doi.org/10.54473/IJTRET.2023.7205
International Journal of Trendy Research in Engineering and Technology
Volume 7 Issue 2 April 2023
ISSN NO 2582-0958

DESIGN AND ANALYSIS OF SUSPENSION SYSTEM USING MR FLUID

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Received 21 March 2023 Received in revised form 24 March 2023 Accepted 27 March 2023

ABSTRACT

MR fluids, also known as magnetorheological fluids, are a smart material that can adapt its rheological properties in the presence of a magnetic field. This unique characteristic allows MR fluids to be utilized in various active and semi-active control systems. The composition of MR fluids includes magnetizable iron particles of micron size, suspended in a base fluid that is non-magnetic, and additives to prevent sedimentation and clustering. Upon exposure to magnetic fields, MR fluids can modify their viscosity and shear strength, offering improved performance in various applications.

Over the last few decades, MR fluids have garnered significant interest in the field of engineering, with numerous studies exploring their potential uses. They have been employed in systems such as vibration control, aircraft landing gears, helicopter lag dampers, dynamometers, brakes, and clutches, among others. MR fluids are considered a promising material in engineering due to their ability to change properties in response to magnetic fields. This versatility has opened up new possibilities and improved existing technologies, making MR fluids a valuable tool in the advancement of engineering systems.

Keywords: - Magnetorheological fluid, smart material, rheological properties, additives, sedimentation .

I. INTRODUCTION

MR fluids have gained significant attention due to their potential applications across various sectors. These fluids are utilized in areas such as automobiles, buildings, prosthetic legs, body armour, and washing machines for controlling vibrations. The discovery can be traced back to the late 1940s at US National Bureau of Standards.

MR fluids are made up of micro-sized iron particles (ranging from 0.5 to 10 micrometers) suspended in a fluid such as synthetic mineral oil, hydrocarbon oil, glycol, or water[1]. Magnetic field can alter the rheological behaviour of fluids, making them smart materials. MR fluid exhibit different rheological properties depending on carrier fluid, particle density, particle size, temperature, and external magnetic field.

The study of MR fluid's deformation and flow under stress is known as rheology, and MR fluids have found use across various industries including civil, mechanical, automobile, and biomedical engineering. MR fluids are becoming increasingly popular for their properties i.e. high yield stress, low viscosity, and a wide dynamic range, which makes them a suitable choice for suspension systems in high-end vehicles.

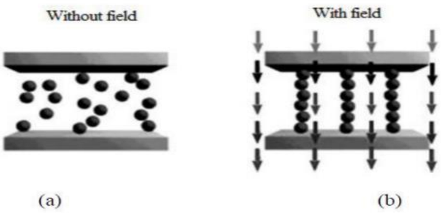

Figure 1: MR Fluid behaviour with and without magnetic field

Figure 1 (a) represents MR fluid with no magnetic field and Figure 1 (b) displays MR fluid after the magnetic field is applied[2]. In the lack of a magnetic field, the ferromagnetic particles in MR fluid are dispersed randomly in carrier fluid. However, once the field is applied, the particles become organized in rows. This change in particle position creates resistance to the flow of the fluid through an orifice, resulting in an increase in resistive force.

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Magnetic field's strength plays a crucial role in controlling the rate of flow of MR fluid, as it directly impacts the fluid's viscosity. A stronger magnetic field increases resistance, leading to a decrease in fluid flow, while a weaker magnetic field reduces resistance, causing an increase in fluid flow. In essence, the strength of magnetic field determines the fluid's vicosity, which can be adjusted accordingly.

II. MAGNETO RHEOLOGICAL FLUID

A. Properties of typical MR Fluid:

Table 1: Properties of typical MR Fluid

Properties	Range
Density	3 to 4.5 gm/cm^3
Initial viscosity	0.2 –1.0 (Pa.s) at 24^{0}C
Magnetic field strength	160 –240 (KA/m)
Max yield stress	50 –100 (KPa)
Reaction Time	10–20 millisecond (ms)
Stability	Good
Working temperature	-50^{0}C –150^{0}C
Supply voltage and current	12V and 0.1 –2A

B. Components of MR Fluid[3]

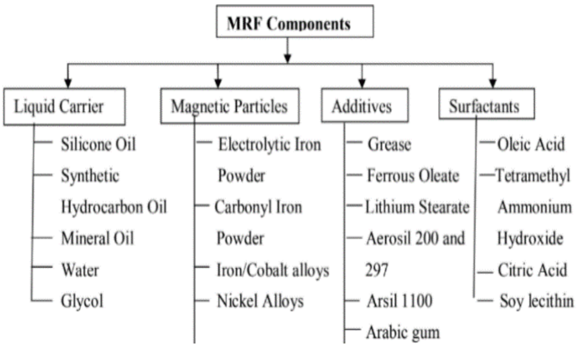

Figure 2: Components of MR Fluid [3]

Researchers are working to enhance the performance and decrease the cost of MR fluid. Different types of carrier fluids such as silicon oil, synthetic oil, castor oil, and vegetable oil have been used to create MR fluid for various purposes. The stability of MR fluid can be improved by using various additives that are dependent on the properties of the carrier fluid. Many studies have been direct to determine the effect of different particle sizes on the yield strength of the fluid. Despite these efforts, there is still a lot of room for further exploration, particularly with the use of alternative carrier fluids such as water, kerosene, paraffin oil, vegetable oils, and mineral oil. To achieve better stability, the optimum combination of additives can be explored.

C. Preparation of MR Fluid

1st procedure

In order to prepare 175ml of MR fluid following constituents are required in following quantities: [4]

- Carrier oil: Soybean oil
- Magnetic particle: Carbonyl iron powder
- Additives: White lithium grease
- Constituents and their Quantity:
- Low viscosity soyabean oil:- 81.2gm
- Iron particle (10 microns) :- 220gm
- White lithium grease:- 12.22gm

Preparation process:

STEP 1. First take low viscosity soybean oil and grease (white lithium grease) with the correct proportion in a beaker.

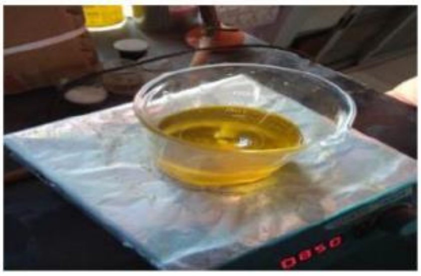

Figure 3: Soyabean oil and grease

STEP 2. Mix this inappropriate blend of soybean oil and white lithium oil with the assistance of a mechanical stirrer for legitimate blending

Figure 4: Stirring the mixture

STEP 3. At that point hold up for 2hrs so that oil gets totally solvent in soybean oil.

Figure 5: Grease completely soluble in soyabean oil

STEP 4. After that add iron particles of 10-micron size in above mixture and again stir it with the help of a mechanical stirrer for 15 to 20 min. for proper mixing.

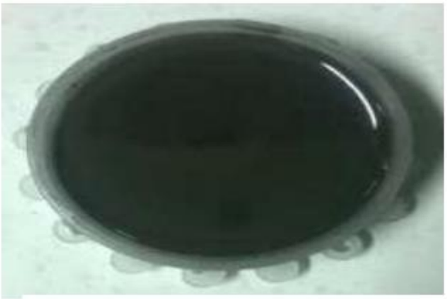

Figure 6: Prepared MR Fluid

2nd procedure

Composition of MR fluid by weight division of constituents utilized within the preparation:

Table 2: Composition of MR fluid by weight fraction of constituents used in the preparation

Sample	Constituents		
	E.I. Powder (Electrolytic iron) (%)	Additive (Stearic acid + Guar gum) (%)	Silicone Oil (%)
A	60	3	37
B	30	0	70
C	30	3	67

Procedure followed for preparation is as follows: [5]

1) A mixture of electrolytic iron particles and guar gum was prepared by blending them for half an hour at a stirring speed of 400 rpm.

2) A solution was made by mixing stearic acid with silicon oil, which was then stirred for a period of 30 minutes at 400 rpm.

3) The electrolytic iron mixture was mixed with silicon oil solution in a gradual manner, with continuous stirring.

4) The resulting MR fluid was agitated continuously for five hours to attain a stable solution.

5) Three separate samples were taken and labelled as A, B, and C, and set aside for evaluating the anti-settling properties of the MR fluid.

III. SUSPENSION SYSTEM

The suspension system connects the wheels of a vehicle to its frame and allows for movement between them. This system includes the shock absorber, spring, and linkages, and serves the purpose of improving the vehicle's road handling, braking, and overall driving experience while providing comfort to the occupants by minimizing road disturbances. The suspension must also keep the tires in contact with the road for optimal traction[6].

Damping is the process of reducing motion or oscillation through the use of valves and hydraulic gates in a vehicle's shock absorber. Damping can be adjusted deliberately or unintentionally and controls the speed at which the suspension moves. A car without proper damping will oscillate up and down, but with adequate damping, it will quickly return to its normal state. The damping in modern vehicles is often controlled by adjusting the fluid's viscosity in the shock absorber, leading to the development of Magnetorheological Fluids.[2]

A. Types of Suspension

1. Active Suspension

Vehicles typically use active suspension components like coil springs or leaf springs, which are referred to as traditional suspension.

2. Passive Suspension

Passive suspension systems feature an onboard control system that adjusts damping, as opposed to relying solely on road irregularities like traditional suspension. There are two types of

International Journal of Trendy Research in Engineering and Technology
Volume 7 Issue 2 April 2023
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dynamic suspension: fully active and semi-active. Fully active suspension uses actuators to elevate the chassis in response to road conditions, while semi-active suspension adjusts fluid viscosity for desired damping, including the use of Magnetorheological Dampers.
The main components of a suspension system are:[7]

1. Springs: The springs are responsible for absorbing road shocks and vibrations and provide a smooth ride. They are available in various types, such as coil springs, leaf springs, air springs, etc.

2. Shock absorbers: Shock absorbers are responsible for controlling the rebound and compression of the springs and damping the motion of the vehicle. This helps to prevent excessive bouncing or swaying of the vehicle.

3. Linkages: The linkages are responsible for transferring the movement of the wheels to the frame. They help to keep the wheels in proper alignment with the road and distribute the load evenly.

4. Anti-roll bars: Anti-roll bars are used to prevent the body roll of the vehicle during cornering. They work by connecting the opposite wheels and stiffening the suspension system.

5. Bushes and bearings: Bushes and bearings are used to reduce friction and wear between the moving parts of the suspension system. They also help to absorb road shocks and vibrations.

The suspension system plays a crucial role in ensuring a smooth, safe and comfortable ride for vehicle occupants.

IV. MAGNETO-RHEOLOGICAL DAMPERS IN AUTOMOTIVE SUSPENSIONS

Construction of MR Damper

(a) (b) (c)

Figure 7: Suspension system -Various part

Fig 7 shows the different parts of the Suspension: (a) Twin tube suspension, (b) Damper, (c) Outer cylinder, (d) Inner cylinder, (e) Piston and piston rod, (f) Valves with orifice.

The above figure illustrates the key components of the suspension system responsible for managing the vibrations of the unit. To meet the requirement of incorporating a magnetic field around the working fluid, modifications were made to the original suspension design, which can be viewed in a separate figure. These changes were necessary to accommodate the magnetic field aspect of the model.

Figure 8: suspension after the modifications done on the original suspension

Fig.8 Shows the suspension after the modifications done on the original suspension (a) Solenoid wound over the inner cylinder, (b) Welded lower section of the inner cylinder, (c) Assembly of suspension with modifications.

The changes made to the suspension system included the substitution of the seal valve at the bottom of the inner cylinder with a mild steel component of similar shape and size. This alteration helps prevent the fluid from leaking from the inner cylinder to the outer cylinder, maintaining the fluid within the inner cylinder and converting the dual-tube design into a single-tube setup. A solenoid was also wound around the inner cylinder for a length of 80mm, beginning 10mm below the top of the inner cylinder where the fluid is operational. This solenoid, when supplied with an electric current, will produce a magnetic field around the active fluid area.

V. CONCLUSION

In conclusion, the MR fluid damper is a highly effective and efficient solution for controlling vibration and damping in various engineering applications. It combines the advantages of both conventional hydraulic and electromagnetic damping systems, making it an attractive option for engineers. With its ability to adjust damping forces in real-time, it has the potential to greatly improve the safety and performance of various structures and machines. Additionally, the development of new MR fluid materials and the integration of smart technologies are likely to lead to even more advanced MR fluid dampers with improved performance and versatility.

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