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**PARAMETRIC STUDY ON THE MAGNETIC CIRCUIT OF MR MOUNTS
UTILIZING MAGNETIC SHIELDING**

Summary. This study proposes a novel Magnetorheological (MR) Mount incorporating an aluminum non-magnetic shield to mitigate magnetic flux leakage. Using 3D magnetostatic FEM simulations under 0-2 A excitation, results demonstrate that the shield successfully eliminates short-circuit paths, forcing magnetic flux through the working fluid gap. Consequently, the magnetic field intensity at the gap increases 12-fold (from 20.27 to 244 kA/m), amplifying the overall damping force by over 8 times (from 22 N to approximately 180 N). Quantitative parametric analysis identifies the optimal configuration: MRF-140CG fluid (yielding ~275 N), a 4 mm oil gap (increasing force 2.7-fold), a 25 mm disc radius, and a 4.5–5 mm shield thickness. The study identifies local magnetic saturation at the journal neck (2.2 Tesla) as a performance bottleneck, establishing a critical foundation for future axial dimension optimization.

Keywords: magnetorheological mount, magnetic shield, finite element method, damping force

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1. INTRODUCTION

Magnetorheological (MR) mounts have garnered significant attention due to their potential applications in automotive suspension and vibration isolation systems, offering effective semi-active vibration damping characterized by low latency and a wide dynamic force range [1, 2]. In MR mount designs, the magnetic field generated by the electromagnetic coil plays a decisive role in altering the apparent viscosity (yield stress) of the MR fluid, which consequently regulates the damping force of the entire system [3, 4].

However, conventional magnetic circuit designs frequently suffer from significant performance limitations caused by uneven magnetic field distribution and magnetic flux leakage [5, 6]. Both simulations and experimental observations indicate that magnetic field intensity is predominantly localized at the edge regions adjacent to the coil, whereas the majority of the active working area experiences a substantially lower magnetic field [7, 8]. The root cause of this phenomenon is the tendency of magnetic flux to follow the path of least magnetic reluctance – typically short-circuiting through magnetically permeable components such as the base plate or housing, rather than penetrating the MR fluid gap, which inherently possesses a higher reluctance [9, 10].

To comprehensively address this issue, this study proposes a novel structural solution that integrates a magnetic shield. This paper details the development of a 3D model for the mount and conducts a series of parametric studies on its physical and structural variables using the Finite Element Method (FEM). These simulations aim to comprehensively evaluate and optimize the force-generating performance of the MR mount.

2. METHODOLOGY

2.1. Theoretical model for determining the damping force generated in the MR mount

Figure 1 illustrates the primary structural configuration of the proposed magneto-rheological (MR) bearing. The prototype utilizes an axisymmetric design to ensure mechanical stability and optimize the magnetic field distribution [11]. The 3D model consists of five main components: a disk, a housing, an electromagnetic coil, a rubber element, and an MR fluid gap. Concentric and surface-to-surface geometric constraints were rigorously established to maintain a uniform thickness of the working fluid gap along the disk profile.

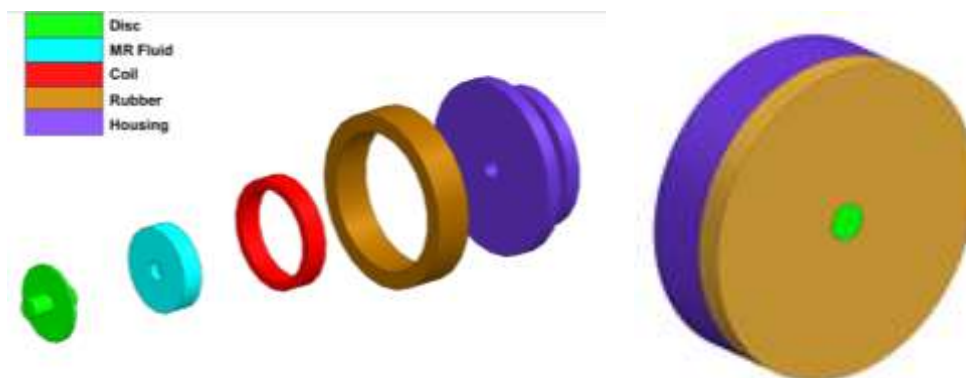


Fig. 1. Main structural components of the proposed MR mount

To formulate and analyze the damping force generated by the device, the analytical model is established based on the following core assumptions [12]:

- The magneto-rheological (MR) fluid is incompressible.
- The variation of the magnetic field in the axial direction (across the fluid gap thickness, z-axis) is neglected. This assumption is justified by the fact that the gap thickness is exceptionally small compared to other geometric dimensions, allowing the magnetic field to be treated as uniform at any given radial coordinate.
- The disk is restricted to purely vertical translational motion.

The total damping force of the MR mount is illustrated in Figure 2 and can be expressed by the following equation [12]:

$$F_d = F_1 + F_\eta + F_\tau \quad (1)$$

where: F_1 is the elastic force of the rubber (N), F_η is the viscous force of the fluid (N), and F_τ is the force generated by the magnetic field effect (N).

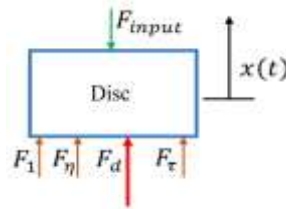


Fig. 2. Force components acting within the MR mount system

According to Hooke's law, the elastic force of an object is directly proportional to its deformation within the elastic limit, which is expressed by the following equation [13]:

$$F_1 = k \cdot x(t) \quad (2)$$

The viscous damping force is a resistance that occurs when the fluid undergoes shear deformation caused by the relative motion between the boundary surfaces, which is given by [12]:

$$F_\eta = c \cdot \dot{x}(t) \quad (3)$$

where: $x(t)$ is the disc displacement (m), $\dot{x}(t)$ is the disc velocity (m/s), and c is the viscous damping coefficient, expressed as:

$$c = \frac{3\pi\eta(r_{max}^2 - r_{min}^2)^2}{2(h_1 - x(t))^3} + \frac{3\pi\eta(r_{max}^2 - r_{min}^2)^2}{2(h_2 + x(t))^3} \quad (4)$$

For the field-dependent force component, the MR fluid is assumed to exhibit Bingham plastic behavior when subjected to an external magnetic field. Within this model, the fluid's shear stress comprises a yield stress component (τ_y). The pressure drop induced during compression can be approximated by the following equation [12]:

$$\frac{\partial P_{MR}}{\partial r} = - \frac{2\tau_y}{h - x(t)} \quad (5)$$

where P_{MR} denotes the pressure induced by the magnetic field effect, and r is the radial coordinate. By applying the boundary condition $P_{MR}(r_{max}) = 0$, in conjunction with the magnetic circuit analysis results and integrating the pressure over the circular contact area, the field-dependent damping force is calculated via radial integration as follows [12]:

$$F_\tau = \int_{r_{min}}^{r_{max}} \frac{2\tau_y}{h-x(t)} (r_{max} - r) 2\pi r dr = \frac{4\pi\tau_y}{h-x(t)} \left(\frac{r_{max}(r_{max}^2 - r_{min}^2)}{2} - \frac{r_{max}^3 - r_{min}^3}{3} \right) \quad (6)$$

Although the magnetic field is assumed to be uniform in the axial direction (across the gap thickness), in reality, the magnetic field intensity is non-uniformly distributed in the radial direction (along the r -axis) due to the configuration of the magnetic circuit. This non-uniformity causes the yield stress (τ_y) to vary as a function of the radius r . For a more precise computation, the disc surface is discretized into 10 concentric annular zones (labeled T_{E1} to T_{E10}), each defined by an inner radius r_i and an outer radius r_{i+1} , as depicted in Figure 3a. Within each i -th zone (bounded by an inner radius r_i and an outer radius r_{i+1} , the yield stress τ_{yi} is assumed to be constant along both the z -direction and the r -direction of that specific region. This piecewise approach allows us to accurately integrate the radial variation of the magnetic field into the total damping force calculation (Eq. 8) without violating the initial simplifying assumption established for the axial direction.

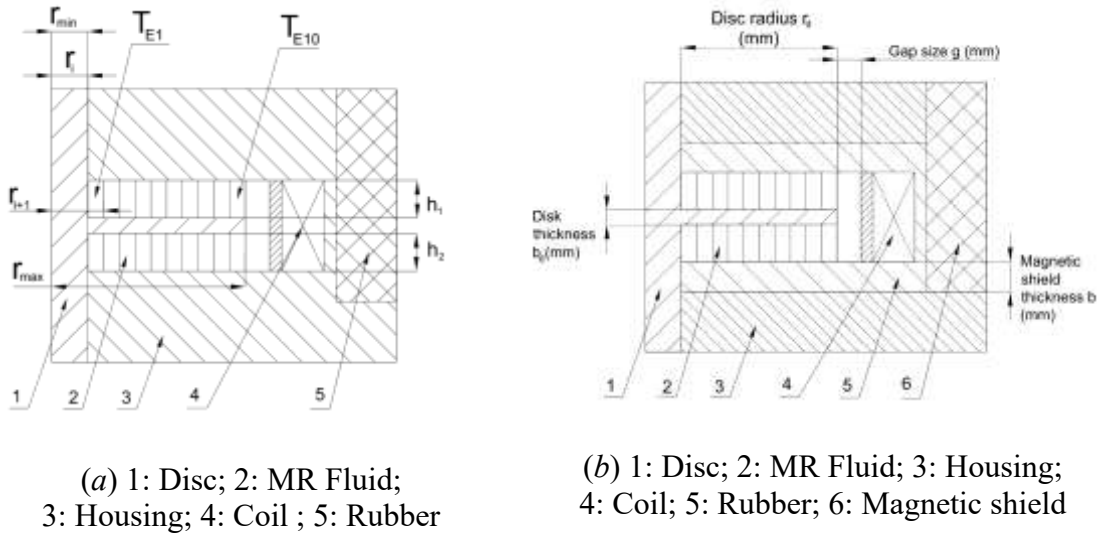


Fig. 3. Geometric models: (a) Conventional MR mount; (b) Enhanced MR mount with an integrated magnetic shield

In this study, the relationship between the yield stress and the magnetic field intensity is represented by the characteristic curves of the 132DG fluid grade provided by Lord Corporation [15]. By applying the curve-fitting method in MATLAB software, a polynomial expressing the relationship between the yield stress and the magnetic field intensity was derived. The equation and the corresponding coefficients are presented below:

$$\tau_y = 0.0123 + 0.2151H_{MR}^1 + 5.00E - 03H_{MR}^2 + (-1.01E - 04)H_{MR}^3 + 1.08E - 06H_{MR}^4 + (-7.15E - 09)H_{MR}^5 + 2.80E - 11H_{MR}^6 + (-5.87E - 14)H_{MR}^7 + 5.07E - 17H_{MR}^8 \quad (7)$$

where: H_{MR} is the magnetic field intensity at each point on the disk is determined from the 3D FEM simulation results (A/m).

Within each annular zone, under the assumption of a constant yield stress $\tau_{yi}(H_{MR})$ the field-dependent force component for the i -th region is approximated as follows:

$$F_{\tau,i} = \int_{r_i}^{r_{i+1}} \frac{2\tau_{yi}}{h-x(t)} (r_{max} - r) \cdot 2\pi r dr = \frac{4\pi\tau_{yi}}{h-x(t)} \cdot \left(\frac{r_{max}(r_{i+1}^2 - r_i^2)}{2} - \frac{r_{i+1}^3 - r_i^3}{3} \right) \quad (8)$$

The total magnetic field-induced force exerted across the entire disc can be expressed as follows:

$$F_{\tau} = \sum_{i=1}^{10} F_{\tau,i} \quad (9)$$

Taking into account the axial translational dynamics and the working mechanism of the magnetorheological fluid, only the gap subjected to compression produces a magnetic field-induced force [12]. Therefore, the resulting force is contingent upon the velocity direction.

$$F_{\tau} = \begin{cases} \frac{4\pi\tau_y}{h_1-x(t)} \cdot \left(\frac{r_{max}(r_{max}^2 - r_{min}^2)}{2} - \frac{r_{max}^3 - r_{min}^3}{3} \right), & \dot{x}(t) > 0 \\ \frac{4\pi\tau_y}{h_2+x(t)} \cdot \left(\frac{r_{max}(r_{max}^2 - r_{min}^2)}{2} - \frac{r_{max}^3 - r_{min}^3}{3} \right), & \dot{x}(t) < 0 \end{cases} \quad (10)$$

2.2. Magnetic Simulation of the MR Mount

2.2.1. Materials

The proposed design incorporates two distinct metallic materials with contrasting magnetic properties to effectively guide the magnetic flux [3]. Specifically, AISI 1010 steel is utilized for the disk and housing due to its high magnetic permeability and high saturation magnetization, facilitating an efficient magnetic circuit [14]. Conversely, aluminum is selected for the magnetic shield; as a non-magnetic and low-density material, it effectively prevents undesired magnetic flux leakage [14]. Furthermore, this study employs the magnetization properties (B-H curves) of three commercial MR fluids manufactured by Lord Corporation: MRF-140CG, MRF-132DG, and MRF-122EG [15-17]. These fluids differ significantly in their iron particle volume fractions, a parameter that directly governs their base viscosity and dynamic yield stress.

Tab. 1

Magnetic and rheological properties of the selected MR fluids

	MRF-122EG [17]	MRF-132DG [15]	MRF-140CG [16]
Density ρ (kg/m^3)	2280, 2480	2950, 3150	3054, 3074
Viscosity η ($Pa \cdot s$)	0.042 ± 0.020	0.112 ± 0.02	0.280 ± 0.070
Operating Temperature ($^{\circ}C$)	-40 to 130	-40 to 130	-40 to 130

2.2.2. Finite Element Model Setup

The 3D magnetostatic analysis was performed using the Altair Flux 3D finite element software to fully capture the effects of magnetic flux leakage in three-dimensional space [18]. Figure 4 illustrates the mesh model of the mount, which utilizes a uniform tetrahedral mesh with a total element count of approximately 1,426,737, a mesh growth rate of 0.15, and a minimum mesh size of 0.15 mm within the MR fluid gap region.

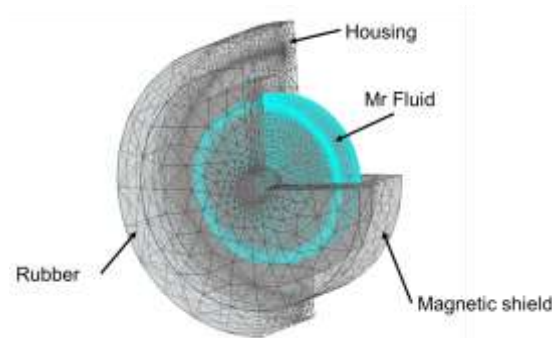


Fig. 4. Finite element mesh of the MR mount model

An infinite box domain was established surrounding the model to account for the magnetic field propagation at the boundaries. The excitation current supplied to the electromagnetic coil was varied from 0 A to 2 A during the investigation.

Tab. 2
Mesh quality parameters and convergence criteria for
the FEM model

Mesh Quality Metric	Percentage (%)
Unevaluated elements	0%
Excellent quality elements	74.36%
Good quality elements	24.09%
Fair quality elements	1.55%
Poor quality elements	0%

Furthermore, Table 2 indicates that the mesh quality was strictly controlled, with 74.36% of the elements achieving 'Excellent' quality and a complete absence (0%) of 'Poor' quality elements. This high-quality mesh structure enables the model to accurately capture complex physical phenomena, particularly in regions characterized by high magnetic field gradients and localized saturation.

2.2.3. Boundary Conditions and Model Assumptions

Three-dimensional 3D magnetostatic analysis of the MR mount was performed using the Finite Element Method (FEM) within the Flux software environment to solve Maxwell's equations. The physical model-comprising magnetically permeable materials (AISI 1010 steel for the disc and housing), non-magnetic components (aluminum shield and rubber), and the magnetorheological fluid-was investigated under excitation currents ranging from 0 to 2 A with an increment of 0.25 A. The simulation applies Dirichlet boundary conditions (magnetic potential = 0) at the outer domain and Neumann boundary conditions at the symmetry planes to appropriately constrain the magnetic flux [19].

3. RESULTS AND DISCUSSION

3.1. Evaluation of Magnetic Flux Leakage and the Effectiveness of Magnetic Shielding

Figure 5 illustrates the magnetic field intensity distribution within the MR fluid gap of the original MR mount configuration (without a magnetic shield) at an excitation current of 2 A. The simulation results reveal a significant non-uniformity in the magnetic distribution. Specifically, the magnetic field is locally concentrated at the outer periphery of the disk (near-coil region), reaching a peak value of approximately 20.27 kA/m. Conversely, the central region (far-coil region) remains largely unmagnetized, as evidenced by the dark blue contours. This phenomenon is primarily attributed to the magnetic flux preferentially bypassing the fluid gap through the disk base-constructed from high-permeability steel-to complete the magnetic circuit via the path of least reluctance. This magnetic short-circuiting and flux leakage result in substantial energy inefficiency, as the yield stress of the MR fluid in the central zone is not activated, thereby significantly degrading the damping force controllability of the mount.

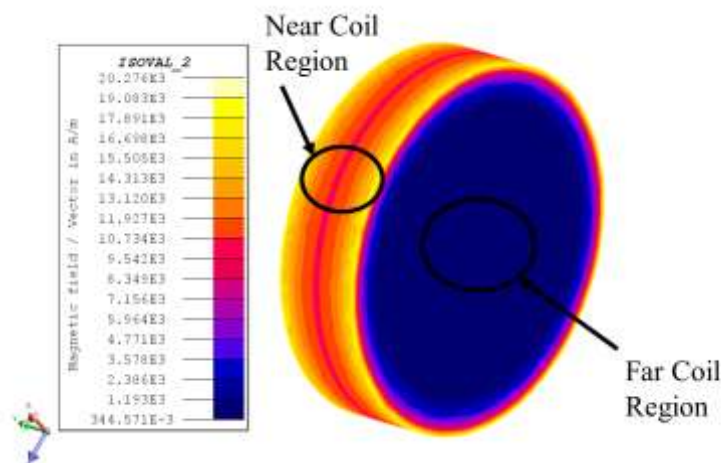


Fig. 5. Magnetic field intensity distribution within the MR fluid gap at 2 A

In the initial configuration, a substantial portion of the magnetic flux tends to bypass the working gap by traveling through the steel shaft (high-permeability material), thereby significantly diminishing the damping efficiency of the MR mount. To mitigate this magnetic short-circuiting, an aluminum magnetic shield is incorporated into the design (Fig 3b). This

modification reconfigures the magnetic circuit by forcing the flux lines to penetrate the MR fluid gap to complete the loop.

Figure 6 illustrates the magnetic field intensity distribution of the enhanced MR mount featuring the magnetic shield at an excitation current of 2 A. In contrast to the original design, where the magnetic field is concentrated only at the outer periphery, the enhanced design achieves a more uniform distribution across the entire effective radius. Notably, the peak magnetic field intensity within the fluid gap surges to 244 kA/m, representing a more than 12-fold increase compared to the initial model.

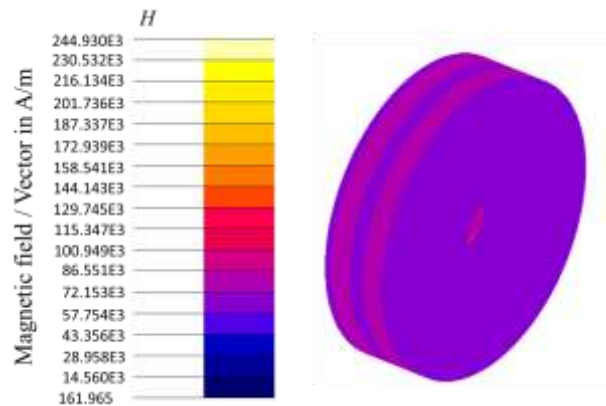


Fig. 6. Magnetic field intensity of the shielded MR mount at an excitation current of 2 A

This breakthrough improvement is attributed to the non-magnetic aluminum layer, which functions as a high-reluctance barrier that effectively eliminates the magnetic short-circuit path through the disk base. Under the forcing effect of this shield, the magnetic flux vectors are compelled to penetrate directly through the MR fluid gap. Consequently, the design establishes a closed magnetic circuit traversing the active fluid zone, thereby maximizing the activation of the yield stress and substantially enhancing the damping performance of the MR mount.

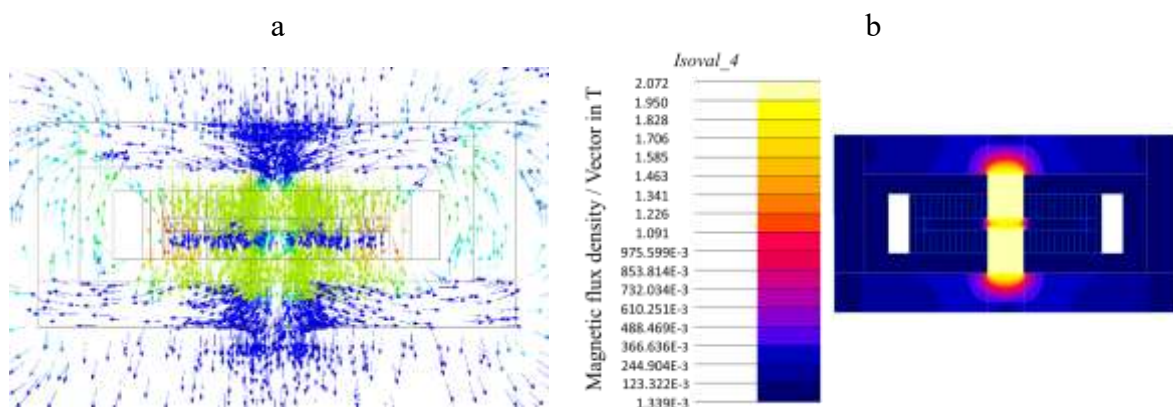


Fig. 7. Magnetic circuit analysis at 2 A: (a) Magnetic flux paths; (b) Magnetic flux density distribution

However, magnetic flux density analysis (Figures 7a and 7b) reveals a significant magnetization imbalance. While the large disk safely operates within the linear region ($B < 0.5$ T), the narrow shaft neck experiences localized magnetic saturation. At this location, flux density reaches approximately 2.2 T, substantially exceeding the 1.9–2.0 T limit of AISI 1010 steel. To eliminate this critical performance bottleneck in future prototypes, it is essential to increase the shaft neck radius to expand its magnetic cross-section.

The breakthrough improvement in flux density across the gap ensures the maximum activation of the MR fluid's yield stress. The correlation between these microscopic electromagnetic changes and the macroscopic performance of the mount is further evidenced by the increased damping force shown in Figure 8.

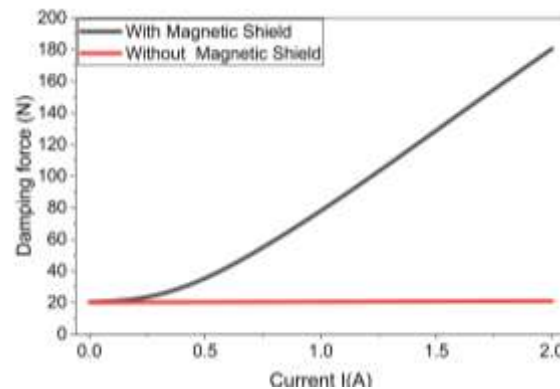


Fig.8. Damping force as a function of excitation current for the enhanced MR mount

The characteristic plots demonstrate that the magnetic shield significantly enhances the performance of the MR mount. Quantitatively, as the excitation current increases from 0 A to 2.0 A, the damping force rises near-linearly from a baseline resistance of 22 N to a peak value of approximately 180 N, achieving an amplification factor of over 8 times. These results confirm that the non-magnetic shield effectively eliminates flux leakage, forcing the magnetic circuit to concentrate through the active fluid gap. Consequently, the device maximizes the MR fluid's yield stress, thereby extending the force control range and ensuring high reliability for semi-active vibration control applications.

3.2. Effect of Material Characteristics on the Damping Force of Magnetic-Shielded Magnetorheological Mounts

Figure 9 illustrates the distinct dependence of the damping force on the type of magnetorheological (MR) fluid employed. Among the evaluated fluids, MRF-140CG generates the highest damping force, significantly outperforming the MRF-132DG and MRF-122EG grades. Quantitatively, at the peak excitation current of 2.0 A, MRF-140CG produces a resistance force of approximately 275 N, which is substantially higher than the 180 N and 135 N recorded for MRF-132DG and MRF-122EG, respectively. Even in the off-state (0 A), MRF-140CG maintains a slightly higher baseline force of approximately 30 N, which is attributed to its inherently higher zero-field viscosity.

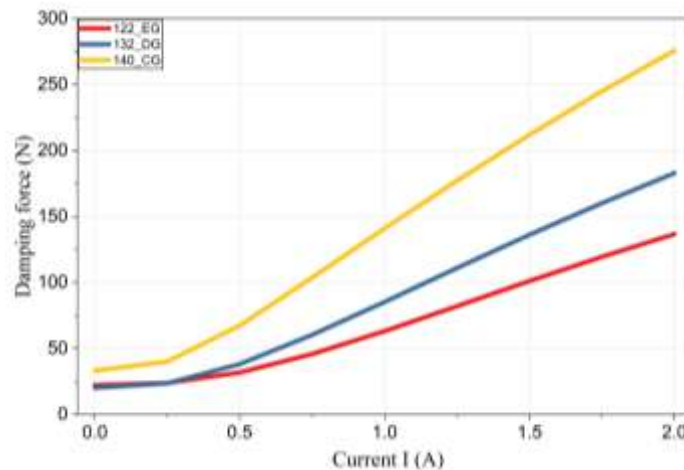


Fig. 9. Influence of different MR fluid grades on damping force versus excitation current

The underlying physical mechanism for this superiority is attributed to the high magnetic particle volume fraction of MRF-140CG. When the magnetic flux is constrained by the shield to concentrate through the working gap, this dense particle population forms robust chain-like structures, leading to a significantly higher field-dependent yield stress. Consequently, the synergy between the magnetic shielding solution and the high-grade MR fluid is demonstrated as an optimal strategy for maximizing the overall damping performance of the system.

3.3. Effect of Geometric Parameters on the Damping Characteristics of an Enhanced MR Mount

3.3.1. MR fluid gap size (g)

Figure 10 illustrates the influence of the MR fluid gap width (varying from 4 mm to 8 mm) on the damping force magnitude. The results indicate that this parameter plays a pivotal role in the device's performance. Specifically, at a peak excitation current of 2.0 A, reducing the gap from 8 mm to 4 mm leads to a significant surge in the damping force, increasing from 105 N to approximately 270 N—a 2.7-fold enhancement.

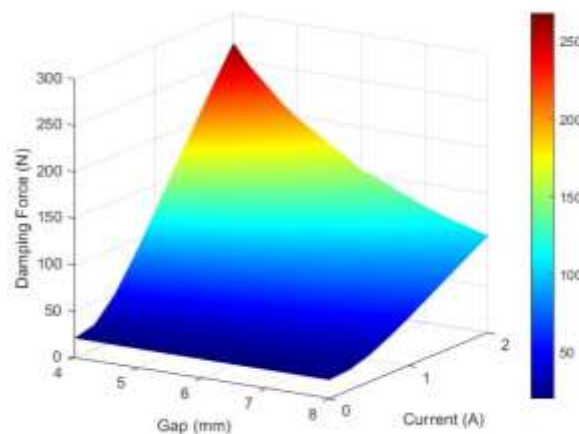


Fig. 10. Impact of MR fluid gap width (4 mm - 8 mm) on the generated damping force

This improvement is attributed to the synergistic interaction between hydraulic and magnetic mechanisms within the active zone. Hydraulically, since the system operates in compression mode, a narrower gap substantially increases flow resistance and fluid constraint, resulting in elevated back-pressure and higher baseline viscous forces. Magnetically, a smaller gap reduces the total reluctance of the magnetic circuit, thereby increasing the flux density across the fluid layer and maximizing the activation of the field-dependent yield stress. Consequently, the small-gap configuration not only yields superior force generation but also expands the dynamic force ratio, enhancing the control sensitivity of the overall system.

3.3.2. Disk radius (r_d)

In addition to axial parameters, the disk radius significantly influences the force-generation performance of the MR mount. Figure 11 investigates the outer disk radius ranging from 25 mm to 32 mm, revealing a clear inverse relationship: an increase in the radius leads to a reduction in the generated damping force.

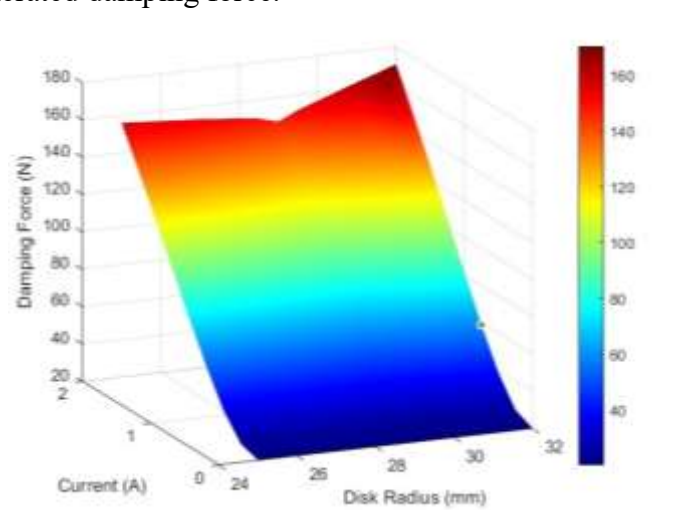


Fig. 11. Relationship between damping force and outer disk radius (25 mm - 32 mm)

Specifically, at an excitation current of 2 A, the 25 mm disk configuration yields a peak force of approximately 160 N, whereas the 32 mm configuration exhibits a decline to around 135 N. This phenomenon is attributed to the variation in magnetic flux density within the working gap. Expanding the disk radius increases the contact surface area of the fluid gap. Since the total magnetic flux supplied by the coil and the core cross-section remain constant, the flux is forced to distribute over a larger area. Consequently, the average flux density penetrating the MR fluid layer decreases. Given that the yield stress of the MR fluid is directly dependent on flux density, this reduction inevitably results in a diminished damping force.

3.3.3. Magnetic shield thickness (b)

The investigation into the magnetic shield thickness (ranging from 4.0 to 6.0 mm with 0.25 mm increments) demonstrates that this parameter exerts a direct influence on the flux guidance capability and the resulting damping force of the MR mount. As illustrated in Figure 12, the damping force exhibits a near-linear increase across all configurations as the excitation current rises from 0 to 2 A. Notably, thinner shield configurations (4.0-4.75 mm) yield superior

damping forces, reaching a peak of approximately 175 N, compared to the thicker variants (5.5-6.0 mm), which achieve approximately 155 N.

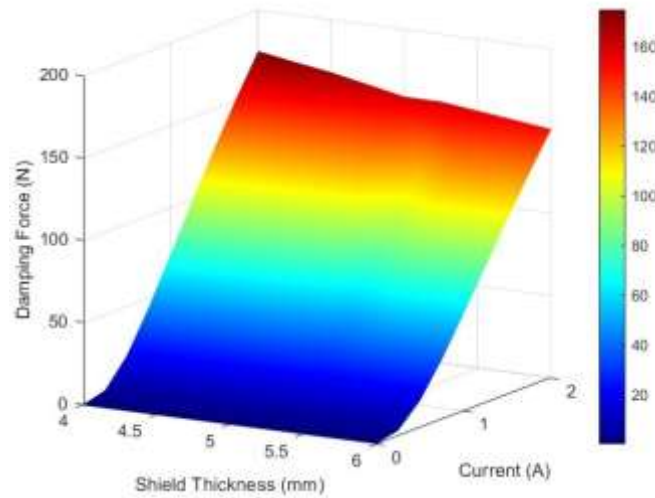


Fig. 12. Effect of magnetic shield thickness on the damping force performance

This discrepancy arises because an excessively thick shield increases the overall magnetic reluctance, thereby hindering flux transmission to the active zone and reducing the effective magnetic field intensity. Conversely, a shield that is too thin lacks the necessary barrier effect to optimally direct the magnetic flux. Consequently, to balance system performance, a thickness range of 4.5-5.0 mm is identified as the optimal configuration, ensuring efficient magnetic transmission and robust damping force generation.

3.3.4. Rotor disk thickness (b_d)

The investigation into the disk thickness (varying from 2 mm to 5 mm) reveals that this parameter has a negligible impact on the force-generation performance of the MR mount. As illustrated in Figure 13, despite a 2.5-fold increase in thickness, the damping force curves relative to the excitation current (0-2 A) remain nearly coincident.

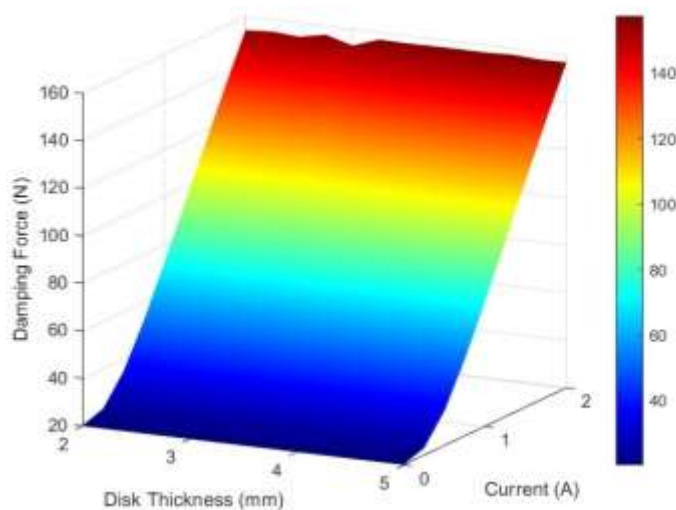


Fig. 13. Sensitivity of damping force to disk thickness variations (2 mm - 5 mm)

At the peak current of 2 A, the damping force across all configurations consistently maintains a value of approximately 160 N, with statistically insignificant deviations. This phenomenon is elucidated by the magnetic saturation characteristics of the structure. Fundamentally, the disk thickness determines the cross-sectional area available for radial magnetic flux transmission. However, since the disk in the current design operates within the low-field (linear) region of the magnetization curve, the material remains far from its saturation limit. Consequently, the existing cross-section provides sufficient capacity for flux conduction, and further increasing the thickness does not enhance the magnetic circuit efficiency. These findings provide a solid foundation for selecting the minimum disk thickness (2 mm), thereby optimizing both the system mass and spatial requirements without compromising performance.

4. CONCLUSIONS

This study successfully implemented a 3D Finite Element Method (FEM) simulation to comprehensively address the issue of magnetic flux leakage in magnetorheological (MR) mounts through the integration of a magnetic shield. Based on the quantitative analyses, the following key conclusions can be drawn:

- The aluminum magnetic barrier effectively eliminates the magnetic short-circuit path through the disk base, redirecting the magnetic flux to concentrate within the active fluid zone. This structural enhancement results in a 12-fold increase in the peak magnetic field intensity within the MR gap, reaching 244 kA/m. Consequently, the damping force is amplified by more than 8 times, rising from a baseline of 22 N to approximately 180 N at an excitation current of 2 A.
- The force-generation capacity of the MR mount is highly sensitive to both physical properties and geometric parameters, specifically:
- Magnetorheological (MR) Fluid Properties: MRF-140CG, with its high iron particle volume fraction, produces the highest yield stress, resulting in a superior damping force of approximately 275 N, compared to 180 N and 135 N for MRF-132DG and MRF-122EG, respectively.
- Working Zone Geometry: A narrow fluid gap of 4 mm yields a 2.7-fold increase in damping force compared to an 8 mm gap, attributed to the synergistic effect of increased hydraulic resistance and reduced magnetic reluctance. Additionally, a compact disk radius of 25 mm achieves the highest average flux density and force output (~160 N).
- Magnetic Circuit Configuration: The magnetic shield thickness achieves optimal flux guidance efficiency within the 4.5–5.0 mm range. Conversely, variations in disk thickness (2–5 mm) have a negligible impact on force generation (~160 N), as this region operates within the unsaturated low-field region.

Although the magnetic shield significantly enhances overall performance, localized magnetic saturation (up to 2.2 T) at the shaft neck—due to its limited cross-section—remains a critical bottleneck. Future research will focus on optimizing the shaft neck geometry to fully exploit the potential of the magnetic circuit.

Furthermore, a current limitation of this study is the lack of experimental validation. The primary objective of this paper is to provide a proof of concept and a detailed parametric study for a novel structural solution featuring an integrated aluminum non-magnetic shield. Given that prototype fabrication requires high-precision manufacturing and specialized sealing solutions for aluminum-steel assemblies, experimental verification is scheduled for the next

research phase. Future work will focus on optimizing the shaft neck geometry to fully exploit the potential of the magnetic circuit while conducting prototype testing to comprehensively validate these simulation results.

List of symbols:

r	radial coordinate (mm)
r_{min}	Inner radius of the active MR fluid region (mm)
r_{max}	Outer radius of the active MR fluid region (mm)
r_d	Disk radius (mm)
b_d	Disk thickness (mm)
h_1	Upper MR fluid gap thickness (mm)
h_2	Lower MR fluid gap thickness (mm)
h	Thickness of the compressed MR fluid gap (mm)
g	Total axial MR fluid gap size (mm)
b	Magnetic shield thickness (mm)
r_i	Inner radius of the i -th annular zone (mm)
r_{i+1}	Outer radius of the i -th annular zone (mm)
$x(t)$	Axial disc displacement (m)
$\dot{x}(t)$	Disc velocity (m/s)
F_d	Total damping force of the MR mount (N)
F_1	Elastic force of the rubber element (N)
F_η	Viscous damping force of the MR fluid (N)
F_τ	Field-dependent damping force (N)
$F_{\tau,i}$	Field-dependent force component at the i -th zone (N)
k	Stiffness coefficient (N/m)
c	Viscous damping coefficient (N.s/m)
P_{MR}	Pressure induced by the magnetic field effect (Pa)
η	Zeno-field dynamic viscosity of the MR fluid (Pa.s)
τ_y	Yield stress of the MR fluid (Pa)
τ_{yi}	Yield stress of the MR fluid at the i -th zone (Pa)
H_{MR}	Magnetic field intensity (A/m)
$p_0 \dots p_8$	Polynomial coefficients for the MR fluid characteristic curve

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