International Journal of Advanced Research in Engineering Innovation
e-ISSN: 2682-8499 | Vol. 3, No. 4, 8-15, 2021
http://myjms.mohe.gov.my/index.php/ijarei

A Technological Review of Magnetorheological Dampers

Ahmad Fadzil Ismail[1*], Mohd Fuad Ibrahim[2], Kamarul Hisyam Osman @ Othman[2]

[1] Department of Mathematics, Science and Computer, Politeknik Seberang Perai, Pulau Pinang, Malaysia
[2] Department of Mechanical Engineering, Politeknik Seberang Perai, Pulau Pinang, Malaysia

[*]Corresponding Author: afadzil@psp.edu.my

Accepted: 15 November 2021 | Published: 1 December 2021

DOI: https://doi.org/10.55057/ijarei.2021.3.4.2

Abstract: *Damper is part of suspension system where it is function to prevent noise, bumps, and vibrations. Most dampers are categorized in three categories which is active, semi-active and passive damper. Magnetorheological (MR) damper is categorized under semi-active damper. This type of damper utilize rheological fluids which is in normal state its free-flowing liquid but when magnetic field or current is applied, the fluid will change its viscosity. This paper review 8 MR damper which are hybrid with eddy current, multi-coil, rotary high torque, orifice hole, permanent magnet, serial-type with flow channel, extra grooves around the housing, and high speed adaptability. The research and development still on going to find the best means as possible to utilize rheological fluids in MR damper. This review is very important to the new researcher in order to find new way to further improve MR damper.*

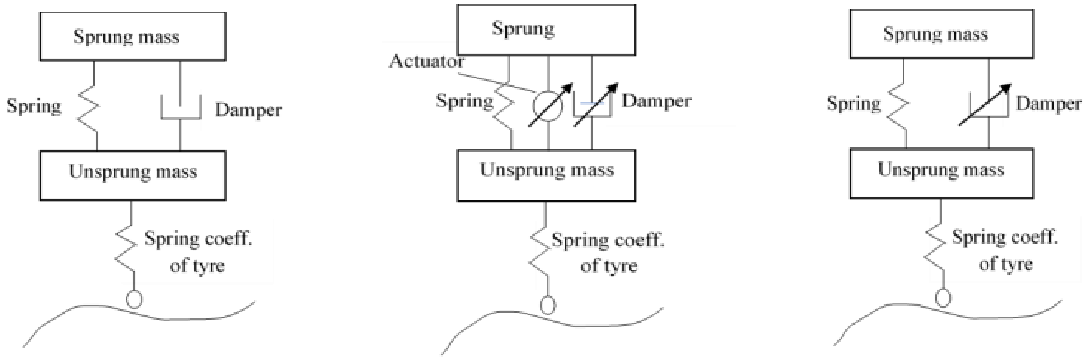
Keywords: Damper, rheological fluids, magnetorheological damper, electrorheological damper, smarts materials

---

1. Introduction

Dampers are also known as a shock absorber (Jugulkar et al., 2016) are the most underappreciated components of the automobile although it was sold more than 50 million units a year (Singh & Srilatha, 2018). This is because they are not visible or noisy as other automobile components. Dampers are part of a system called the suspension system. The function of the suspension system is to prevent noise, bumps, and vibrations from being conveyed to the passenger compartment (Khot, 2019).

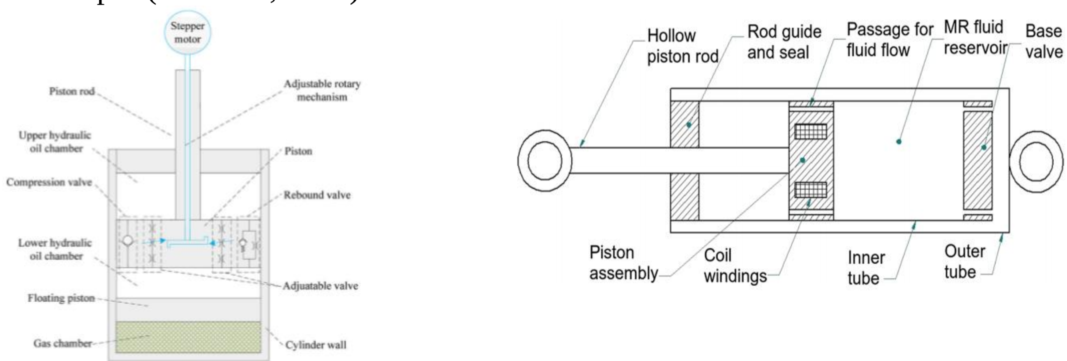
Most of dampers are divided into 3 categories which are active, semi-active, and passive damper (Kabariya & James, 2020; Khot, 2019; Rahman et al., 2017). In an active damper, the system has a sensor and other electronic components where the components will give a feedback according to the signal given and the system can decide whether to add or to absorb energy from the system. On the other hand, a passive damper is a static damper and it only absorbs energy from the system. The combination of these two dampers is a semi-active damper.



[a] [b] [c]

Figure 1: Categories of suspensions [a] Passive [b] Active, and [c] Semi-active (Yaakub et al., 2020)

Jugulkar et al., (2016) suggested automobile damper should be categorized according to its damping method which is fluid damper, automobile damper, twin-tube (figure 1(b)), mono tube (Figure 2(a)) damper, and magnetorheological damper. In contrast, other researchers only categorized automobile dampers into two categories only which are twin-tube damper and mono-tube damper (Ma et al., 2019).



[a] [b]

Figure 2: Basic structure of [a] mono-tube hydraulic damper (Ma et al., 2019), [b] twin-tube MR damper (Madhavrao et al., 2019)

Currently, Magnetorheological (MR) or Electrorheological (ER) damper has attracted attention of researchers around the world because this type of damper utilizes rheological fluid that changes its viscosity after magnetic field or current or both is applied to the fluid (Basheer, 2020). The term is interchangeable because both fluids react identically when a current or magnetic field is applied. Table 1 shows the property of MR and ER fluid and MR fluid has attracted more attention and acceptance because of its higher yield stress and working temperature, low voltage and able to withstand higher level of contamination (J. Wang & Meng, 2001). This review paper will explore how rheological fluid works and current design of MR damper in an automobile.

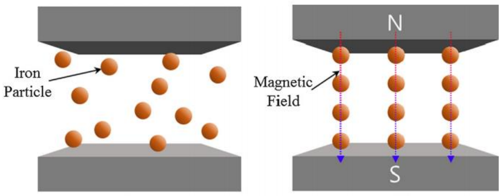
Table 1: Property feature between MR and ER (Olabi & Grunwald, 2007).

Property feature	MR	ER
Maximum yield stress	50–100 kPa	2–5 kPa
Power supply	12-24 V @1-2 A	2-5 kV @ 1-10 mA
Response time	Some milisecond	Some millisecond
Operational field	~250 kA/m	~4Kv/mm
Energy density	0.1 J/cm^3	0.001 J/cm^3
Stability	Good for most impurities	Poor for mst impurities
Operational temperature	-40^{0}C up to 150^{0}C	-25^{0}C up to 125^{0}C

International Journal of Advanced Research in Engineering Innovation
e-ISSN: 2682-8499 | Vol. 3, No. 4, 8-15, 2021
http://myjms.mohe.gov.my/index.php/ijarei

2. Rheological Fluid Characteristic

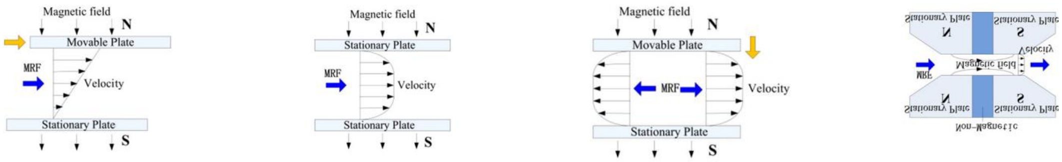
Rheological fluid is smart materials and was discovered in 1940s by Jacob Rabinov and W. Wislow in The United States (Olabi & Grunwald, 2007; Sodeyama et al., 2004) although the term "smart materials" is thought to have originally originated in the late 1980s (Ahamed & Choi, 2018). Typically, the rheological fluid includes 20–40% clean soft iron particles by volume, combined with mineral oil, synthetic oil, water, or glycol (Rahman et al., 2017). These fluids are made up of magnetizable micron-sized particles suspended in a carrier liquid. Rheological fluids are normally free-flowing liquids with a viscosity comparable to that of lubrication engine oil (Yang et al., 2002). Figure 3 shows how the rheological fluid behaves before and after the fluid is subjected to the magnetic field.



[a] **[b]**

Figure 3: Magnetorheological fluid [a] before and [b] after, magnetic field is applied (Yoon et al., 2019)

When the rheological fluid is subjected to a magnetic field (or current or both), the particles in the fluid form a chain structure and form particle clusters that obstruct the fluid movement (Sodeyama et al., 2004). When using MR fluid in a device, there are four fundamental operational modes which are shear mode, flow mode, squeeze mode and pinch mode (Yu et al., 2016) (figure 4).



[a] **[b]** **[c]** **[d]**

Figure 4: Fundamental operational modes in magnetorheological fluid [a] Shear mode [b] Valve mode [c] Squeeze mode and [d] Pinch mode (Yu et al., 2016).

3. Magnetorheological Damper (MR)

Over the years, researchers have come up a few different designs and arrangements in MR dampers to exploit the advantages of rheological fluid and at the same time to overcome the drawback of fluid that comes with it. MR damper is a semi-active damper that has a design simplicity and durability as a passive system but its rapid response, large dynamic range and adaptability as active system (Oh & Choi, 2019; M. Wang et al., 2019).
Asghar Maddah et al. (2017) proposed a mix between MR damper and eddy current damper in order to achieve lower stiffness. The research is done by combining passive eddy current damper with semi-active MR damper. The proposed design able to lower 12% stiffness of the damper. Zheng et al. (2016) designed a multi-coil MR damper where each coil has an individual exciting current. The novel design of multi-coil MR damper shows a significant improvement compare to a typical multi-coil damper which is subjected to sinusoidal and triangle displacement.

International Journal of Advanced Research in Engineering Innovation
e-ISSN: 2682-8499 | Vol. 3, No. 4, 8-15, 2021
http://myjms.mohe.gov.my/index.php/ijarei

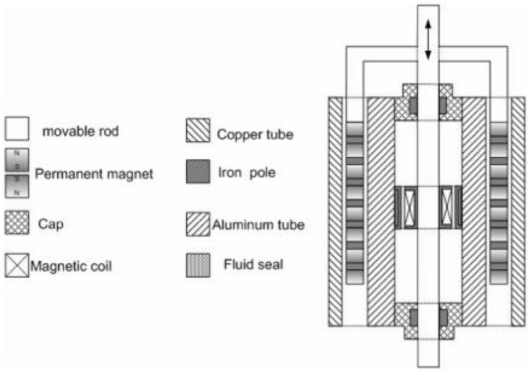


Figure 5: Schema of hybrid eddy current damper and MR damper (Asghar Maddah et al., 2017).

[a] **[b]**

Figure 6: Schematic diagrams of MR damper with electromagnetic coils [a] Typical multi coils damper [b] Proposed multi coils MR damper design (Zheng et al., 2016).

Wei et al. (2020) designed a high torque MR damper to provide adequate damping performance for heavy truck suspension. Instead of using a piston type damper, this design using a high toque rotary MR damper. After experiment and computer simulation, it is concluded that this type of damper can be used in heavy truck suspension although it produces a significant amount of heat which will be studied in the future. On the other hand, Oh & Choi (2019) manufactured an MR damper with an orifice hole to study the relationship of passenger ride comfort with MR damper with and without an orifice hole. A robust sliding controller was designed to evaluate the performance and it was found that through computer simulation that the designed MR damper can deliver better ride comfort when the MR damper with an orifice hole is applied in suspension system.

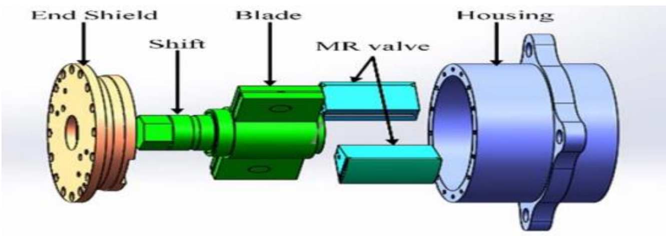


Figure 7: High-torque rotary magnetorheological (MR) damper with a parallel plate Channel (Wei et al., 2020)

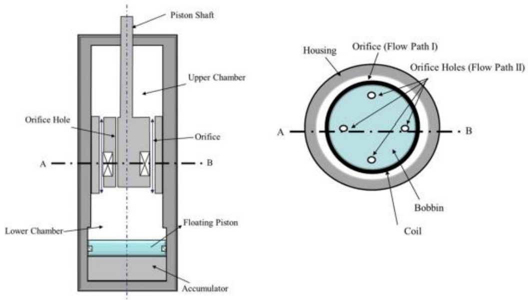
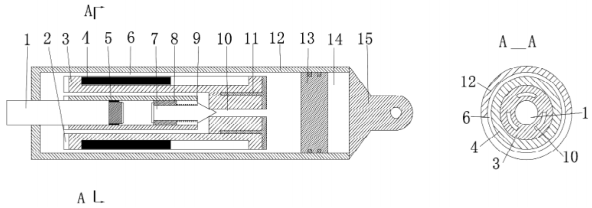


Figure 8: Schematic diagram of MR damper with orifice hole (Oh & Choi, 2019).

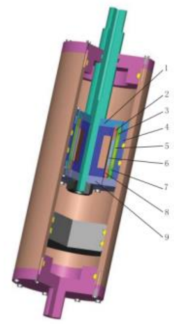
International Journal of Advanced Research in Engineering Innovation
e-ISSN: 2682-8499 | Vol. 3, No. 4, 8-15, 2021
http://myjms.mohe.gov.my/index.php/ijarei

Xiao et al. (2017) trying to avoid the magnetic field supplied to MR damper from failing by redesign MR damper with permanent magnet and magnetic valves. The damper was tested in experiment and computer simulation based on quarter suspension model that was built later. The result shows were good like it was expected. Hu et al. (2019) manufactured an MR damper with a serial-type flow channel to provide higher damping force at the same time reduce the size of the damper. The damper was tested and studied on the test rig under different currents and shows that the damper has high vibration control capability and better mechanical properties.



1. Piston rod; 2. Stainless-steel magnetoresistive plate; 3. I-section piston head; 4. Circular permanent magnet; 5. Magnet coil; 6. Damp channel; 7. Valve plug; 8. Screw tube; 9. Back spring; 10. Magnetic valve pipe; 11. Stainless-steel magnetoresistive plate; 12. Cylinder barrel; 13. Moving piston; 14. Compensation chamber; 15. Ear loop

Figure 9: Mechanical structure of magnetorheological damper with permanent magnet and magnetic valve (Xiao et al., 2017).



1: piston upper cover; 2: magnetic sleeve I; 3: magnetic sleeve II; 4: outer sleeve; 5: non-magnetic sleeve II; 6: non-magnetic sleeve I; 7: magnetic sleeve III; 8: magnetic sleeve IV; 9: piston lower cover.

Figure 10: The diagram is a schematic of serial type flows MR damper (Hu et al., 2019)

Yoon et al. (2019) proposed new MR damper that response faster than typical MR damper. The damper was made to have more grooves around the housing to decrease the eddy current magnitude. From experimental test shows that the strategy of reducing eddy current around the magnetic field zone indeed make the MR damper faster. Kim et al. (2020) proposed a novel MR damper where the vehicle suspension system with excellent adjustability at both low and high speeds. By altering the effective area of the primary orifice and changing the coefficient of damping, the desired adaptability can be achieved.

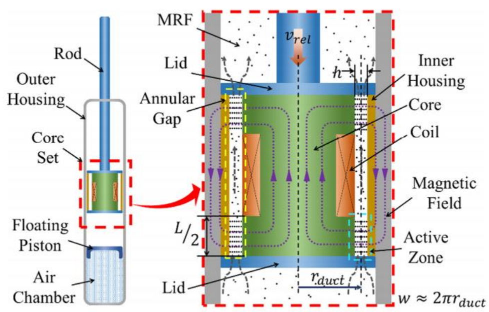
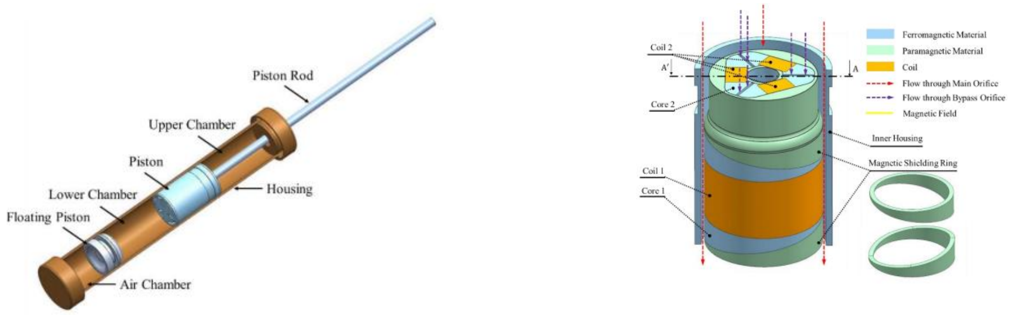


Figure 11: Schematic diagram MR damper that give fast response (Yoon et al., 2019)



[a] **[b]**

Figure 12: Proposed MR damper with pole shape function configuration [a] overall schematic [b] core part schematic (Kim et al., 2020).

4. Conclusion

Although magnetorheological fluid has been discovered almost 80 years ago, the development of the devise that utilize and exploit this kind fluid still just only taking off just 2 decades ago. Magnetorheological damper are starts to be commercialized by engineering company. Extensive research and development by university and private firm was funded to find the best means to utilize magnetorheological fluids. One of the devices is MR damper. Last five years is the most fruitful years to MR damper development. Researchers still and already have found the best means possible to utilize MR fluids to use in MR damper. Table 2 shows all MR damper that have been reviewed in this article.

Table 2: Latest design and development in MR damper

No	Type of Damper	Note	Reference
1.	Piston type with permanent magnet (Flow mode)	To develop hybrid eddy current damper and MR damper to achieve lower stiffness.	Figure 5. (Asghar Maddah et al., 2017)
2.	Piston type with electromagnetic coil (Flow mode)	To design multi coil MR damper with four electromagnetic coil and each coil have individual exciting current.	Figure 6. (Zheng et al., 2016).
3.	Rotary type with high torque (Flow mode)	To design high torque MR damper to provide sufficient damping performance for heavy truck suspension.	Figure 7. (Wei et al., 2020).
4.	Piston type with orifice hole (Flow mode)	To study a relationship of passenger ride comfort between MR damper with orifice hole and without orifice hole.	Figure 8. (Oh & Choi, 2019)
5.	Piston type with permanent magnet	To design MR damper with permanent magnet to avoid fail safe problem which can be applied to all MR damper in the future	Figure 9. (Xiao et al., 2017)
6.	Piston type with serial-type flow channel (Flow mode)	To manufacture a MR damper with serial-type flow channel that can increase the damping force with limited size in vehicle suspension system	Figure 10. (Hu et al., 2019)
7.	Piston type with groove inner surface housing to reduce eddy current	To design and a fast response MR damper capable of producing enough dampening force in a few of milliseconds	Figure 11. (Yoon et al., 2019)
8.	Mono-tube piston type damper (Flow mode)	To design a new MR damper that can adjust both the damping coefficient and the slope breaking point in order to obtain desired damping properties at both high and low speeds	Figure 12. (Kim et al., 2020)

References

Ahamed, R., & Choi, S. (2018). *A state of art on magneto-rheological materials and their potential applications*. *29*(10), 2051–2095. https://doi.org/10.1177/1045389X18754350

Asghar Maddah, A., Hojjat, Y., Reza Karafi, M., & Reza Ashory, M. (2017). Reduction of magneto rheological dampers stiffness by incorporating of an eddy current damper. *Journal of Sound and Vibration*, *396*, 51–68. https://doi.org/10.1016/j.jsv.2017.02.011

Basheer, A. A. (2020). Advances in the smart materials applications in the aerospace industries. *Aircraft Engineering and Aerospace Technology*, *92*(7), 1027–1035. https://doi.org/10.1108/AEAT-02-2020-0040

Hu, G., Liu, H., Duan, J., & Yu, L. (2019). Damping performance analysis of magnetorheological damper with serial-type flow channels. *Advances in Mechanical Engineering*, *11*(1), 1–12. https://doi.org/10.1177/1687814018816842

Jugulkar, L. M., Singh, S., & Sawant, S. M. (2016). Fluid flow modeling and experimental investigation on automobile damper. *Construction and Building Materials*, *121*, 760–772. https://doi.org/10.1016/j.conbuildmat.2016.05.142

Kabariya, U., & James, S. (2020). Study on an Energy-Harvesting Magnetorheological Damper System in Parallel Configuration for Lightweight Battery-Operated Automobiles. *Vibration*, *3*(3), 162–173. https://doi.org/10.3390/vibration3030013

Khot, S. M. (2019). Design and Analysis of Magneto-Rheological (MR) Damper Amey Pramod Marathe. *2019 International Conference on Nascent Technologies in Engineering (ICNTE)*, *Icnte*, 1–6.

Kim, B. G., Yoon, D. S., Kim, G. W., Choi, S. B., Tan, A. S., & Sattel, T. (2020). Design of a novel magnetorheological damper adaptable to low and high stroke velocity of vehicle suspension system. *Applied Sciences (Switzerland)*, *10*(16). https://doi.org/10.3390/app10165586

Ma, X., Wong, P. K., & Zhao, J. (2019). Adaptive regulating of automotive mono-tube hydraulic adjustable dampers using gray neural network–based compensation system. *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, *233*(10), 2532–2545. https://doi.org/10.1177/0954407018800580

Oh, J. S., & Choi, S. B. (2019). Ride quality control of a full vehicle suspension system featuring magnetorheological dampers with multiple orifice holes. *Frontiers in Materials*, *6*(February), 1–10. https://doi.org/10.3389/fmats.2019.00008

Olabi, A. G., & Grunwald, A. (2007). Design and application of magneto-rheological fluid. *Materials and Design*, *28*(10), 2658–2664. https://doi.org/10.1016/j.matdes.2006.10.009

Rahman, M., Ong, Z. C., Julai, S., Ferdaus, M. M., & Ahamed, R. (2017). A review of advances in magnetorheological dampers: their design optimization and applications. *Journal of Zhejiang University: Science A*, *18*(12), 991–1010. https://doi.org/10.1631/jzus.A1600721

Singh, W. S., & Srilatha, N. (2018). Design and Analysis of Shock Absorber: A Review. *Materials Today: Proceedings*, *5*(2), 4832–4837. https://doi.org/10.1016/j.matpr.2017.12.058

Sodeyama, H., Suzuki, K., & Sunakoda, K. (2004). Development of large capacity semi-active seismic damper using magneto-rheological fluid. *Journal of Pressure Vessel Technology, Transactions of the ASME*, *126*(1), 105–109. https://doi.org/10.1115/1.1634587

Wang, J., & Meng, G. (2001). Magnetorheological fluid devices: Principles, characteristics and applications in mechanical engineering. *Proceedings of the Institution of Mechanical Engineers Part L: Journal of Materials: Design and Applications*, *215*(3), 165–174. https://doi.org/10.1243/1464420011545012

Wang, M., Chen, Z., & Wereley, N. M. (2019). Magnetorheological damper design to improve vibration mitigation under a volume constraint. *Smart Materials and Structures*, *28*(11). https://doi.org/10.1088/1361-665X/ab4704

Wei, M., Rui, X., Zhu, W., Yang, F., Gu, L., & Zhu, H. (2020). Design, modelling and testing of a novel high-torque magnetorheological damper. *Smart Materials and Structures*, *29*(2). https://doi.org/10.1088/1361-665X/ab6436

Xiao, P., Gao, H., & Niu, L. (2017). Research on magnetorheological damper suspension with permanent magnet and magnetic valve based on developed FOA-optimal control algorithm. *Journal of Mechanical Science and Technology*, *31*(7), 3109–3119. https://doi.org/10.1007/s12206-017-0601-7

Yaakub, S. F., Yahaya, S. H., Ahmad, F., Salleh, M. S., & Warikh, A. R. M. (2020). A comprehensive review on the related models in magneto-rheological automobile suspension system. *International Journal of Engineering Research and Technology*, *13*(7), 1700–1708. https://doi.org/10.37624/ijert/13.7.2020.1700-1708

Yang, G., Spencer, B. F., Carlson, J. D., & Sain, M. K. (2002). Large-scale MR fluid dampers: Modeling and dynamic performance considerations. *Engineering Structures*, *24*(3), 309–323. https://doi.org/10.1016/S0141-0296(01)00097-9

Yoon, D. S., Park, Y. J., & Choi, S. B. (2019). An eddy current effect on the response time of a magnetorheological damper: Analysis and experimental validation. *Mechanical Systems and Signal Processing*, *127*, 136–158. https://doi.org/10.1016/j.ymssp.2019.02.058

Yu, J., Dong, X., & Wang, W. (2016). Prototype and test of a novel rotary magnetorheological damper based on helical flow. *Smart Materials and Structures*, *25*(2), 25006. https://doi.org/10.1088/0964-1726/25/2/025006

Zheng, J., Li, Y., & Wang, J. (2016). *Design and multi-physics optimization of a novel magnetorheological damper with a variable resistance gap*. *0*(200), 1–17. https://doi.org/10.1177/0954406216643109