DESIGN OPTIMIZATION OF MAGNETO-RHEOLOGICAL DAMPER FOR VEHICLE SUSPENSION SYSTEM

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Abstract:A magnetorheological damper or magnetorheological shock absorber is a damper filled with magnetorheological fluid, which is controlled by a magnetic field, usually using an electromagnet. This allows the damping characteristics of the shock absorber to be continuously controlled by varying the power of the electromagnet. Fluid viscosity increases within the damper as electromagnet intensity increases. This type of shock absorber has several applications, most notably in semi-active vehicle suspensions which may adapt to road conditions, as they are monitored through sensors in the vehicle. Many applications have been proposed using magnetorheological (MR) dampers. While vehicle applications are the most common use of MR dampers, useful medical applications have risen as well, including implants and rehabilitation methods. The performance of the MR damper can be modified by changing the fluid flow gap, Magnetic field, percentage of iron particle, percentage of additives.to find optimum combination taguchi optimisation method is used also the analysis of variance is done to find out the most important parameter.

Keywords: magnetorheological damper, optimisation method, ANOVA (analysis of variance).

I. INTRODUCTION

The dampers or shock absorbers are widely used in automotive vehicles to dissipate the vibration energy of sprung and un-sprung mass under resonance conditions. Many types of dampers have been designed to meet the comfort and control requirements of passenger vehicles. Also, in Machines there is need of damping the vibration of machine as quickly as possible, to get good performance of machine less vibration should be transferred from base. The fluid inside the damper is usually throttled through the orifices at the piston due to pressure difference. The frequent throttling of fluid changes the velocity of the fluid to cause increase in temperature, thereby dissipating energy. The commonly used fluids for dampers are synthetic oil, mineral oil etc. During recent years the smart fluids such as MR and ER have been used inside the dampers to provide the variable damping under the application of current or voltage. Among the smart fluid, MR fluid is much popular due high dynamic range.

Semi-active controllable devices with magneto-rheological (MR) fluid have drawn significant attention especially in transportation vehicles, building suspensions and biomedical applications in the last two decades owing to their unique advantages. MR fluids are suspensions of magnetically polarizable particles with a few microns in size dispersed in a carrying liquid such as mineral or silicon oil.

In the presence of an applied magnetic field, the iron particles acquire a dipole moment aligned with the external field which causes particles to form linear chains aligned to the magnetic field. They are characterized by rapid changes in the fluid viscosity resulting from the rearrangement of the particles in the fluid due to changes in the applied magnetic field. The application of such fluids in dampers allows control of their damping characteristics, adjusting them to the varying needs of the system. This property qualifies MR fluids as ‘‘smart materials.’’ Dampers with MR fluids may offer an improved control of vibrations in airplanes upon landing, in cars, mechanical and medical devices, and industrial machinery.

Recently, some studies in literature have been focused on the modeling and control strategy of MR devices. Design methods that can decrease the cost and the manufacturing period and improve the performance have been more important. Many factors need to consider in developing of MR damper to obtain optimal designs, which makes the problem very challenging when using conventional optimization methods.

Parlak et al. [1] carried out design optimization method for the objectives of target damper force and maximum magnetic flux density of an MR damper. Finite element methods, electromagnetic analysis of magnetic field and CFD analysis of MR flow, have been used to obtain optimal value of design parameters. The new approach that is use of magnetic field and MR flow together and simultaneously has specified optimal design values. Two optimal design of MR damper obtained have been verified with experimental study by manufacturing and testing of the dampers.**Yang et al. [2]** analyzed quasi-static model of MR fluid damper. they theoretically studied axisymmetric model. They derived quasi-static axisymmetric model on the basis navier stokes equation to predict force velocity relation.**Avinash et al. [3]** described the damping characteristics of magneto rheological damper under different fluid environments i.e. air damping, viscous damping and MR damping. They concluded that MR fluid has good damping characteristics than that of the other fluids due to fluid-particle interaction and friction near fluid-structure interface.**Yao et al. [4]** studied a semi-active control of vehicle suspension system with magneto- rheological (MR) damper. They analyzed mathematical model of Magneto-rheological damper is analyzed by using Matlab software. A scaled quarter car model is set up including the model of the MR damper and a semi-active control strategy is adopted to control the vibration of suspension system. They concluded that the MR damper has a very broad changeable damping force range under magnetic field and the damping coefficient increases with the electric current, but decreases with excitation amplitude. The MR damper will become saturated as the applied electric current reaches a certain value.**Paul et al. [5]** analyzed the tool holder along with magneto rheological damper during turning operation. MR fluid damper received great attention due to its ability to reversibility change from free flowing, linear, viscous liquid to semisolid in millisecond when exposed to magnetic field. They analyzed turning tool by using ansys software with and without damping effect. The computational and ansys results are compared.

II. PARAMETER SELECTION AND OPTIMIZATION METHOD

Percentage of Iron Particle-when particle concentration is increased, it also increases particle density in sample, which should also increase particle settling rate. However, sedimentation rate reduces with increase in particle concentration as shown in fig. This may be due to increase in particle concentration as it causes large particles to settle rapidly but as particle size in not uniform as small particles are also present in the sample. Therefore, settling of large particles causes upward flow of carrier fluid with high velocity. This fluid flow causes suspension of lighter density particle Percent of Surfactant-Oleic acid is used as a surfactant. It is generally used to reduce particle agglomeration. However, it can also change sedimentation behaviour of MRF. Therefore, three sample are prepared with different concentration of Oleic Acid.

Table No.1: Different levels of parameters

Sr. No.	Variable	Level 1	Level 2	Level 3
1	% Of iron particle	20%	30%	40%
2	Gap width	1mm	1.5mm	2mm
3	Surfactant	5%	10%	15%
4	Voltage Level	2V	3V	4V

There are total 81 combination can be made from these 12 values of different parameters. Analysis of each and every combination will take more time. So, it's necessary to reduce number of experiments to reduce time. For this Taguchi method is used.

III. PREPARATION OF MR FLUID

To obtain a stable MR fluid, the compatibility of carbonyl iron particle with the solution formed by mixing it with different carrier fluids using different surfactants was analyzed. The carrier fluid is silicone oil and oleic acid, were added in the carrier fluids for proper dispersion of the iron particle. Before preparing the MR, solution consisting carrier fluid–surfactant-iron particle, it is important to first analyze the compatibility of the surfactant in the carrier fluid. The procedure followed to evaluate the compatibility of surfactant in the carrier fluid is described as below:

(i) 100 ml of carrier fluid was mixed with surfactant of 25% weight of the carrier fluid.

(ii) The mixture was mixed for 24 h using a rotary mixing machine as shown in Fig. 2. The rotary mixing machine consists of a DC motor whose rotational speed can be varied using a speed adjusting knob from 0 to 50 rpm. An attachment is provided at the end of the motor where samples can be loaded. The attachment consists of seven number of holders on either side of the attachment. In the present case, the samples were rotated at 50 rpm.

(iii) The comparability of different samples was determined by visual inspection.

Taguchi Method is used for designing of experimental tests. Considering the radius of steel balls and particle filling percentage as two parameters, which can be varied at three different levels. The following table 1 shows the parameters and their levels. For above two parameters and three levels, according to Taguchi method nine tests need to be carried out.

IV. EXPERIMENTATION AND OBSERVATIONS

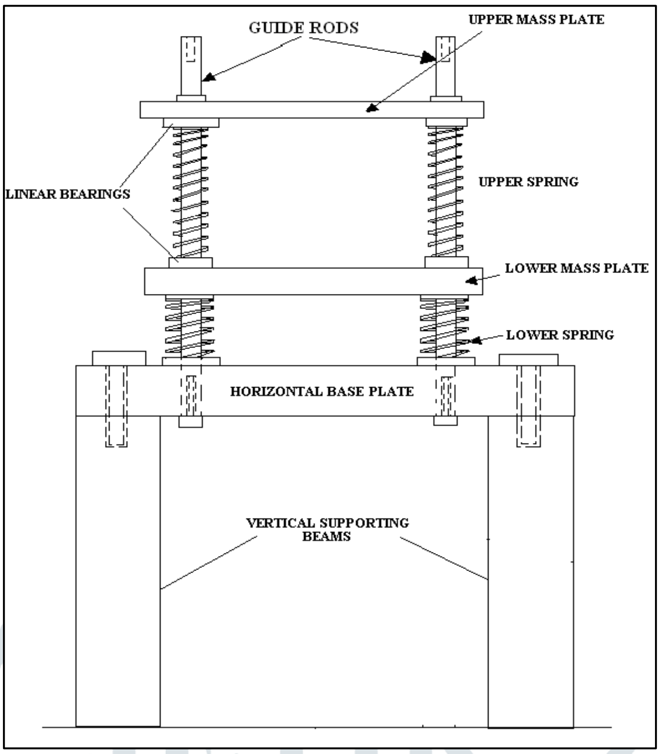

Fig. 2 Experimental set up

The experimentation is carried out by using following procedure.

1. Mix the sample of MR fluid by using motorized stirrer so that fluid is properly mixed and make sure sedimentation has not happened before poring it in to the damper.
2. Then pour all the MR fluid into the damper. There are seals attached to the damper to avoid the leakage of MR fluid.
3. Then arrange damper to exciter as shown in figure.
4. After all arrangement connect the wire of copper winding of damper to the DC power supply unit.
5. Then attach the accelerometer to moving mass of system and it has connected to the ADASH FFT analyzer to record the signal.
6. Then start the exciter and set the particular amplitude of vibration by using arrangement on exciter machine controller.
7. Then vary frequency from 1Hz to 10 Hz using frequency knob on controller by the span of 10 sec.
8. Record the signal by using FFT analyzer.

Table No 2. Result from experiment for optimization

L9 Orthogonal Array

Experiment no.	Independent variables				
	% of iron particle	Gap width	% Surfactant	Magnetic field	Amplitude(μm)
1	20	1mm	5	2V	65.0
2	20	1.5mm	10	3V	35
3	20	2mm	15	4V	5.85
4	30	1mm	10	4V	22.1
5	30	1.5mm	15	2V	71.2
6	30	2mm	5	3V	47.5
7	40	1mm	15	3V	56.4

8	40	1.5mm	5	4V	37.9
9	40	2mm	10	2V	33.8

V. STATESTICAL ANALYSIS FOR OPTIMIZATION

Analysis of experimental results has carried out using the Minitab 17 statistical software, which gives the numerical value tables. % of iron particle, 5% of surfactant, gap width and magnetic field are the input parameters. Damped amplitude at top side is the response variable. Optimal values of damped amplitude for trial experiments are find out by Taguchi method. Experiments were conducted based on the L-9 orthogonal array. Above table shows experimental observations. The results of the experiments performed are studied using an analysis of the S/N ratio.

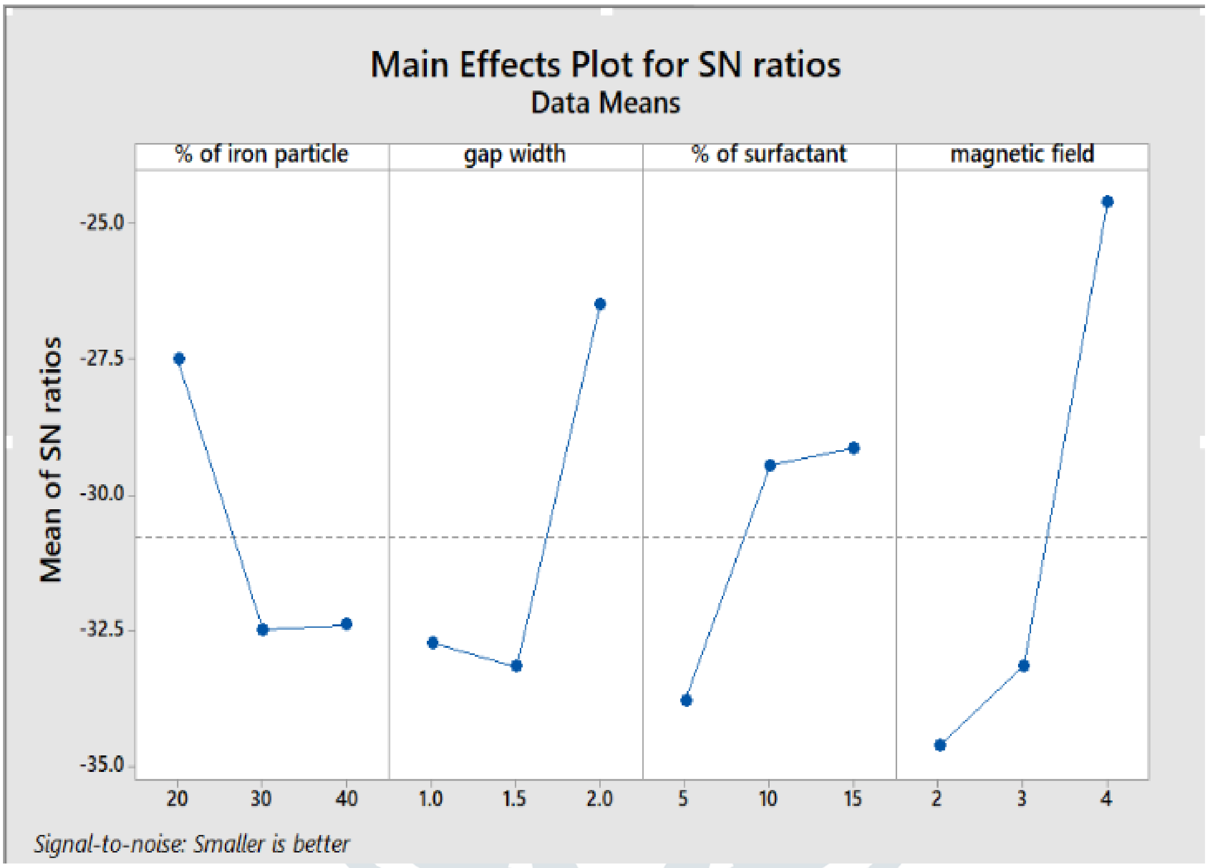

Fig 3.S/N ratio obtained from minitab software

The effect of input parameters on damped amplitude has shown in Fig. 6.4. Form S/N ratio graph % of iron particle for optimum design is 30%, the optimum gap with is 1.5mm, optimum surfactant percentage is 5%and optimum magnetic field is 2V.

Analysis of variance (ANOVA)

Table No.3 Result from ANOVA

Level	% of iron particle	Gap width	% of surfactant	Magnetic field
1	-27.72	-33.72	-33.79	-34.63
2	-32.49	-33.17	-29.45	-33.15
3	-32.39	-26.49	-29.14	-24.60
Delta	5	6.68	4.65	10.03
Rank	3	2	4	1

VI. CONCLUSION

a) The amplitude of vibration is decreases with increase in damping force i.e. voltage individually. As Voltage increase the magnetic force applied on iron particle increases.

b) The amplitude of vibration is decreases as percentage of surfactant increase in MR sample but it is true for weight of surfactant up to 15% of base fluid then its increases.

c) The amplitude of vibration is decreases as percentage of iron particle increase in MR sample but it is true for weight of iron particle up to 30% of base fluid then its increases.

d) Most influencing parameter is Magnetic field.

e) The combine optimum damping obtained at 30% iron particle, 1.5mm gap width,5 % surfactant and 2V power supply.

VII. ACKNOWLEDGEMENT

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