GEOMETRICAL OPTIMIZATION OF VEHICLE SHOCK ABSORBERS WITH MR FLUID

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Abstract

Magnetorheological (MR) shock absorber have received remarkable attention in the last decade due to being a potential technology to conduct semi-active control in structures and mechanical systems in order to effectively suppress vibration. To develop performance of MR shock absorbers, optimal design of the dampers should be considered. The present study deals with optimal geometrical modeling of a MR shock absorber. Optimal design of the present shock absorber was carried out by using Taguchi experimental design approach.

Keyword: *Magnetorhelogical Damper, MR damper, MR devices, MR Fluid, Bouc-Wen model*

1. Introduction

Magnetorheological (MR) fluid are suspensions of magnetically polarizable particles with a few microns in size dispersed in a carrying liquid such as mineral or silicon oil. When a magnetic field is applied to the fluid, particles in the fluid form chains, and the suspension becomes like a semi-solid material due to increase in the apparent viscosity. Under the magnetic field, an MR fluid behaves as a non-Newtonian fluid with controllable viscosity. However, if the magnetic field is removed, the suspension turns to a Newtonian fluid in a few milliseconds, and the transition between these two phases is highly reversible, which provides unique feature of magnetic-field controllability of the flow of MR fluids.

To develop performance of MR shock absorbers optimal design of the dampers should be considered. A lot of factors need to considered in developing of MR of shock absorbers to obtain optimal designs.

The present study deals with optimal geometrical modeling of a MR shock absorber. Hence, a MR shock absorber has been modeled and optimized. Finally, optimal design of the present shock absorber was carried out by using Taguchi experimental design approach. The optimized shock absorber was chosen as the candidate geometry that gave the greatest dynamic range which gives to a ratio of total force to uncontrollable forve. As a result, Optimal geometry obtained Taguchi approach provided greatest dynamic range as compared with other 9 candidate geometries which was specified L9 orthogonal array.

2. Design of MR shock absorber

MR fluid flows through gap in the piston head at aimed design of shock absorber Fig1. The volume of fluid though which the magnetic field passes was defined as the active volume; it is only within this active volume that MR effects occur.

An optimized circuit would maintain a balance between the magnetic field produced and power required by the magnetic coils, and a shock absorber design that would make best use of the field to activate the MR fluid yield stress [1].

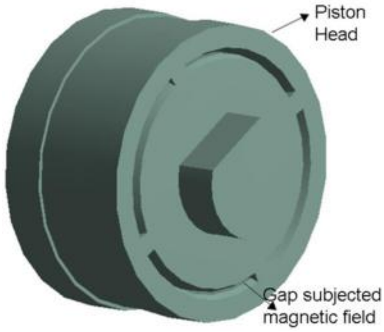

Fig 1: Piston head and gap subjected magnetic field

When an electric current is applied to the coil, a magnetic circuit and some dimensional appears as shown in the figure

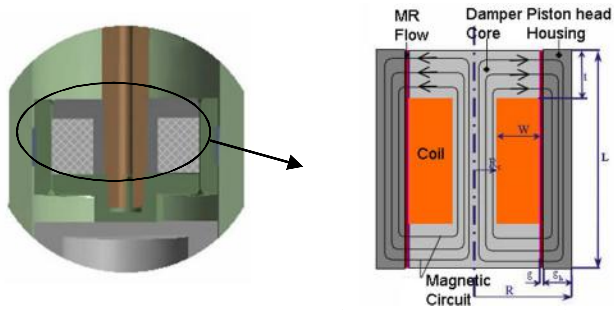

Fig 2: MR valve configurations in a specific volume.

where L is gap length, g_h piston head housing thickness, g gap , t the iron flange thickness, R radius of piston head, R_1 radius of piston core and W coil width. At the two end flanges, flux lines are perpendicular to the flow direction which cause a field-dependent resistance on the flow. The pressure drop of the valve is calculated by

$$\Delta P = \Delta P_{\eta} + \Delta P_{\tau} = \frac{6\eta Q L}{\pi R_1 g^3} + 2c\frac{L}{g}\tau_y \qquad ((1)$$

where ΔP_{η} and ΔP_{τ} are the viscous and uncontrollable pressure drop of MR shock absorber. τ_y is yield stress. Q is the flow rate through the MR shock absorber.

2.1. Controllable force and the dynamic range

The controllable force and the dynamic range are two of the most important parameters in evaluating the overall performance of the MR damper. Dynamic range is ratio of total force to uncontrollable force.

The uncontrollable force includes a viscous force $F_{\square}$ and a friction force $F_{\square}$. The dynamic range is defined as follows [2]:

$$D \;\square\; 1 \;\square\; \frac{F_{\square}}{F_{\square\square} F_{\square}} \qquad (2)$$

3. Calculating Magnetic Flux Density

Equations of magnetic circuit need to be solved to calculate pressure drop and therefore damper force of MR shock absorber. Yield field in active volume would be obtained dependently magnetic flux density by magnetic circuit equations [3].

In this study, the hydrocarbon-based MR fluid product (MRF-132DG) from Lord Corporation is used. By applying the least-squares curve fitting method to the fluid property specifications obtained Eq. 3 [4];

$$\tau_{\square} \;\square\; 52.962B^{\square} \;\square\; 176.51B^{\square} \;\square\; 158.79B^{\square} \;\square\; 13.708B \;\square\; 0.1442 \qquad (3)$$

Magnetic flux density across active volume can be calculated by Eq. 4 obtained manipulations of some equations,

$$B \;\square\; \frac{\mu_{\square} N_{\square} I}{2\frac{g}{\mu_{\square\,\square}} \;\square\; 2\frac{A_{\square} l_{\square}}{\mu_{\square} A_{\square}} \;\square\; 2\frac{A_{\square} l_{\square}}{\mu_{\square} A_{\square}} \;\square\; \frac{A_{\square} l_{\square}}{\mu_{\square} A_{\square}} \;\square\; \frac{A_{\square} l_{\square}}{\mu_{\square} A_{\square}}} \qquad (4)$$

4. Geometrical Optimization of MR Shock Absorber Using Taguchi Experimental Design Method

4 parameters were considered to optimize MR shock absorber and 3 level were specified for each parameter.

Table 1: Parameters and levels which were used for Taguchi Design

Parameters	Level 1	Level 2	Level 3
Gap (g)	0.4 mm	0.8 mm	1.2 mm
Flange thickness (t)	2 mm	3 mmm	4 mm
Core ($R_{\square}$)	5 mm	6 mm	7 mm
Current (I)	0.2 A	0.4 A	0.6 A

L9 orthogonal array was specified for 4 parameters and its 3 levels. L9 orthogonal array need to 9 experimental set to obtain optimal solutions. In the study, analytical study was used instead of experimental study. Dynamic range was specified as response value.

5. Applying To MR Shock Absorber of Taguchi Method

Effect on results of specified parameters and levels selected for Taguchi experimental design can be analysed and owing to the analysis optimal geometry can be obtained. Dynamic range as response value was used for each analytical set. Because it wants maximum value of dynamic range, Signal-noise ratio was chosen as ñlarger is betterò.

After the Signal-noise ratio analysis specified best level for each factors Table 2.

Table 2: Specified optimum levels of SN ratio

Parameters	Optimum Level	Value
g	1	0.4 mm
t	3	4 mm
R	1	5 mm
I	3	0.6 A

5.1. ANOVA Analysis

ANOVA is an statistical tool used in experimental design to determine effects of parameters. Table 3 presents the ANOVA calculation from it is established that the most significant parameters of MR shock absorber.

Table 3: ANOVA computation

Parameters	Optimum Level	Value
g	%6.07	0.4 mm
t	% 14	4 mm
Rc	32.51	5 mm
I	%47.42	0.6 A

Effect of every factor on performance of MR shock absorber specified according to dynamic range can be seen above.

6. Results

After the signal-noise analysis and ANOVA analysis could be specified two new candidate geometries except for 9 geometries specified before. To decide optimal geometry, dynamic range must be calculated again for the two candidate geometries as seen table 4

Table 4: S/N ratio ve Dynamic Range for two new candidate geometries

Level Set	S/N	Dynamic Range
1 3 1 3	13.87447	4.93996301
2 3 1 3	20.10094	10.1168862

According to the results, 2 3 1 3 level of the factors are optimal values specified after Taguchi experimental design method.

Table 5: Optimal geometry for MR shock absorber

Parameters	Optimum Level
g	0.8 mm
t	4 mm
Rc	5 mm
I	0.6 A

7. Conculusion

After which Taguchi experimental design analysis, it can be seen that gap is minimum effect on shock absorber performance. One of the most important reason of the result, chosen gap levels are close to providing maximum dynamic range.

Acknowledgement

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