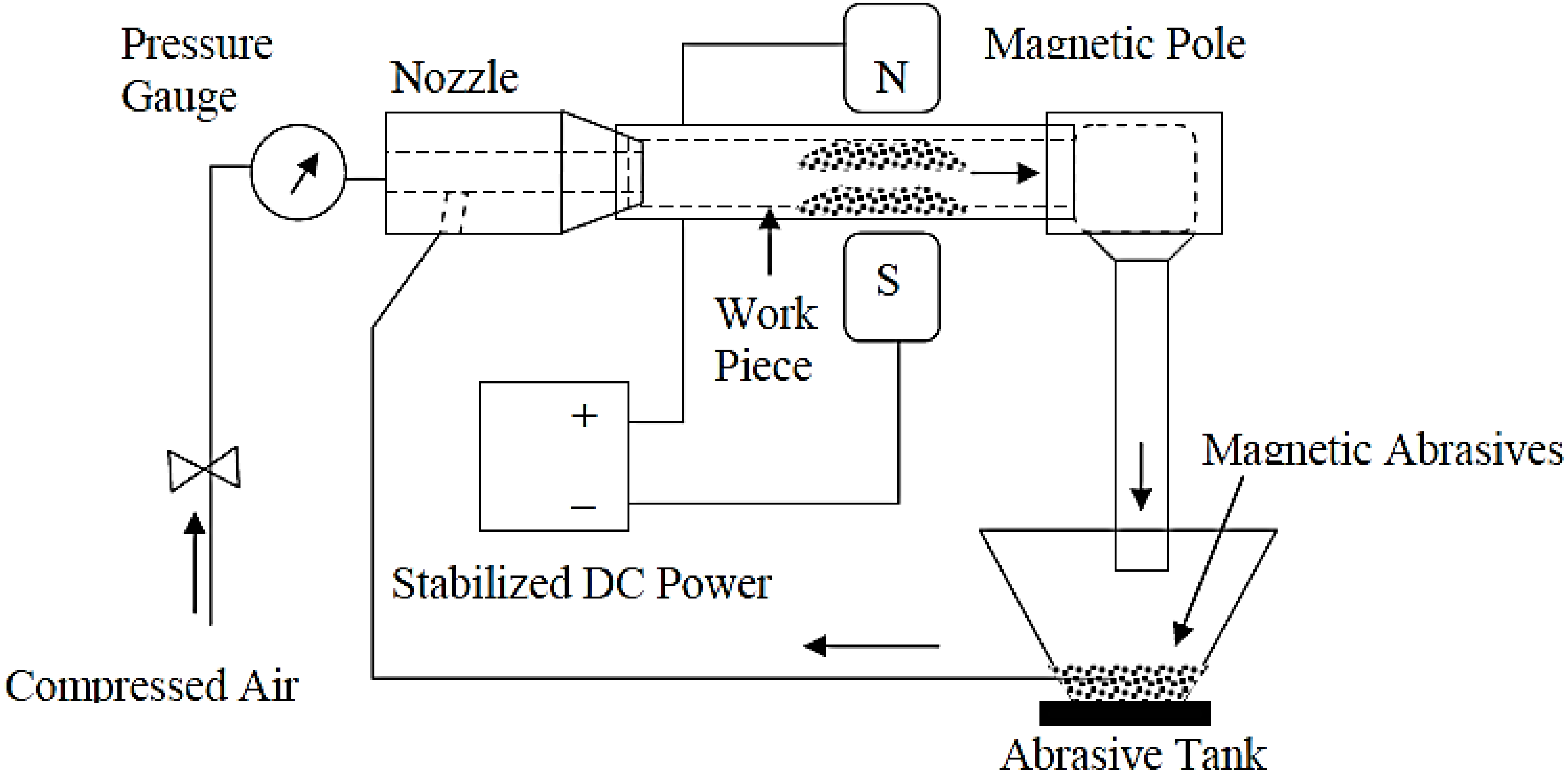
- Magnetic abrasive grains are combined to each other magnetically between magnetic poles along a line of magnetic force, forming a flexible magnetic abrasive brush.

- MAF uses this magnetic abrasive brush for surface and edge finishing.
- Magnetic field retains the powder in the gap, and acts as a binder causing the powder to be pressed against the surface to be finished.

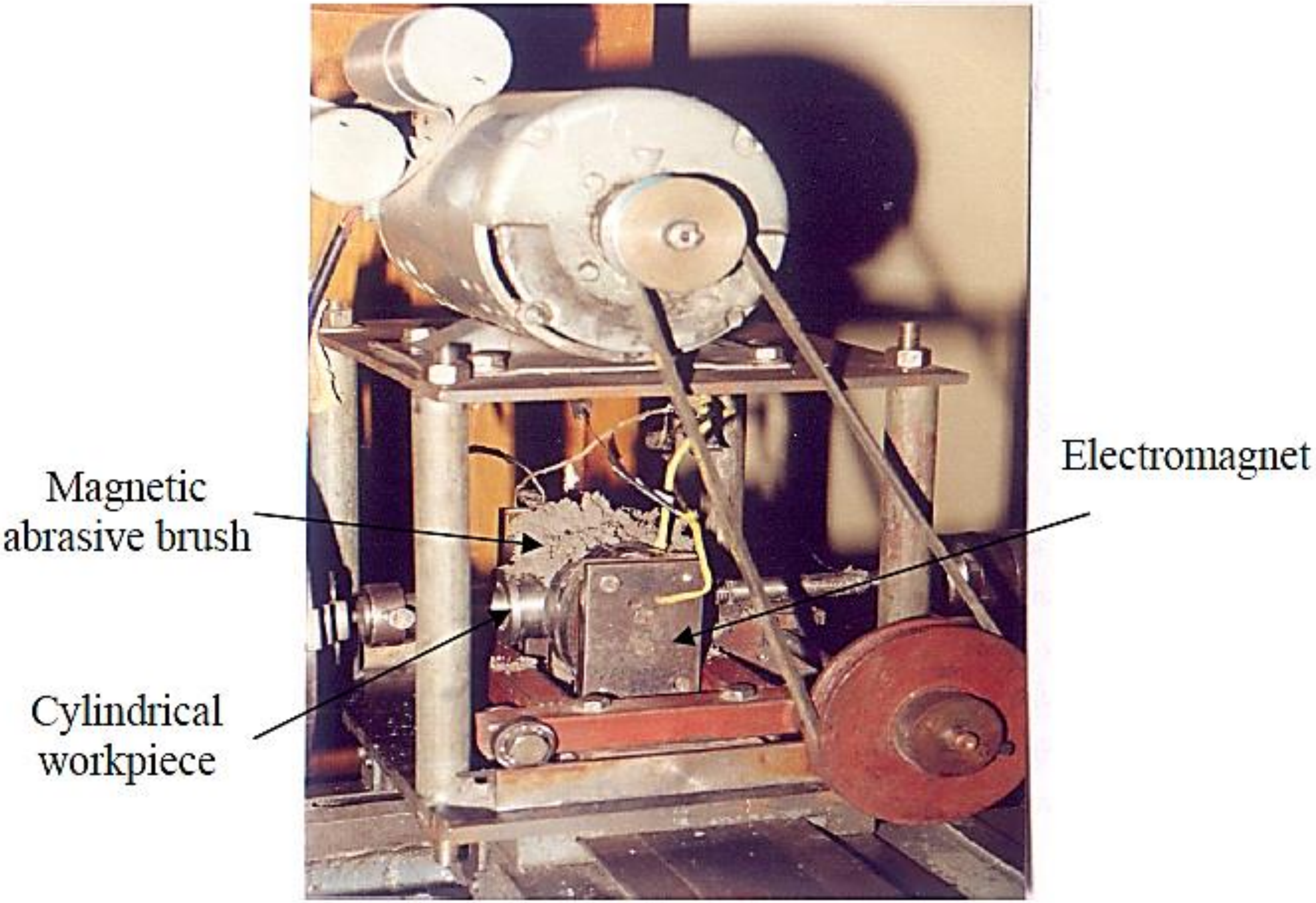
- 3D minute and intricately curved shape can also be finished along its uneven surface.

- Controlling the exciting current of the magnetic coil precisely controls the machining force of the magnetic abrasives on the work piece.

Magnetic abrasive jet finishing



Magnetic Abrasive Finishing of cylindrical surface



- In MAF process, the workpiece to be machined is located between two magnetic poles.
- Gap between the workpiece and the pole is filled with a magnetic abrasive powder. Magnetic abrasive grains are linked to each other magnetically between the north and south magnetic poles along the lines of magnetic force, forming a flexible 2-5 mm long magnetic brush.
- MAF uses this magnetic abrasive brush for surface and edge finishing.
- Magnetic field retains the powder in gaps, and acts as a binder causing the powder to be pressed against the surface to be finished.
- A rotary motion is provided to cylindrical workpiece, such as ceramic bearing rollers between magnetic poles.
- Also axial vibratory motion is introduced in the magnetic field by the oscillating motion of magnetic poles to accomplish surface and edge finishing at faster rate and better quality.

This process is highly efficient and the removal rate and finishing rate depends on the workpiece circumferential speed, magnetic flux density, working clearance, workpiece materials, and size, type and volume fraction of abrasives.

The exciting current of the magnetic coil precisely controls the machining force transferred through magnetic abrasives on the work piece.

Since the magnitude of machining force caused by the magnetic field is very low, results were reported in the literature of finishing stainless steel rollers using MAF to obtain final Ra of 7.6 nm from an initial Ra of 0.22 µm in 30 seconds

Magnetorheological Finishing (MRF)

Lens finishing process

- MRF process relies on a unique "smart fluid", known as Magnetorheological (MR) fluid.

- MR-Fluids are suspensions of micron sized magnetizable particles such as carbonyl iron, dispersed in a non-magnetic carrier medium like silicone oil, mineral oil or water.

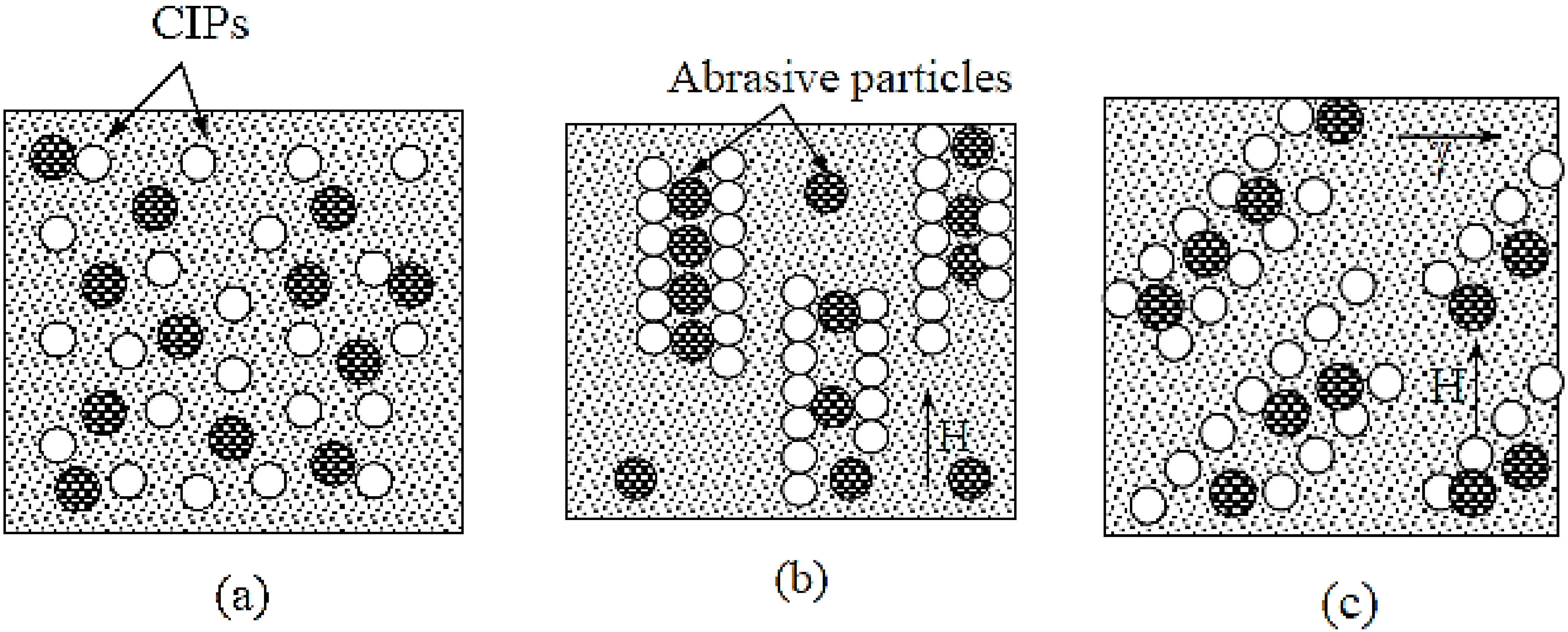
- In the absence of a magnetic field, an ideal MR-fluid exhibits Newtonian behaviour.

On the application of an external magnetic field to a MR-suspension, a phenomenon known as Magnetorheological effect is observed.

Fig.(a) shows the random distribution of the particles in the absence of external magnetic field.

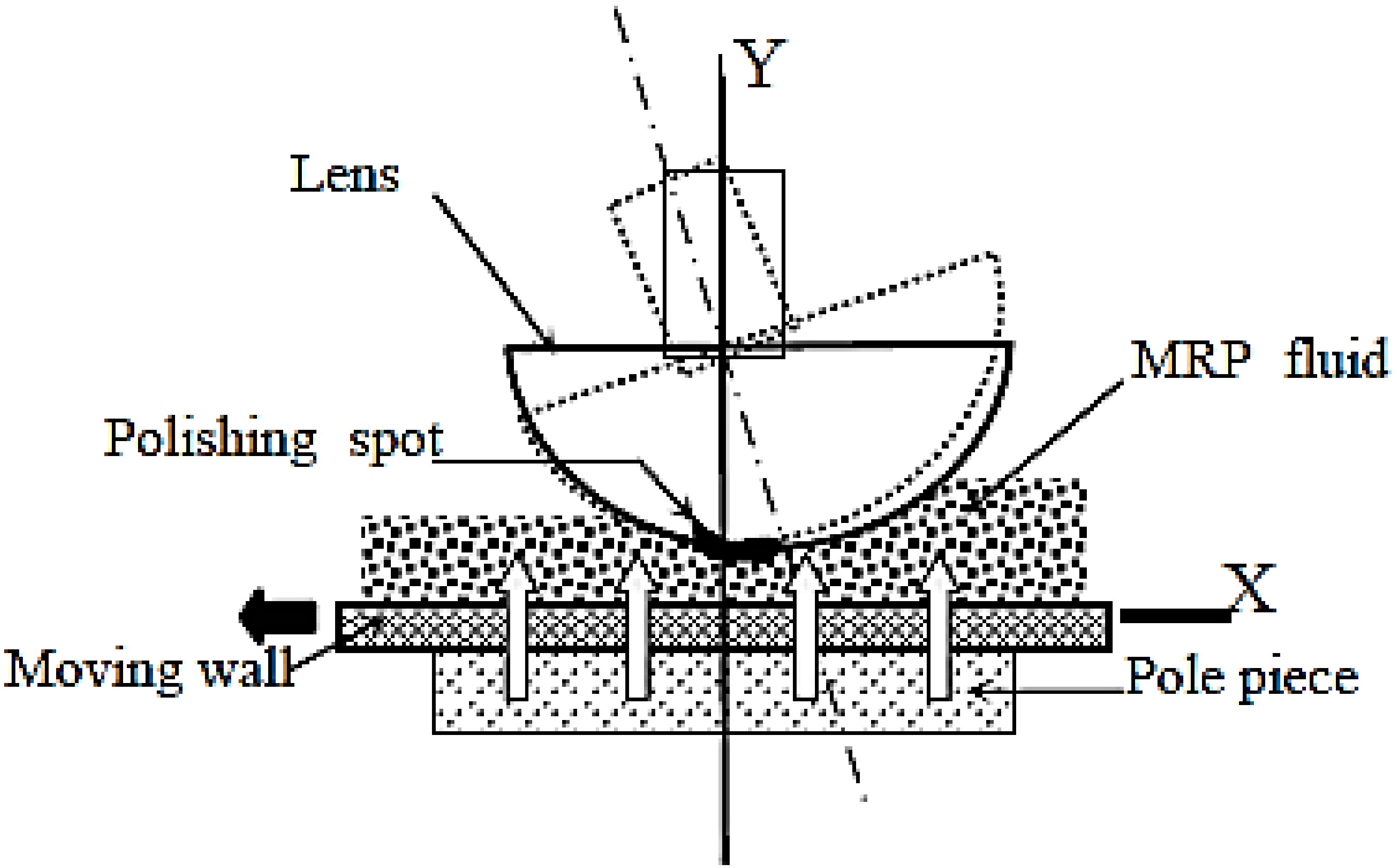
In (b), particles magnetize and form columns when external magnetic field is applied. The particles acquire dipole moments proportional to magnetic field strength and when the dipolar interaction between particles exceeds their thermal energy, the particles aggregate into chains of dipoles aligned in the field direction. Because energy is required to deform and rupture the chains, this micro-structural transition is responsible for the onset of a large "controllable" finite yield stress.

(c) shows an increasing resistance to an applied shear strain, γ due to this yield stress. When the field is removed, the particles return to their random state and the fluid again exhibits its original Newtonian behaviour.

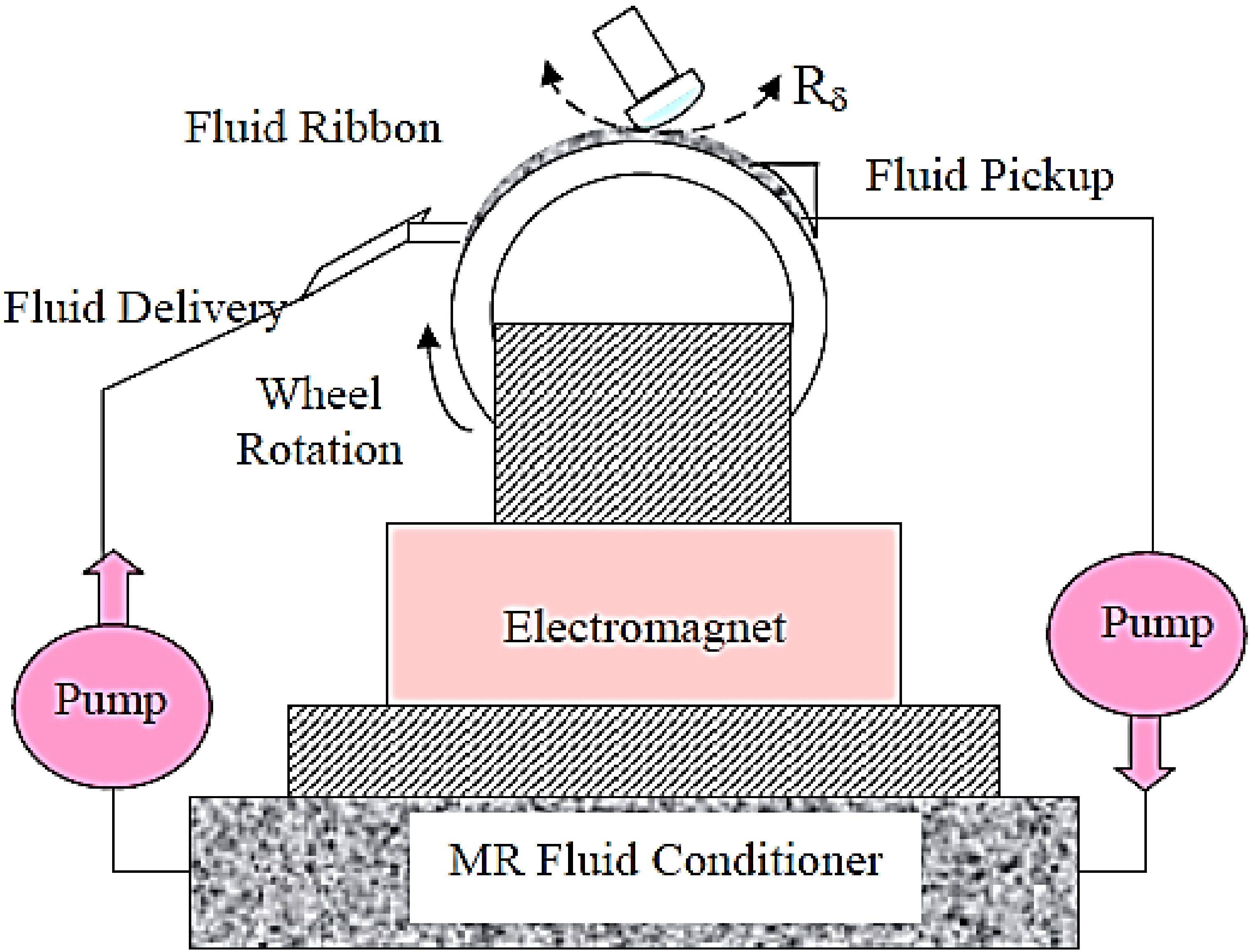


(a) MRP-fluid at no magnetic field,
(b) At magnetic field strength H, and
(c) At magnetic field H & applied shear strain

Magnetorheological finishing process



A Vertical MRF Machine



MR-polishing fluid lap has following merits over traditional lap:-

1. Its compliance is adjustable through the magnetic field.
2. It carries heat and debris away from the polishing zone.
3. It does not load up as in grinding wheel.
4. It is flexible and adapts the shape of the part of the workpiece which is in its contact.