Magnetorheological Fluid Based Braking System Using L-shaped Disks

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Introduction: Magnetorheological fluids (MR fluid) are a class of smart fluids which are composed of liquids (basically oils) and varying percentages of iron particles. They are widely being used in applications where controllability and flexibility are important.

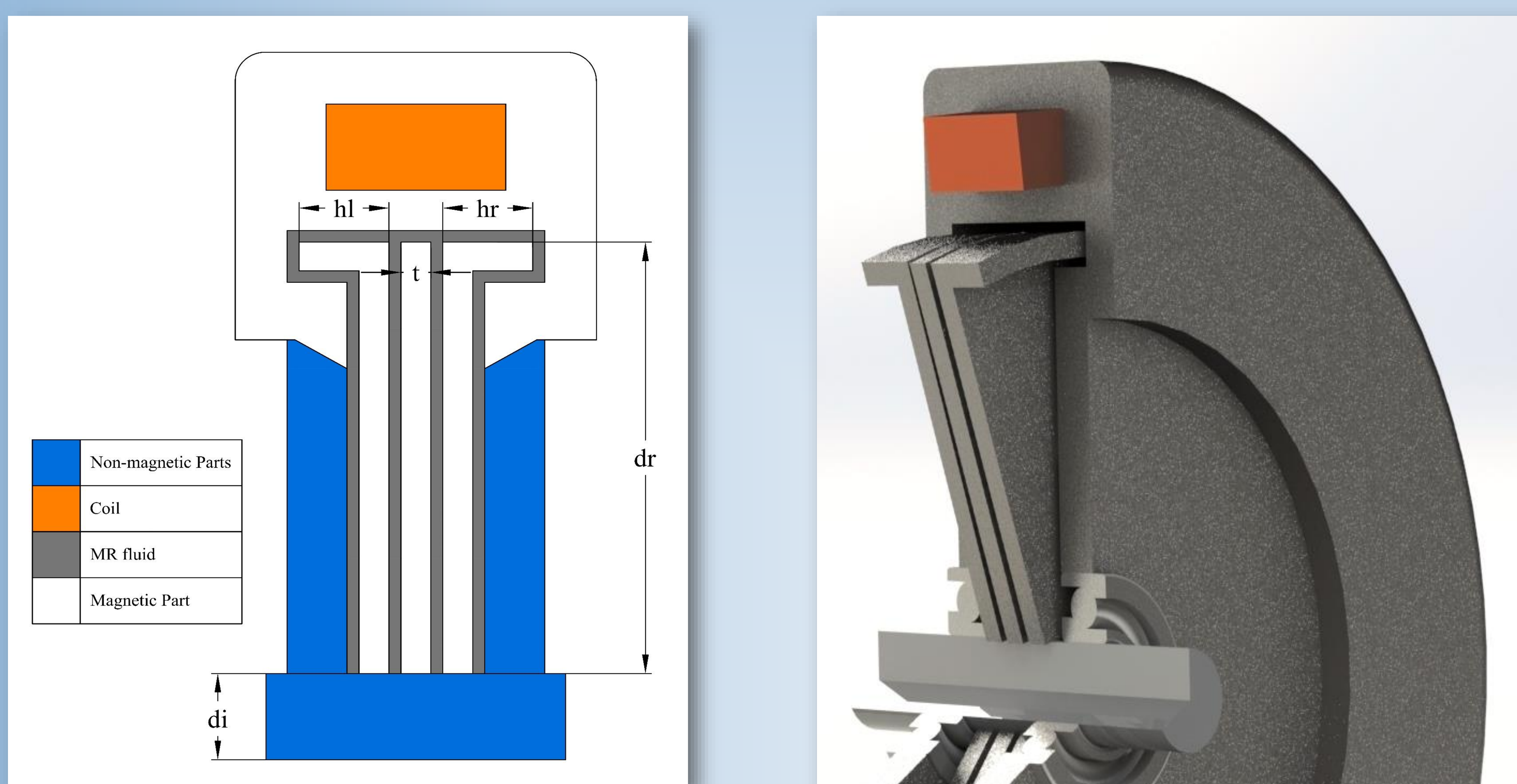
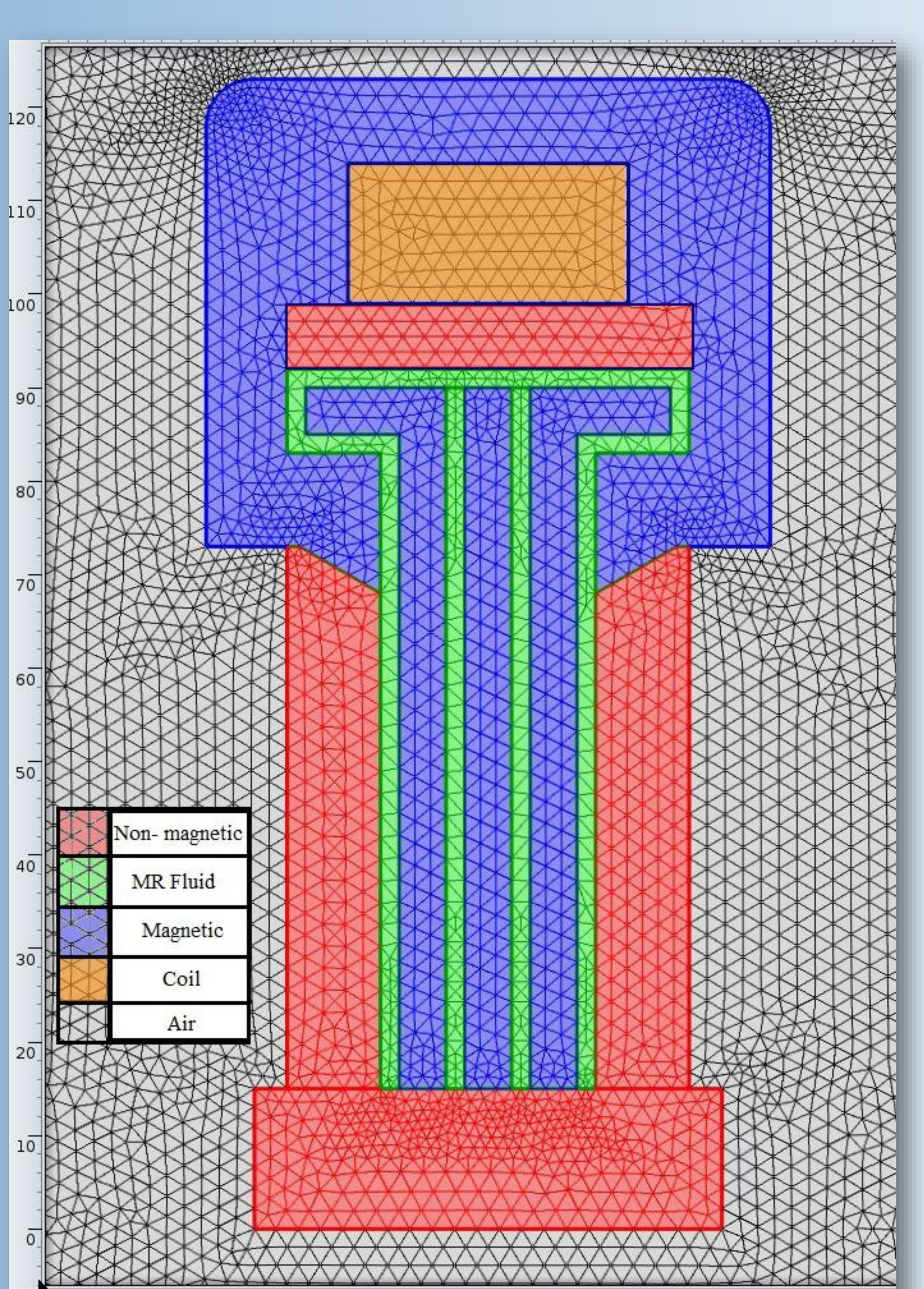


Figure 1. Parameters and CAD model of the proposed design.

Numerical Methods: In this study Bingham Model is used to describe the behavior of MR fluid in the presence of magnetic field.

$$T_b = 2\pi N \int_{r_i}^{r_o} (\mu_p \frac{r\omega}{h} + KH^{\beta}) r^2 dr$$

To calculate the magnetic field intensity (H) across the shear surfaces, the line and area integrations available in the post-processor of AC/DC module is utilized.



Approximately 9000 triangular elements are used to solve the following electromagnetic equations:

$$J_e = \nabla \times H$$

$$\nabla . B = 0$$

Table 1. Material Description

Parts	Material
Magnetic	AISI-1010
Non-magnetic	AISI-4340
MR fluid	MRF-132DG
Coil	Copper

Figure 2. Mesh used for the proposed system using small size triangular element.

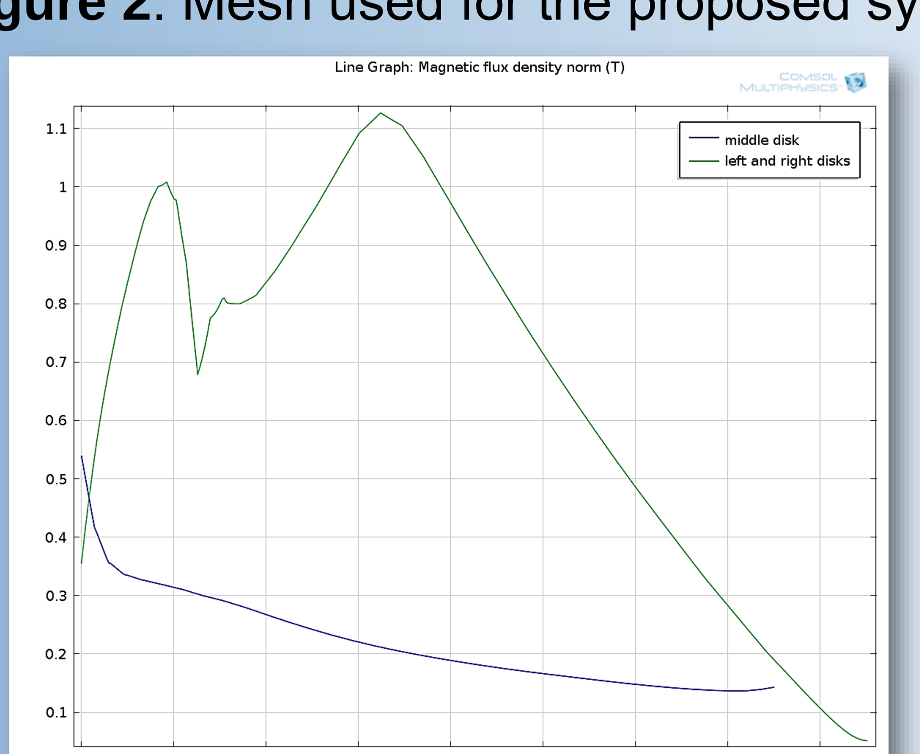


Figure 3. Magnetic flux on disks.

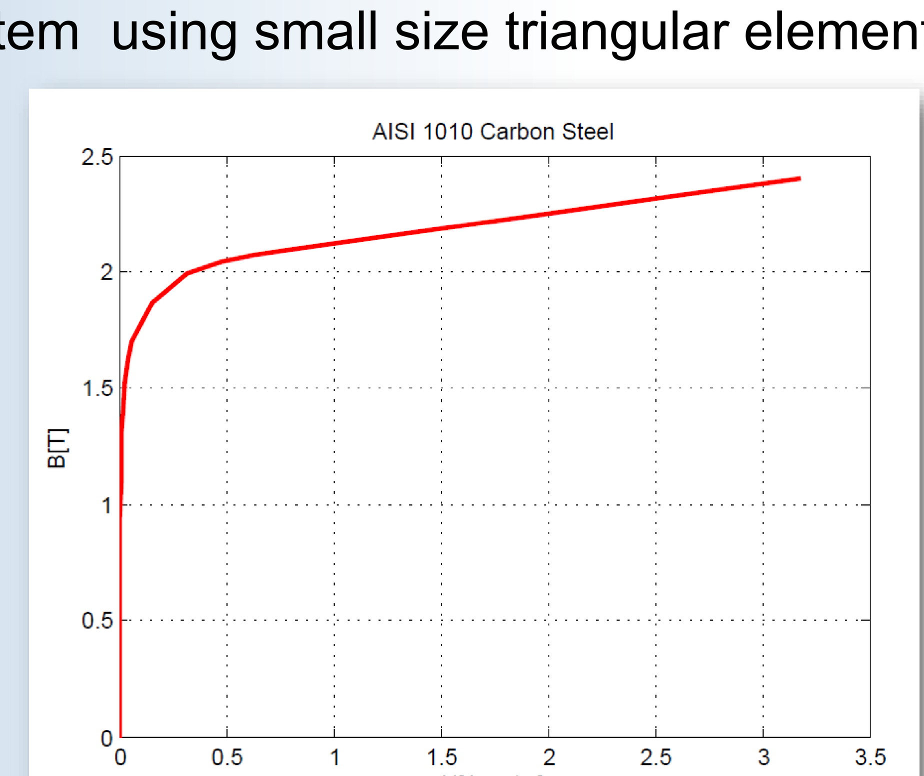


Figure 4. B-H Curve for AISI-1010.

Results: Directing an increasing amount of magnetic flux through the MR fluid can provide higher braking torques.

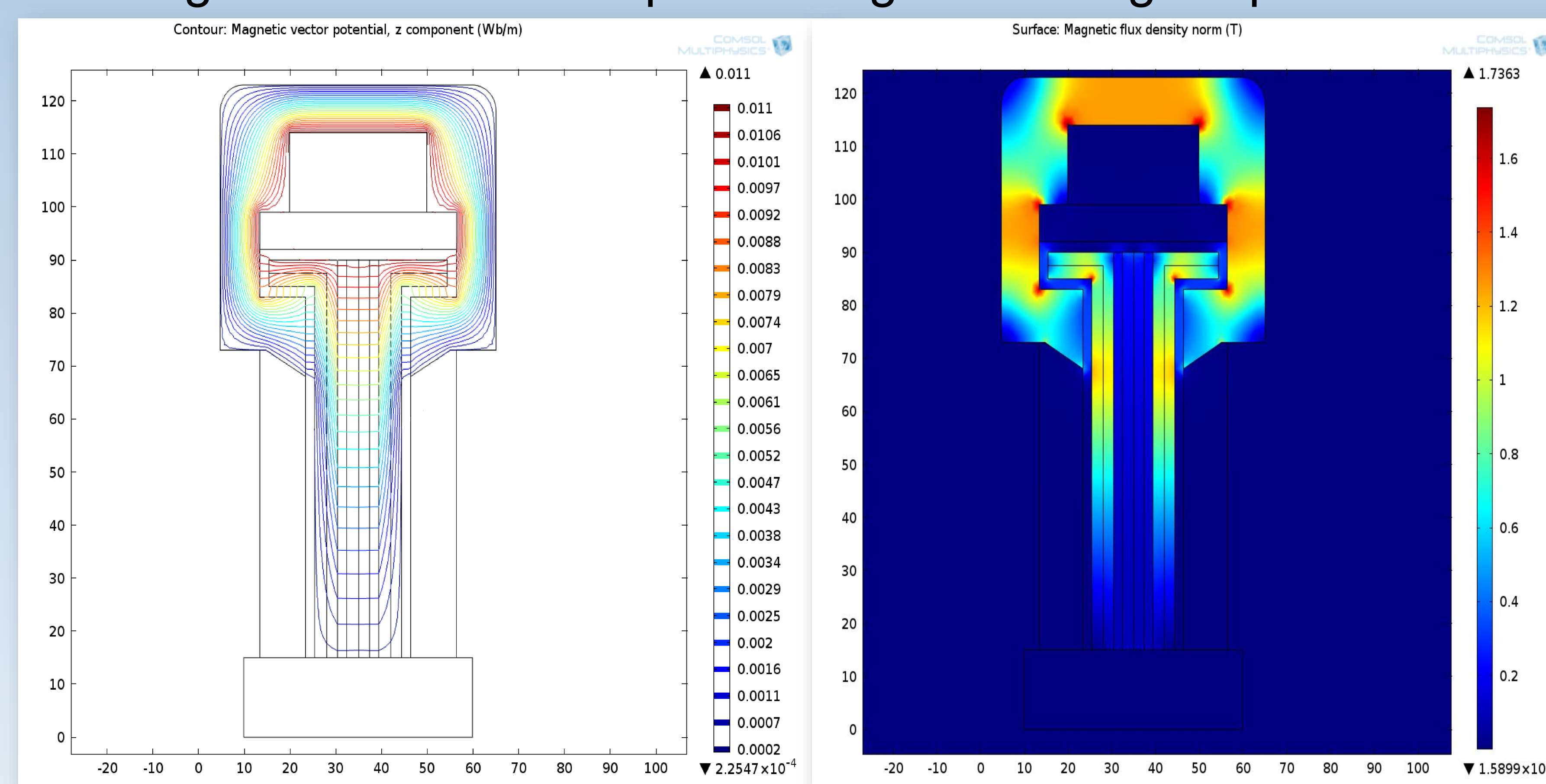


Figure 5. Magnetic flux and Magnetic vector potential when current density is J=10E5 [A/m²].

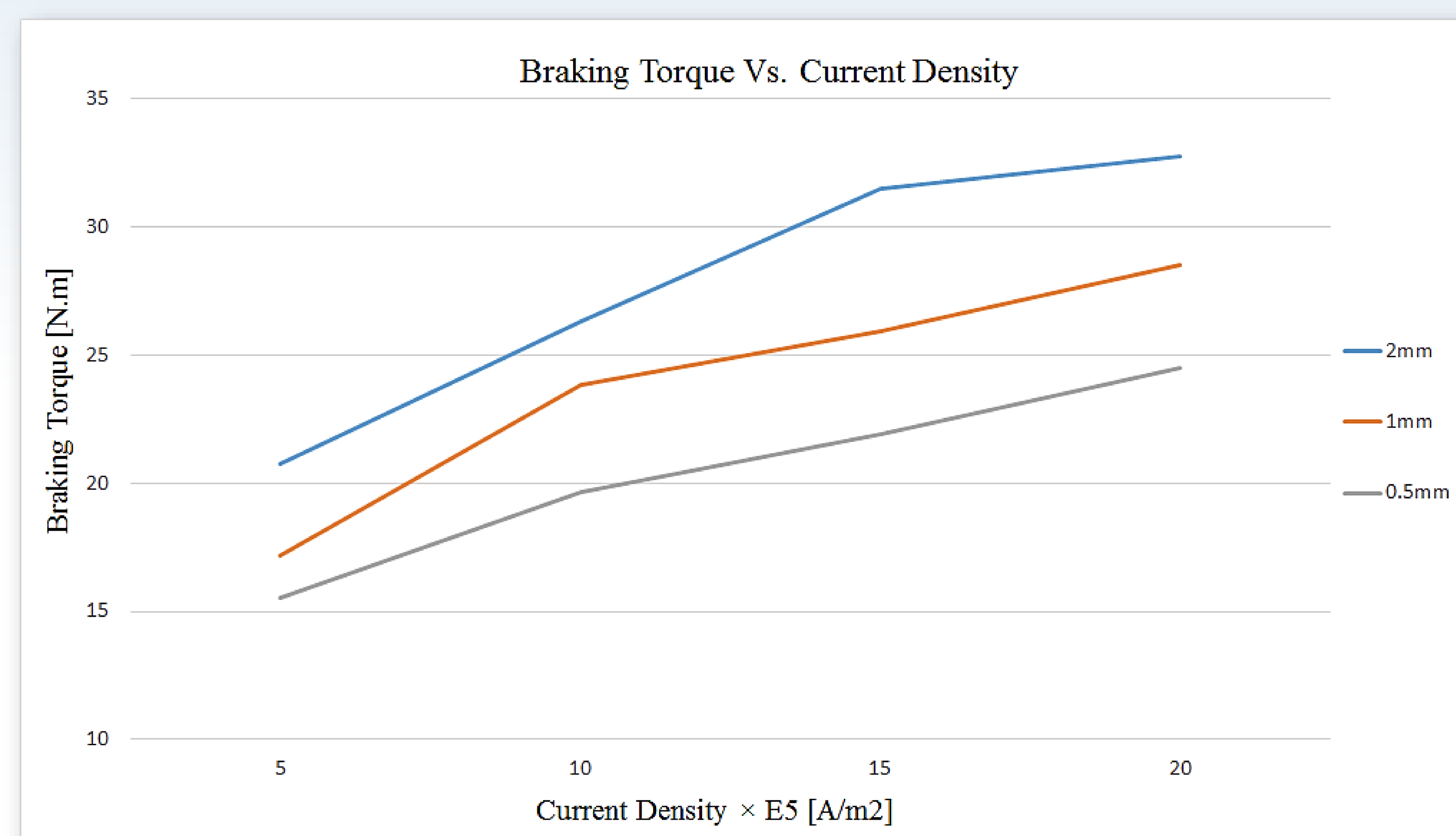


Figure 6. Braking torque vs. Current density with different MR fluid gap.

Conclusions: Figure 5 shows the corresponding magnetic vector potential contours and magnetic flux inside the braking system. Figure 6 provides braking torque of the system when different current densities are applied. The maximum possible current density is around 20E5 [A/m²]. Beyond this point MR fluid and electromagnetic core saturate and may cause unwanted heat generation by the coil which results in greater loss. The proposed design shows improvement over the designs available in the current literature with same limitations.

References:

1. I. Iryani, M. Yazid, S. A. Mazlan, T. Kikuchi, H. Zamzuri, and F. Imaduddin, “Design of magnetorheological damper with a combination of shear and squeeze modes," Materials and Design, vol. 54, pp. 87-95,2014.
2. K. Karakoc, E. J. Park, and A. Suleman,Design considerations for an automotive magnetorheological brake," Mechatronics, vol. 18 no.8, pp. 434-447, 2008.
3. M. Benetti and E. Dragoni, “Nonlinear magnetic analysis of multi-plate magnetorheological brakes and clutches," in COMSOL Users Conference 2006 Milano, 2006.
4. Q. H. Nguyen and S. B. Choi, “Selection of magnetorheological brake types via optimal design considering maximum torque and constrained volume“, Smart Materials and Structures, vol. 21 no. 1, pp. 12-20, 2012.