Design and development of MR fluids: A review

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ABSTRACT

This paper aims to determine the stress of MR fluids in an on-state condition. Different MR fluids samples were made and tested inside the laboratory. The equipment was made to test the fluid. In the experimentation, it was found that MR fluids have high stress and can be used in military design and fabrication. This paper paves away for any researcher to develop MR fluids at very less cost. The MR fluids have very high yield stress which depends on the particles being used in their formulation. It can be concluded that MR fluids yield stress can be found in an economical manner using a set up and can be used in various engineering ventures.

Keywords: *Smart materials; Yield stress; electromagnet; ANOVA; Magnetic propertie.*

1. INTRODUCTION

Magneto rheological fluid found vast applications in field of military equipments design and fabrication [1]. They are useful in solving vibrations related problems that are encountered in daily life[2].

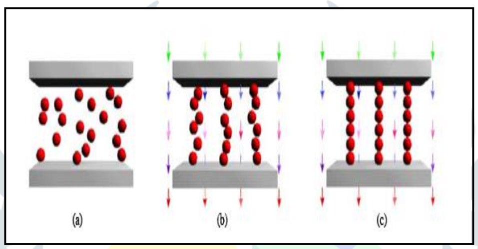

Fig.1 Application of magnetic Field to MR Fluid particles

In this research the fluid is made and is characterized. An experimental set up is made in order to characterize the fluid. Following equations can be used to determine the torque and thus to further determine the stress of the fluid[3].

$$T_1 = \int_{R_{int}}^{R_{ext}} \int_0^{2\pi} \tau_y \, r^2 dr d\theta = 2\pi \, \tau_y \frac{R_{ext}{}^3 - R_{int}{}^3}{3}$$

$$\tau_y = \frac{T_{total}}{2\pi \left(\frac{R_{ext}{}^3 - R_{int}{}^3}{3} + R_{ext}{}^2 L \right)}$$

2. COMPONENTS OF FLUID FORMATION

- Carbonyl Iron particles are used to make fluid.
- Silicon Oil is used to float the aforesaid particles.
- Tetra methyl ammonium hydroxide is used to stop fluid from settling down under the effect of gravity.

3. METHOD OF FLUID FORMATION

Carbonyl iron particles (80% by weight) are mixed with tetra methyl ammonium hydroxide (0.5% by volume)[4] for 30 minutes at 400 rpm using a stirrer in a steel container. Further, silicon oil was added (67 % by volume) in this mixture and the whole liquid was stirred for around 3 hours at 450 rpm using the stirrer inside the steel container.

Table 1: Levels of Various components for MR Fluid Formation

Volume %	Levels		
Iron	22	27	32
Silicon Oil	67	72	77
Tetra Methyl Ammonium Hydroxide	0.5	0.6	0.7

4. TAGUCHI L-9 ORTHOGONAL ARRAY

L-9 array is used to determine the properties of MR fluids and is shown in Table2. The input and output parameters can be seen below:

Table 2: Orthogonal Array for MR Fluid Formation

	Factor 1	Factor 2	Factor 3	Factor 4	Response
Sr.	Iron Vol. %	Silicon Oil Vol. %	Oleic acid Vol. %	Tetra Methyl Vol. %	Yield Stress (KPa)
1	22	67	0.5	0.6	27.0388
2	22	72	0.6	0.7	24.786
3	22	77	0.7	0.8	27.021
4	27	67	0.6	0.8	34.321
5	27	72	0.7	0.6	33.32
6	27	77	0.5	0.7	35.465
7	32	67	0.7	0.7	45.684
8	32	72	0.5	0.8	47.7888
9	32	77	0.6	0.6	48.896

5. ANOVA RESULTS FOR YIELD STRESS

Based on the Taguchi L-9 orthogonal array following results were calculated for yield stress as a rheological characteristic as shown in Table 3.

Table 3: ANOVA results for Yield Stress

Analysis of variance table [Classical sum of squares - Type II]						
Source	**Sum of Squares**	**D of**	**Mean Square**	**F Value**	**p-value Prob. > F**	
Model	693.6	6	115.61	97.93	0.010	Significant
Iron Vol.%	685.3	2	342.52	290.13	0.003	
Silicon Oil Vol.%	5.58	2	2.79	2.36	0.297	
Oleic acid Vol. %	3.04	2	1.52	1.29	0.437	
Residue	2.36	2	1.18			
Total	696	8				

The Model can be used to develop MR fluids, Various terms are prominent in this model [5]. The MR fluids properties depend on the amount of iron particles used in their formulation and design. One should use good quality particles preferably of the round shape in development of MR fluids. The noise factor is very less which proves that results are indeed of good value [6].

Table 4: R squared results for ANOVA Table

Std. Dev.	1.09		**R-Squared**	0.9966
Mean	36.04		**Adj. R-Squared**	0.9864
C.V. %	3.02		**Pred. R-Squared**	0.9313

PRESS	47.81		**Adeq. Precision**	24.006

Various values are depicted in Table 4. From this values it is clear that all the values are matching well. It can be found that values are matching very well with very less deviation from the values found out in the process of experimentation. Further, the optimized and actual values are shown below in Table 4 [7].

Table 4: Optimized and Actual Values for MR Fluid

Diagnostics Case Statistics				
Run Order	**Actual Value**	**Predicted Value**	**Residual**	**Leverage**
1	27.04	26.66	0.38	0.778
2	24.79	25.51	-0.72	0.778
3	27.02	26.68	0.34	0.778
4	34.32	33.98	0.34	0.778
5	33.32	32.94	0.38	0.778
6	35.47	36.19	-0.72	0.778
7	45.68	46.41	-0.72	0.778
8	47.79	47.45	0.34	0.778
9	48.90	48.51	0.38	0.778

6. CONCLUSIONS

This paper paves away for any researcher to develop MR fluids at very less cost. The MR fluids have very high yield stress which depends on the particles being used in their formulation[8]. It can be concluded that MR fluids yield stress can be found in an economical manner using a set up and can be used in various engineering ventures. This research can be used in determining the various parameters effecting fluid behavior [9]

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