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A review of advances in magnetorheological dampers: their design optimization and applications

Key word: : Magnetorheological fluid dampers; vibration control; self-powered review; energy saving; optimization and advancement

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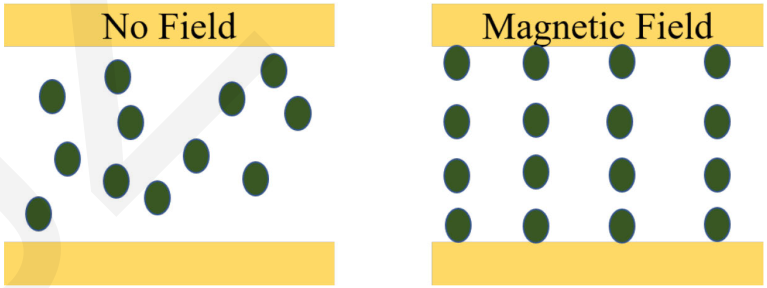
Magnetorheological damper

- An MR damper contains a type of smart fluid called a Magnetorheological Fluid (MRF).
- Without an applied magnetic field, the MRF behaves as a conventional fluid and its viscosity is independent of the flow rate.
- Changes in the applied excitation current vary the strength of the magnetic flux density of the electromagnets and consequently vary the rheological properties of the MR fluid.



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Main Focus of the Study

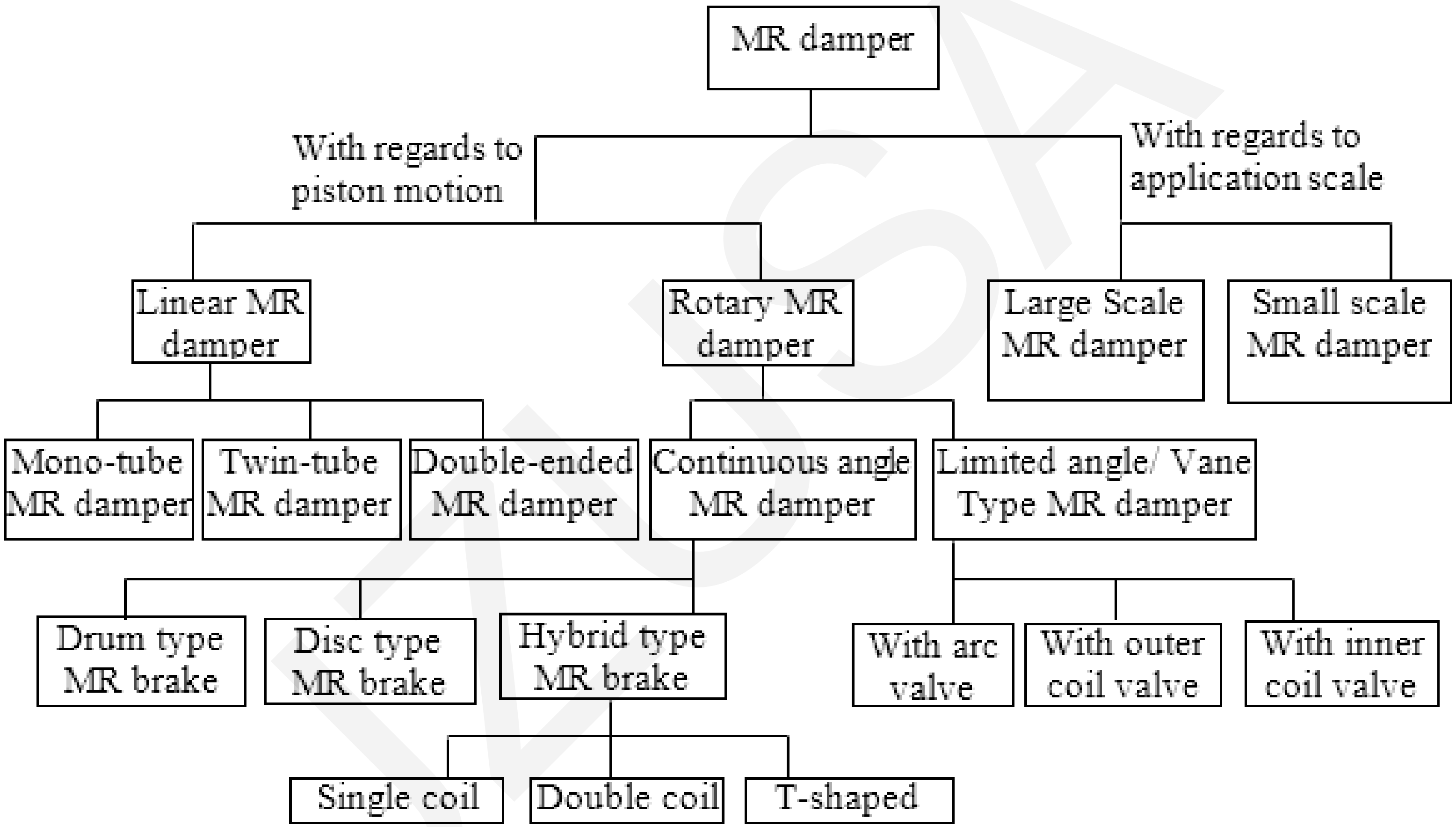
- This study presented an extensive review on enhancement MR damper based on the following features:

  - **Existing design, construction, and classification of MR fluid damper**

  - **Recent advances and optimization in the design of MR dampers**

  - **Design and modeling of energy saving and self-powered MR dampers**

Classification MR damper



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Recent advances and optimization in the design of MR dampers

- Nguyen and Choi optimized the design of an MR damper for a vehicle suspension system by finite element analysis (Nguyen and Choi, 2009) where damping force, dynamic range and valve dimensions were considered as design optimization parameters.

- Mangal and Kumar (2015) developed an optimal MR damper model by considering various geometric parameters such damper cylinder thickness, the pole length, circular distance from piston rod to coil width, and clearance between piston and cylinder

- H. Gavin et al. optimized the design of an MR damper with respect to minimum power consumption and minimal induction time constant (Gavin et al., 2001)

- Different studies presented optimization of **drum type MR brakes** focusing on the radial gap, flux path etc.

- **Disc type MR brake** was optimized based on the enlargement of the working area of the shear mode and number of disc (single disc and multi-disc)

- T-shaped **hybrid type MR brake** was proposed and optimized in different studies which have both rotor and stator coil configurations

Design and modeling of energy saving and self-powered MR dampers

- MR damper system with power saving magnetizing circuit
  - Sato and Umebara (2012) developed an energy saving technique to magnetize the MRF of MR dampers.
  - They replaced the conventional electro-magnet i.e. coils, with a combination of permanent magnet material rods and coils
  - the developed model consumes near zero electric power in applying external excitation to the fluid of the MR damper. The device is capable of maintaining the necessary field intensity continuously with a very small power consumption.

- Smart passive system based MR damper
  - Cho et al. proposed model comprises an MR damper and an electromagnetic induction (EMI) system containing a permanent magnet and a coil.
  - It gives a mechanism for self-powered vibration control and the electromagnetic induction (EMI) exploits vibration energy to produce electrical energy.

- Self-powered and sensing control system based on an MR damper
  - Wang *et al.* (2009) presented a new self-powered MR damper with a self-sensing semi-active control system
  - The system consists of a rack and pinion mechanism, a linear permanent magnet DC generator, a current controlled MR damper, and a control circuit.

- Other important studies on self-power MR damper were done by Jung *et al.*, 2008, Choi and Wereley, 2009, Chen and Liao, 2012

Design and modeling of energy saving and self-powered MR dampers

Table 2 Summary of various self-powered MR dampers

Reference	Focus	Method	Remarks
(Cho, et al., 2005)	Power Generation	EMI device	Large, not applicable in confined spaces
(Jung, et al., 2008)	Self-powered	big scale EMI	Only for civil structures
(Wang, et al., 2009)	Self-powered with sensing	rack and pinion mechanism	The arrangement of four parts is very complicated and increases the weight
(Choi and Wereley, 2009)	Self-powered	energy-harvesting device such as a stator, a permanent magnet, and a spring	Control algorithm is not appropriate for variety of applications.
(Snamina and Sapiński, 2011)	Vibration reduction	mechanical and electrical sub-system of the electromagnetic generator	Needs a large space
(Chen and Liao, 2012)	Self-powered and self-sensing	energy harvesting, dynamic sensing damping	Only modeled for double ended MR dampers and suitable for civil structures.
(Sapiński, 2014)	Energy harvesting, dynamic sensor	electromagnetic energy extractor	Limited range of output voltage

Conclusion

- In this study, the optimal design, fabrication and smart application of various MR dampers, and the latest advances in self-powered and self-sensing technology are reviewed.

- The basic design and construction of MR dampers, along with the configurations of their various types, are discussed in the paper to understand their versatile applicability for a range of environments and purposes.

- To cope with different applications, design modification, optimization and advancement are covered in this review.

- Saving energy is the ultimate demand at present and is a challenge to modern technology. In that connection, self-sensing and power saving i.e. the energy harvesting capability of an MR damper from the wasted mechanical energy, are compared here with their proper modeling.

- This work may be useful to implement MR dampers in various structures for vibration control with minimum current supply.