EFFECT OF MAGNETIC FIELD ON MR-FLUID IN BALL END MAGNETORHEOLOGICAL FINISHING

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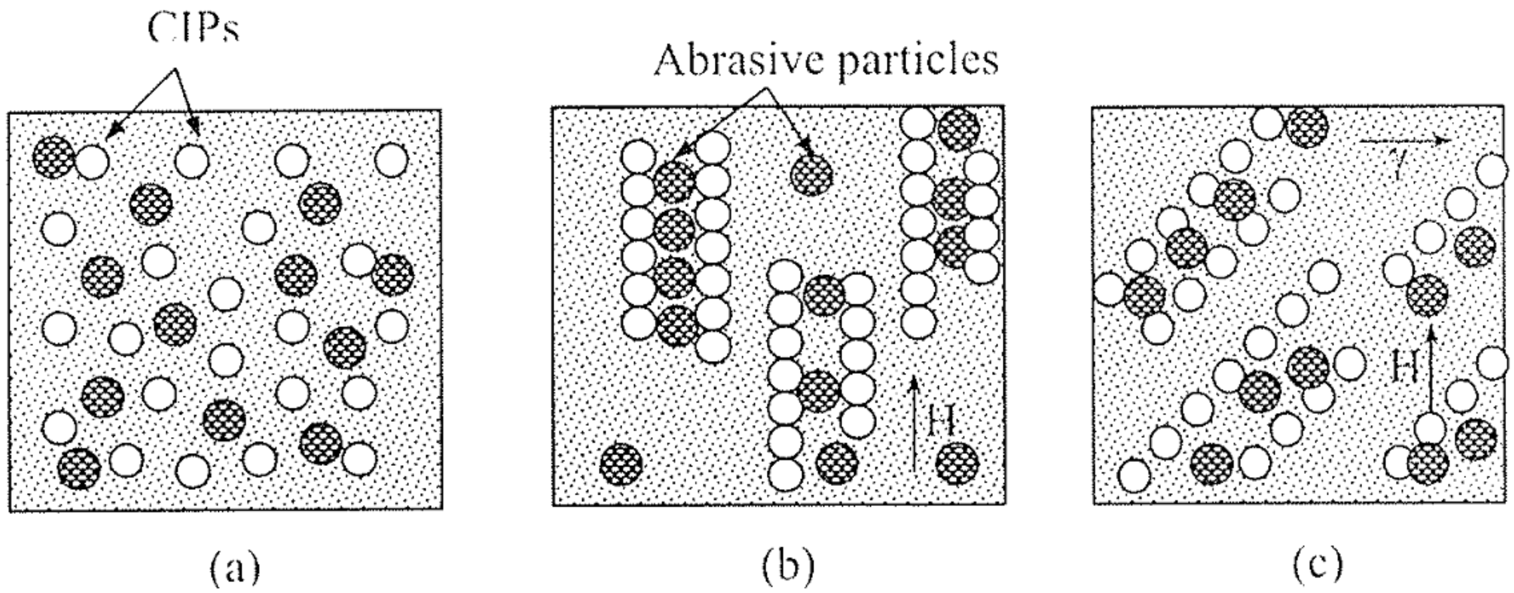
INTRODUCTION

- The MRF process relies on a unique “smart fluid”, known as Magnetorheological (MR) fluid. MR-Fluids are suspensions of micron sized magnetizable partical such as carbonyl iron particles (CIP’s) surrounding the abrasive particle, dispersed in a non-magnetic carrier medium like silicon oil, mineral oil or water. In the absence of a magnetic field, an ideal MR- fluid exhibits Newtonian behavior. On the application of external magnetic field to a MR-suspension, a phenomenon known as Magneto-rheological effect is observed.

- MR-Fluid under defferent action:



- In figure (a) there is no magnetic field.
- In figure (b) at magnetic field of strength, suppose H.
- In figure (c) at magnetic field H and applied shear strain γ

BEMRF (BALL END MAGNETORHELOGICAL FINISHING

- The BEMRF tool has comparatively less limitations on finishing of different work piece surfaces, as compared with regular MRF. The finishing spot of MRP fluid formed at the tip surface of the central rotating core can be easily made reachable for the different 3D surface profiles. The vertical tapered tool tip, with finishing spot of MRP fluid, can be moved and performed finishing with the help of a computer controlled program over different kinds of surfaces in a work piece, such as projections at different angles or in-depth pocket profiles; whereas finishing of these surfaces in the work piece are likely to be inaccessible by a regular MRF process owing to rotating wheel size or mechanical interferences. MR jet finishing was developed to finish the internal surface of a steep concave and spherical dome, where the jet was impinged on the work piece surface from the bottom and the work piece surface was rotated relative to the MR jet. In this process, the relative movement of different 3D complex work piece surfaces, with respect to the MR jet, may have challenged the task. The newly developed finishing process can be found in more industrial applications in the area of MRF processes.

SIMULATION MODELING

- The model is formed and analyzed using Comsol Multiphysics.

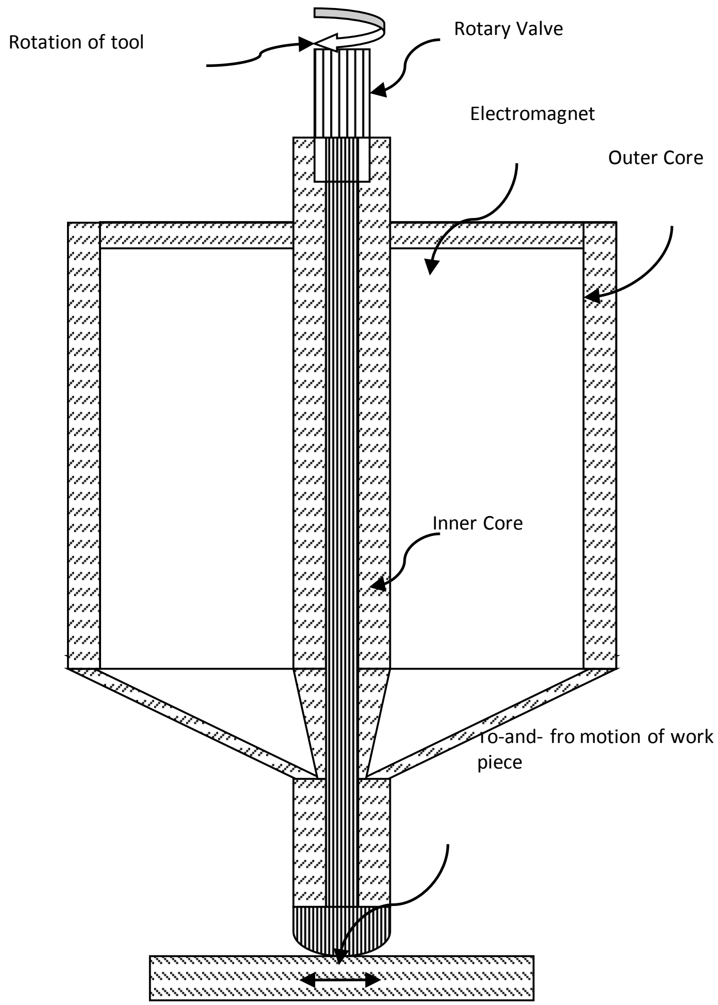
- Physics
  - Laminar Flow
  - AC/DC

CONSTRUCTION AND WORKING

- BEMRF comprises of a central rotating core, stationary electromagnet coil and copper cooling coil wrapped over the outer surface of the stationary electromagnet coil for continuous cooling.

- The ball end generated at the tip of tool due to magnetic field, for the polishing operation is act as the finishing segment to finish the work piece surfaces.

Simulation Diagram



Laminar Flow

- Governing Equations
  - Continuity Equation

$$\nabla.(\rho \mathbf{u}) = 0$$

  - Momentum Equation

$$\rho(\mathbf{u}.\nabla)\mathbf{u} = \nabla.\left[-p\mathbf{I} + \mu(\nabla\mathbf{u} + (\nabla u)^T - \frac{2}{3}\mu(\nabla.\mathbf{u})\mathbf{I}\right]$$
$$+F$$

  - Body force (Volume Force)

$F_x = d(U_B)/dx$, $F_y = d(U_B)/dy$

- Boundary and Initial Condition

  - No slip boundary condition
  - Initial velocity zero
  - Inlet pressure 4bar
  - Outlet pressure 1bar

Magnetic Field

- Governing Equations
  - Amperes Law

$$\nabla \times (\mu_0^{-1} \mu_r^{-1} \mathbf{B}) - \sigma \mathbf{v} \times \mathbf{B} = \mathbf{J}_e$$

$$\mathbf{B} = \nabla \times \mathbf{A}$$

  - Electric Field

$$\mathbf{D} = \varepsilon_0 \varepsilon_r \mathbf{E}$$

  - Magnetic Field

$$\mathbf{B} = \mu_0 \mu_r \mathbf{H}$$

  - Multi-turn coil

$$\mathbf{J}_e = \frac{NI_{coil}}{A} e_{coil}$$

$$\nabla \times (\mu_0^{-1} \mu_r^{-1} \mathbf{B}) - \sigma \mathbf{v} \times \mathbf{B} = \mathbf{J}_e$$

$$\mathbf{B} = \nabla \times \mathbf{A}$$

- Ampere's law (for Fluid)

$$\nabla \times (\mu_0^{-1}\mathbf{B} - \mathbf{M}) - \sigma \mathbf{v} \times \mathbf{B} = \mathbf{J}_e$$

$$\mathbf{B} = \nabla \times \mathbf{A}$$

- Magnetic Field

$$\mathbf{B} = \mu(\mathbf{H} + \mathbf{M})$$

- Initial and Boundary Condition
  - Magnetic insulation (n x A = 0)
  - Initial value of A=0

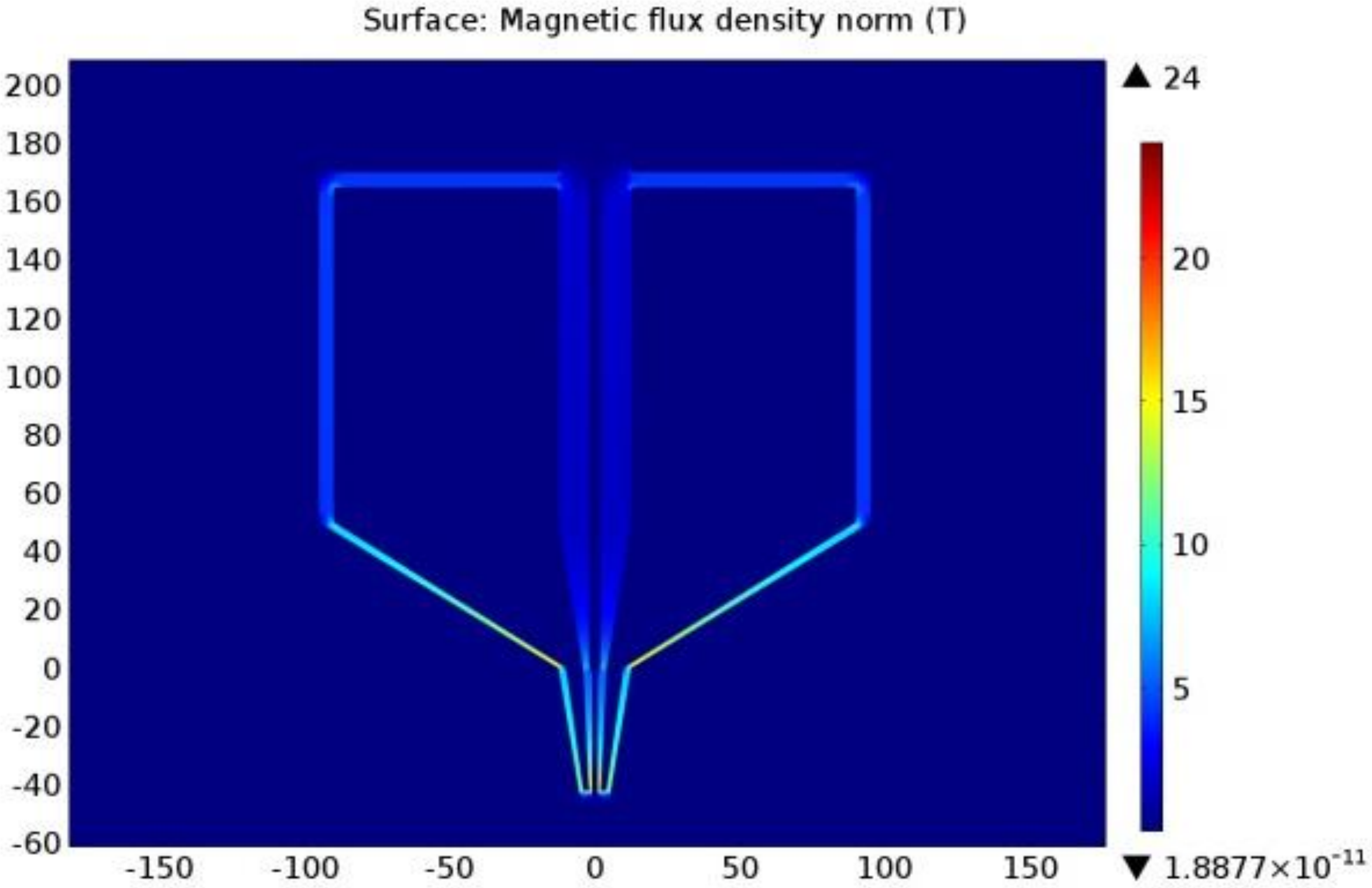
Fluid Properties

- Density
- Viscosity

Magnetic Properties

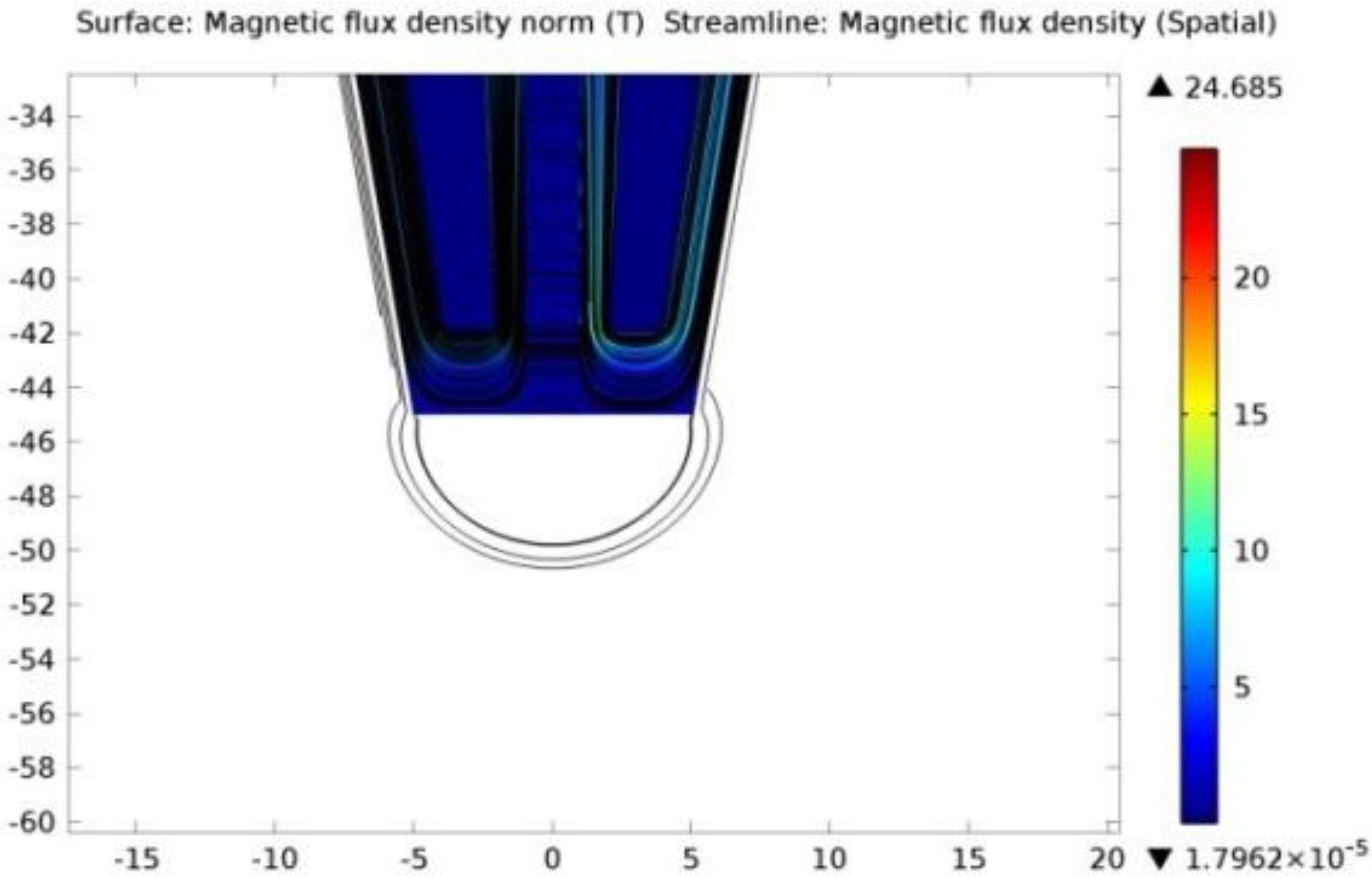
- Magnetic permeability
  - Outer core
  - Inner core
  - Magnetic fluid
  - Copper

RESULTS



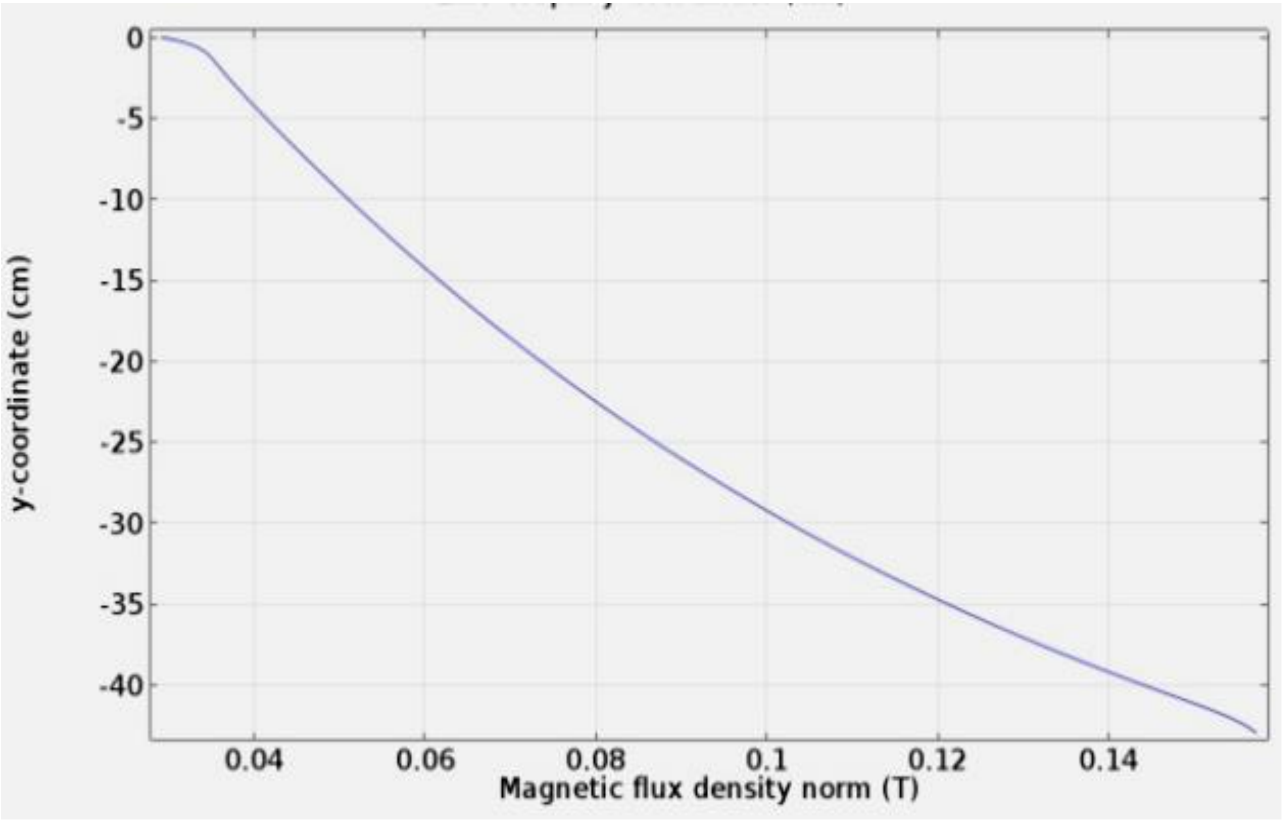
Surface: Magnetic flux density norm (T)
200
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-150
-100
-50
0
50
100
150
▲ 24
20
15
10
5
▼ 1.8877×10^-11

Results



Surface: Magnetic flux density norm (T) Streamline: Magnetic flux density (Spatial)
▲ 24.685
20
15
10
5
▼ 1.7962×10⁻⁵
-34
-36
-38
-40
-42
-44
-46
-48
-50
-52
-54
-56
-58
-60
-15
-10
-5
0
5
10
15
20

RESULTS


y-coordinate (cm)
0
-5
-10
-15
-20
-25
-30
-35
-40
0.04
0.06
0.08
0.1
0.12
0.14
Magnetic flux density norm (T)

CONCLUSION

- Ball End MRF technique can be used for polishing ferrous and non-ferrous component.
- The formation of ball depend on many factors, like Permeability is one.
- Magnetization of MR-Fluid will be maximum at the tip of ball end tool.

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THANK YOU