Development and performance analysis of a Magnetorheological fluid Clutch

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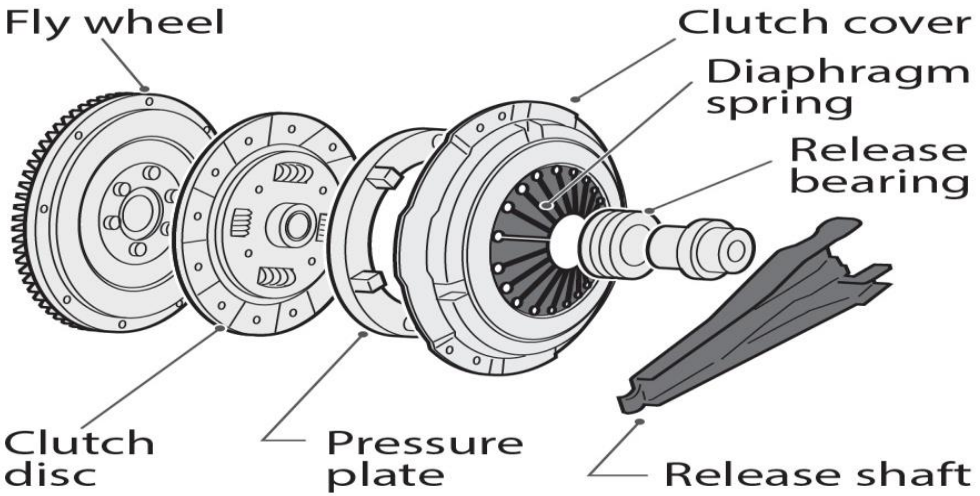
Challenges to maintain torque transmission in conventional Clutch

Uneasy controllability due to many components

Slow response time

Variable torque transmission

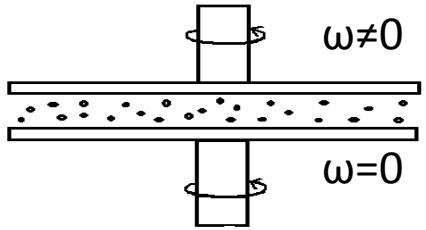
Expensive friction materials



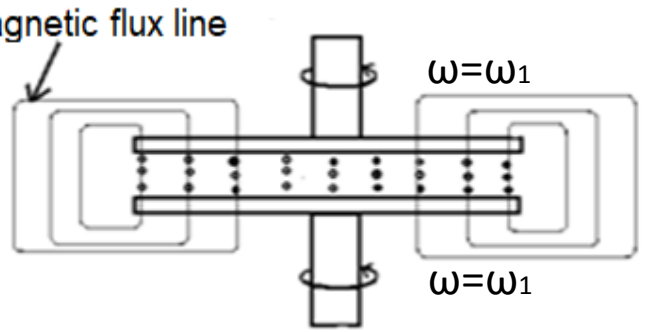
Problem of slipping and sticking

Friction material on the disc wears out

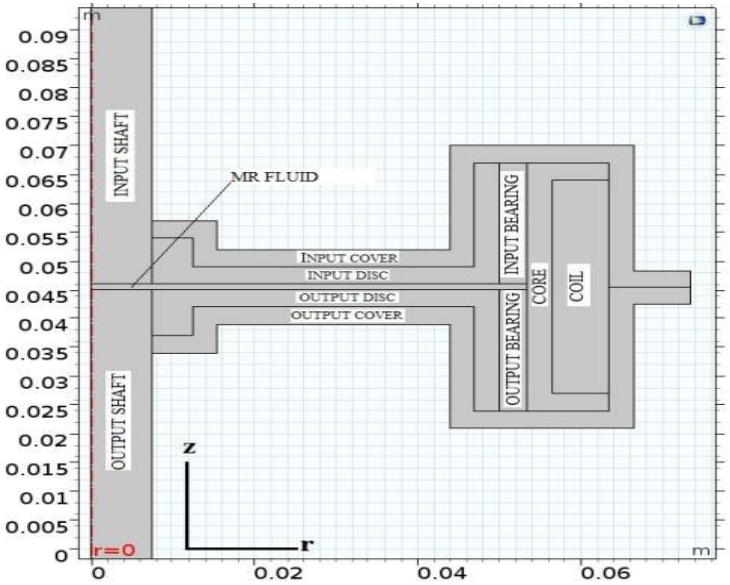
Magnetorheological Fluid Clutch

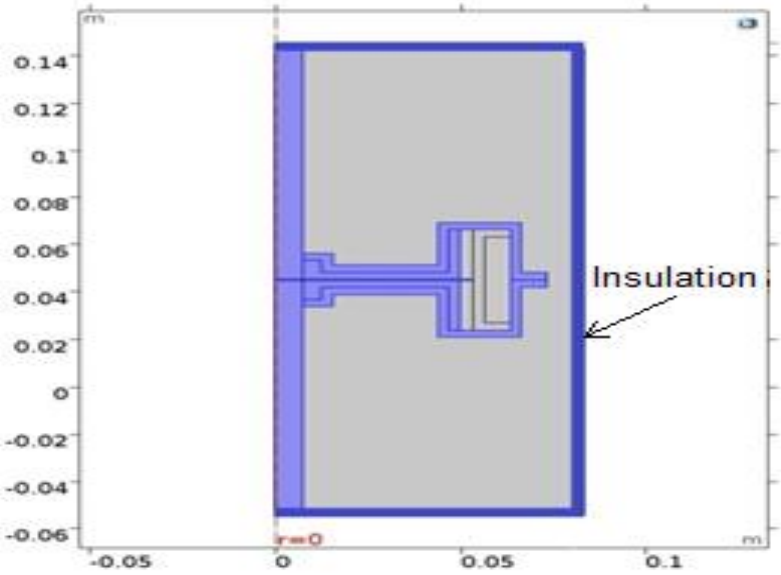


MR Fluid in off state



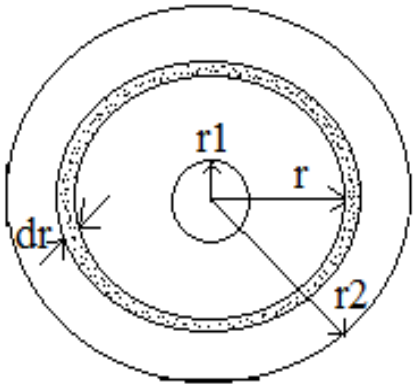
MR Fluid in on state





Magnetic field study

- **For selecting the magnetic field, the full field is used.**
- **Maxwell's equations are a set of equations which is a combination of Ampere's law, Gauss‘ law and Faraday's law that describes electromagnetism.**
- **The components of MR clutch are selected as separate domains for implementing the Ampere’s law.**
- **For a clutch the maximum resistant or transmissible torque is thus function of both $\tau_{yd}(B)$ and $\dot{\gamma}$.**

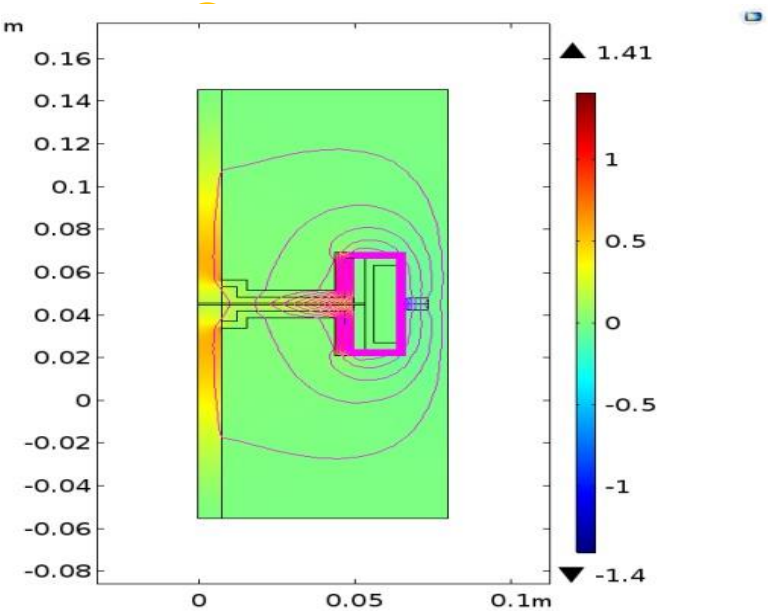


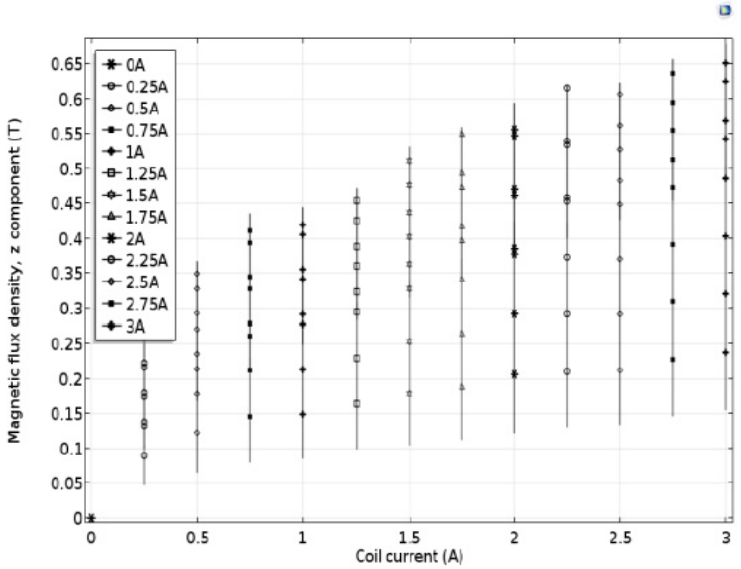
Single disc MR clutch scheme

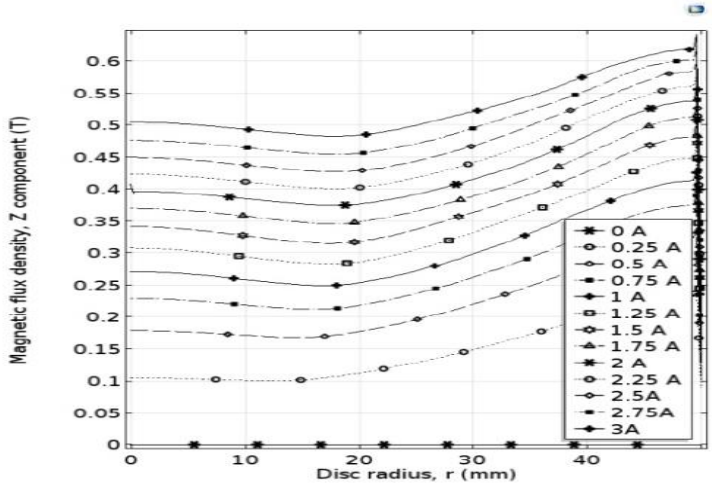
Total torque is as:-

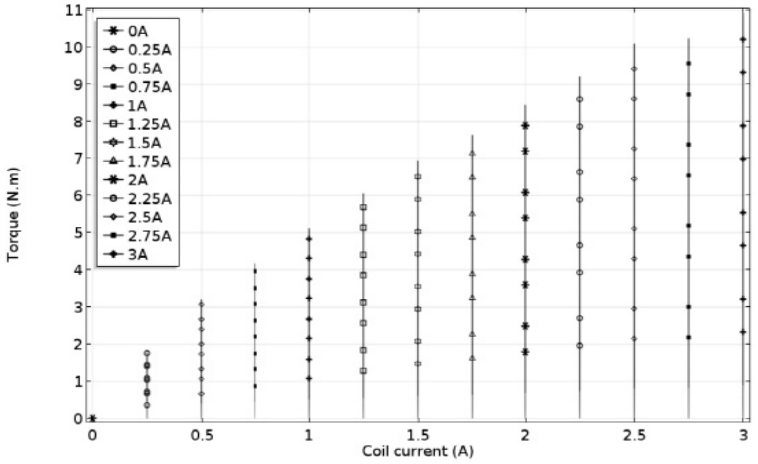
$$T = \frac{2\pi\tau_{yd}(B)r^3}{3} + \frac{\pi^2 \times \eta(B) \times RPM \times r^4}{60 \times h}$$

Magnetic field study (continued)

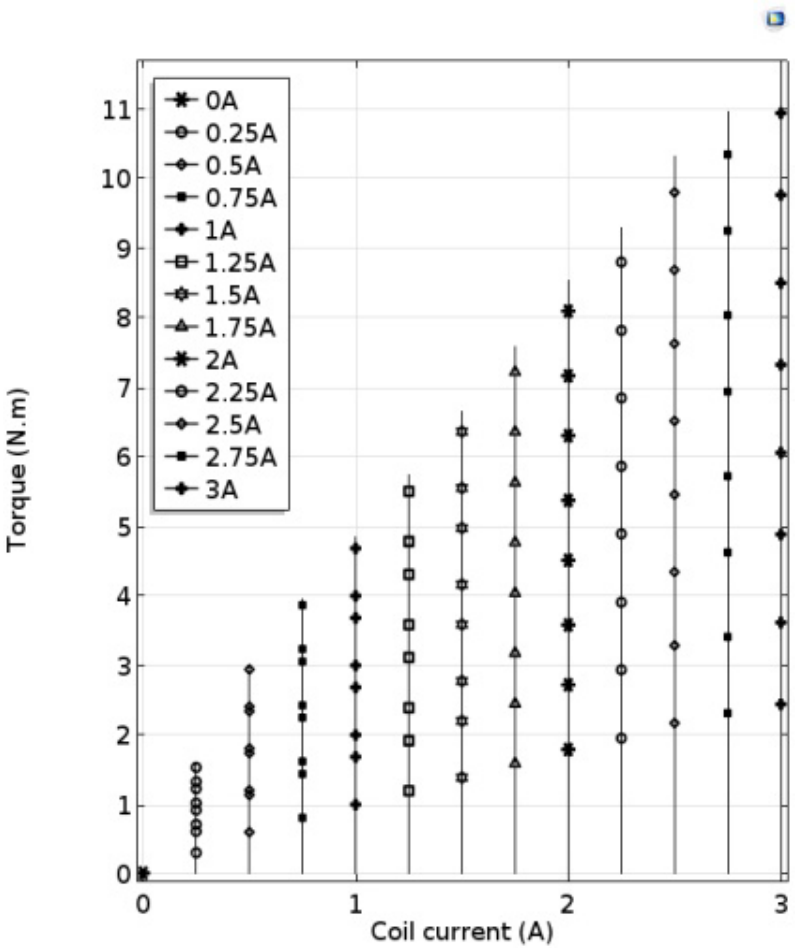




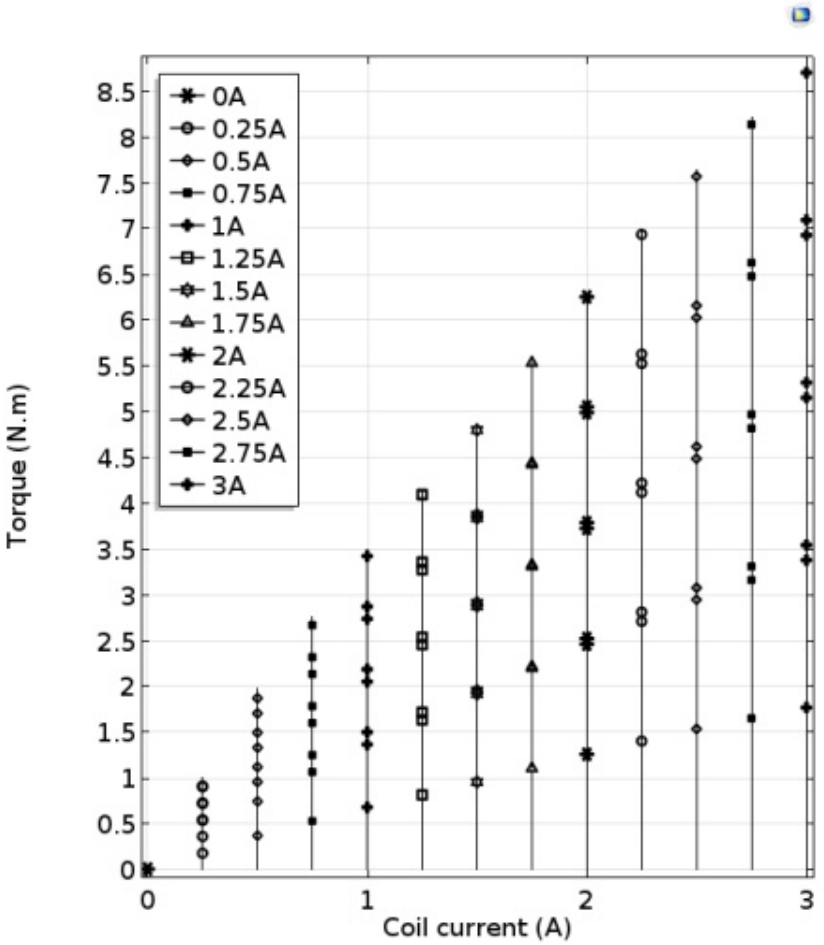




Magnetic field study (continued)



(a) 1mm MR fluid gap

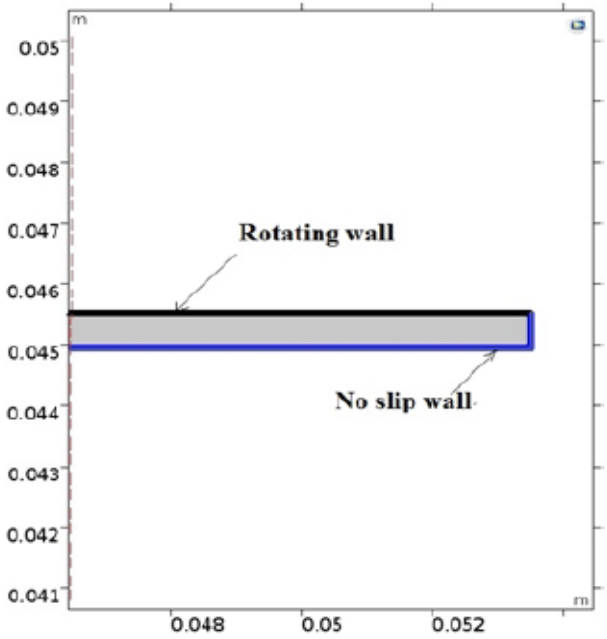


(b) 2mm MR fluid gap

Torque at 1000 rpm for (a) 1mm and (b) 2mm MR fluid gap

Laminar flow study

- **This study is a part of the fluid flow physics, used to simulate single phase flow of fluids.**
- **The laminar flow interface is used for simulating fluid flows at very low Reynolds numbers. The single-phase flow type is referred to as Stokes flow.**
- **The equations solved by the incompressible laminar flow interface are the Stokes equations for conservation of momentum and the continuity equation for conservation of mass.**

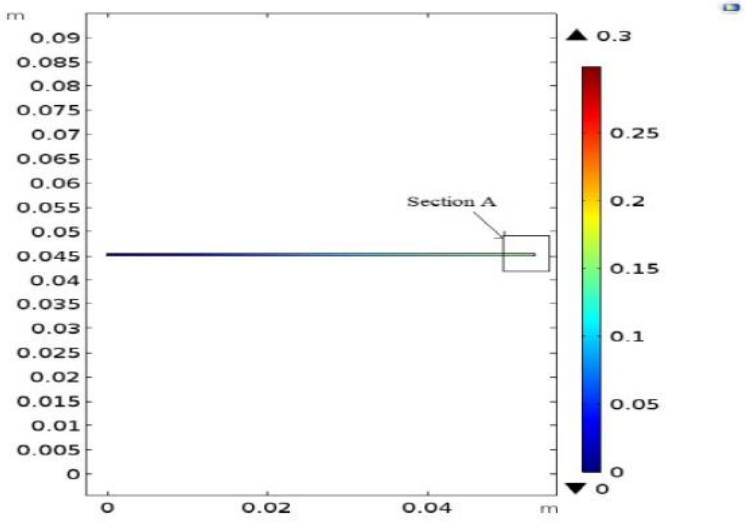


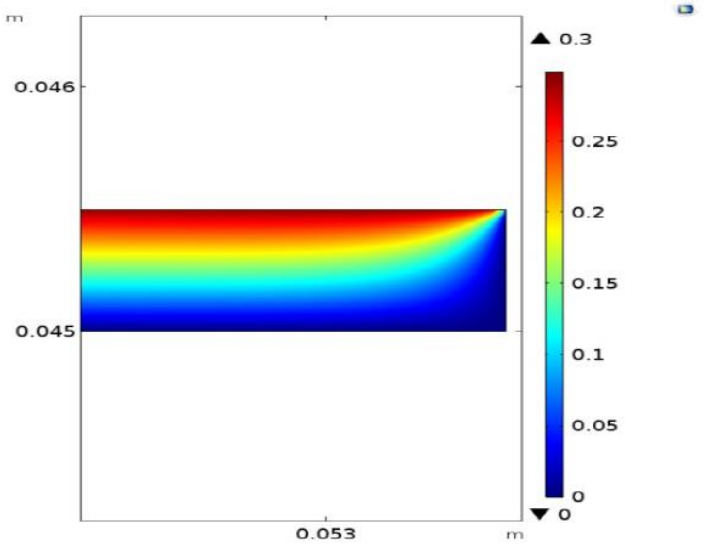
In stationary flow the governing equation for Laminar flow simulation following is used by COMSOL Multiphysics v5.3a:-

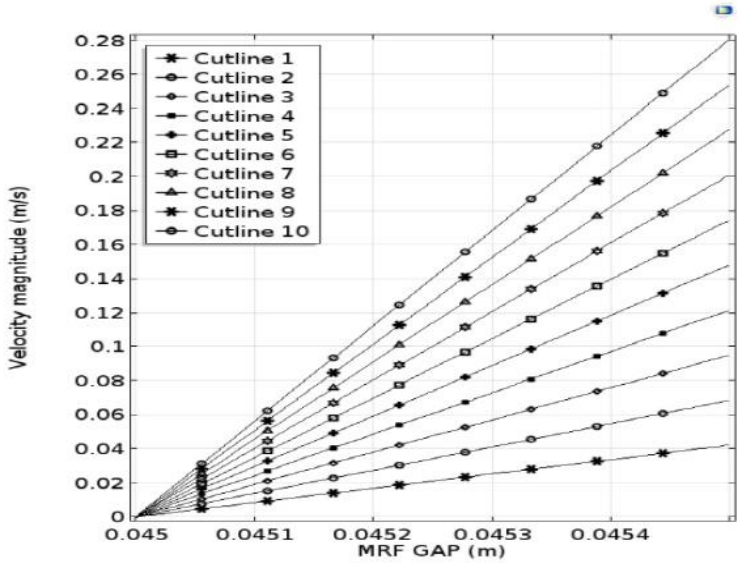
$$\rho(u.\nabla)u = \nabla\left[-PI + \mu(\nabla u + (\nabla u)^T)\right] + F$$

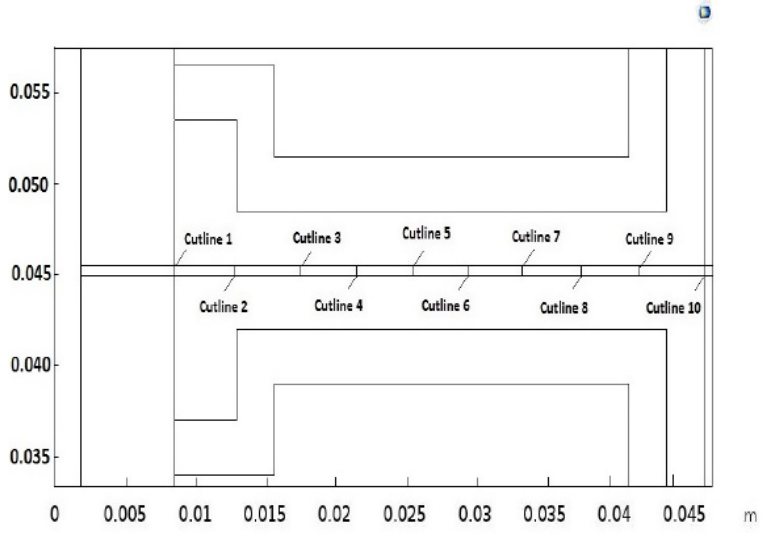
$$\rho\nabla.(u) = 0$$

Laminar flow study (Continued)

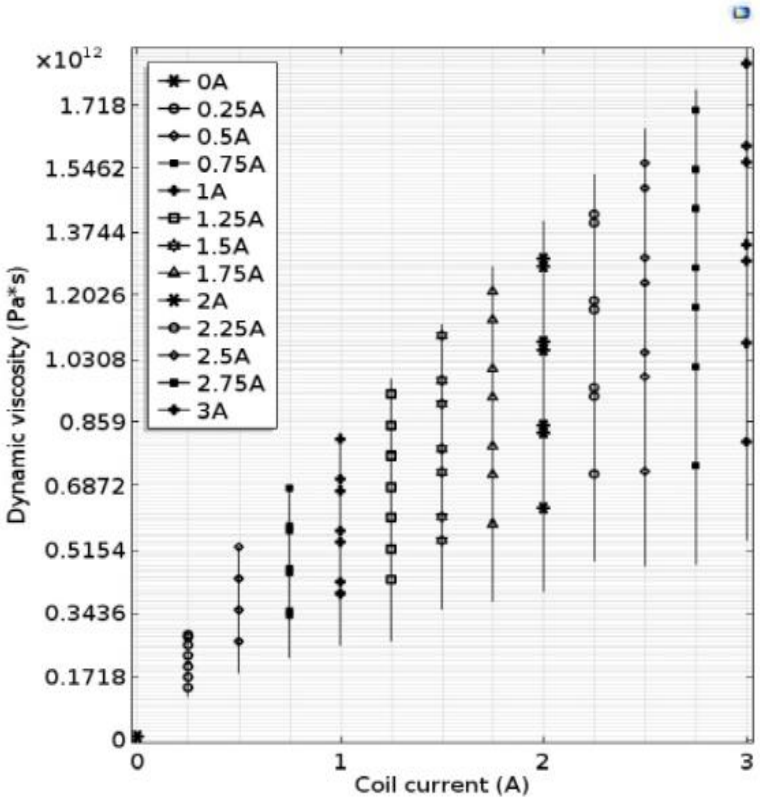




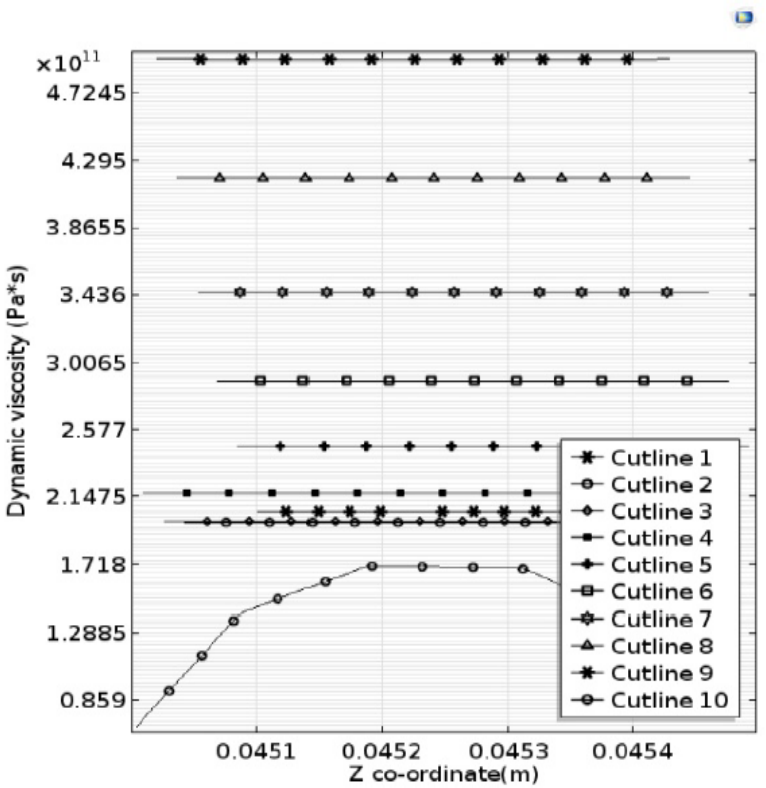




Laminar flow study (Continued)



(a)



(b)

Dynamic viscosity at (a)different current and (b) different cutline at 0.5A

Conclusions

Smart materials such as Magnetorheological fluid has ability to replace the frictional material used in conventional clutch for torque transmission.

As the Magnitude of input current changes the value of transmission Torque changes, it clearly shows controllability action in Magnetorheological clutch.

Transmission torque depends on the size of MR fluid gap, as the gap increases the torque value decreases.

Torque transmission is the main concern for the clutching application and it has maximum value of 20 Nm at 0.5 mm MR gap, 3A current and 1000 rpm.

Velocity and dynamic viscosity also show the effective change as by change in the magnitude of currents. As change in rpm the flow velocity also changes, which is maximum at high rpm.

Thank you