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Resistance Force of a Shock Absorber Using Magnetic Functional Fluids Containing both Micrometer-sized and Nanometer-sized Magnetic Particles

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Abstract

In this paper, properties of resistance force of a shock absorber using magnetic functional fluids having both micrometer- and nanometer-sized magnetic particles are reported. The resistance force can be controlled by changing strength of the magnetic field applied to the magnetic functional fluid. The resistance force is influenced by the mixture ratio of the micrometer- to the nanometer-sized magnetic particles.

Keywords: Shock Absorber; Resistance Force; Magnetic Functional Fluid; Magnetic Particle; Magnetic Field; Damper

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1. Introduction

Applications utilizing magnetic functional fluids having both micrometer- and nanometer-sized magnetic particles have been developed [1]. The size of clusters, the meso-scale structure formation of particles and the cohesion between the magnetic particles are affected by the mixture ratio of the magnetic particles of different sizes in the magnetic functional fluids. Therefore, resistance force properties of the shock absorber using the magnetic functional fluids are influenced by the mixture ratio of the micrometer- and nanometer-sized magnetic particles.

In this paper, resistance force of a shock absorber is investigated experimentally. Two magnetic functional fluids whose mixture ratio of micrometer- and nanometer-sized magnetic particles is different are prepared for the experiment. The resistance forces are measured when load is applied to the shock absorber under magnetic field.

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2. Experimental method

Schematic diagram of the shock absorber is illustrated in figure 1. The cylinder (A) is filled with the magnetic functional fluid. The piston (A) is moved with the shaft. The shaft penetrates the cylinder (A) so as to maintain the capacity inside the shock absorber constant. The coil is installed on the cylinder (A) to apply magnetic field to the magnetic functional fluid. Figure 2 shows the distribution of the magnetic flux density when an electric current is applied to the coil. Figure 3 illustrates the schematic diagram of our experimental apparatus. The shock absorber is attached in the plumb direction. When high pressure air in the air tank is opened by the solenoid valve momentarily, pressure in the cylinder (B) suddenly rises and load is applied to the shock absorber through the piston (B). The load can be changed by adjusting the pressure of the air in the tank. When a load is applied to the shock absorber, displacement and resistance force of the shock absorber are produced. The displacement of the shaft is measured by the laser displacement sensor and the amplifier unit (Keyence Corp., LB-300 and LB-1200), while the resistance force is measured by the load cell and the strain amplifier (Kyowa Electronic Instruments Co., Ltd., LUX-A-1kN and DPM-751A).

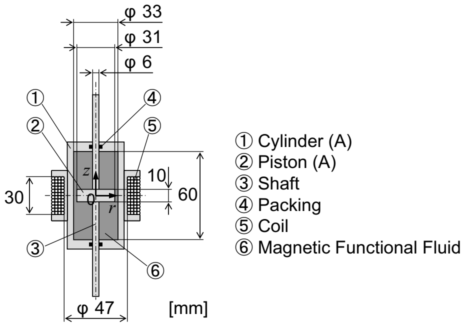


Fig.1 Schematic diagram of shock absorber

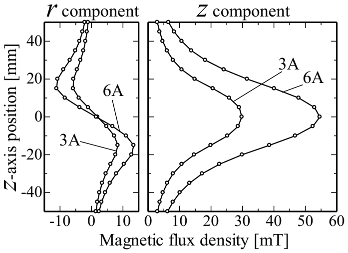


Fig.2 Distribution of magnetic flux density

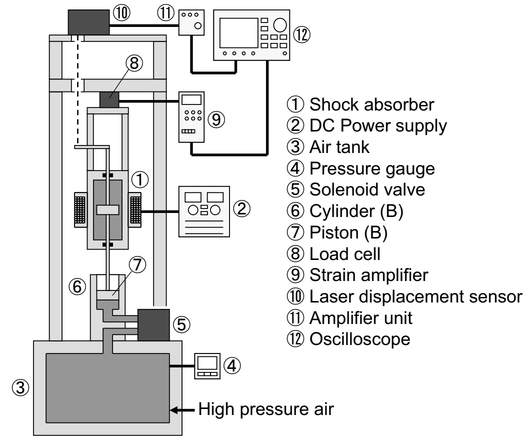


Fig.3 Schematic diagram of experimental apparatus

Table1 Component of magnetic functional fluids

	Magnetic particles [vol.%]		Solvent
	μ m-sized	nm-sized	
Fluid-1	27.2	2.8	Poly- α -Olefin
Fluid-2	24.4	5.6	

Table2 Experimental conditions

Air pressure [MPa] (Load)	0.4, 0.6, 0.8
Electric current [A] (Magnetic field)	0, 3, 6

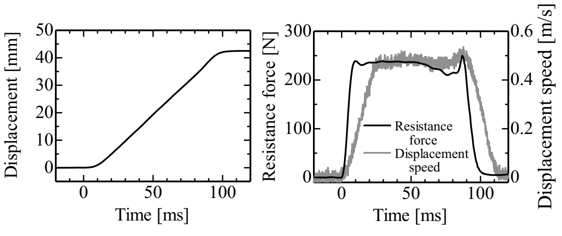
Table 1 shows the components of the magnetic functional fluids prepared for our experiments. Each magnetic functional fluid has the same total volume fraction of magnetic particles. Thus, the number of magnetic particles included in fluid-1 is larger than that of magnetic particles included in fluid-2.

The load applied to the shock absorber (pressure of the air) and the magnetic field applied to the magnetic functional fluid (electric current supplied to the coil) are experimental conditions as shown in table 2.

3. Result and discussion

Figure 4(a) illustrates the time history of the displacement. When the solenoid valve is opened and the load is applied to the shock absorber at time of 0 second, the displacement of the shock absorber is increased in proportion to the time. After about 0.1 second, the piston (B) is out of the cylinder (B). Thus, the load to the shock absorber disappears and the displacement of the shock absorber becomes constant. Such a displacement pattern is the same in all experimental conditions. However, the time when the displacement becomes constant and the gradient of the displacement are different in each experimental condition.

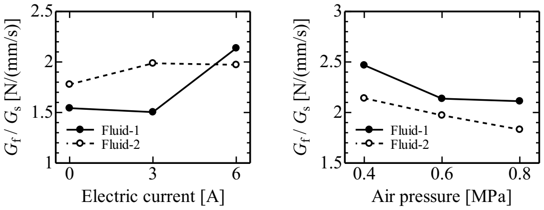
Figure 4(b) shows the time history of the resistance force and displacement speed. The resistance force results from viscosity and solid friction due to the particle–particle interactions and particle–solid surface interactions. The resistance force and the displacement speed suddenly increase just after load applied to the shock absorber. Both of the resistance force and the displacement speed become the constant value afterwards. The time history of resistance force and the time history of the displacement speed have the same waveform pattern. Therefore, the resistance force of the shock absorber rests on the viscosity which depends on the displacement speed. In addition, the time when the resistance force becomes constant is earlier than the time when the displacement becomes constant. Thus, the resistance force of the shock absorber has the friction which is independent of the displacement speed. It is the same as the damping force of the damper using magnetic functional fluids [2] that the resistance force of the shock absorber consists of a viscosity and friction.



(a) Displacement (b) Resistance force and displacement speed

Fig.4 Time history
(Air pressure: 0.6 MPa, Electric current: 6 A)

Next, let us consider the influence of the magnetic field and the load on the resistance force which is the sum of viscosity and friction. We introduce the parameter G_f/G_s, where G_f is the gradient of the resistance force, and G_s is the gradient of the displacement speed. The parameter G_f/G_s being large indicates that influence of the friction becomes strong. Figure 5(a) demonstrates relation between G_f/G_s and the electric current. In region under 3A, G_f/G_s of fluid-2 is larger than that of fluid-1, while G_f/G_s of fluid-1 is larger than that of fluid-2 in case of 6A. As the total volume of nanometer-sized magnetic particles in the magnetic functional fluid increases, the friction increases under weak magnetic field. And as the micrometer-sized magnetic particles in the magnetic functional fluid increases, the friction increases under rather strong magnetic field. Figure 5(b) shows the relation between G_f/G_s and the air pressure. As the load increases, G_f/G_s decreases in both fluid-1 and fluid-2. This phenomenon results from the decrease of friction. When the load is large, some clusters collapse, i.e. the number of contact points of magnetic particles decreases, and the friction decreases.



(a) Air pressure: 0.6 MPa (b) Electric current: 6 A

Fig.5 Influence of the friction

Figure 6 shows the resistance force - displacement curves just after opening the solenoid valve under constant load. When the electric current is small in fluid-1 and fluid-2, longer displacement is necessary till the resistance force becomes constant comparing with the cases under rather strong magnetic field. This phenomenon results from the increase of friction. As the strength of the magnetic field increases, cohesion of the magnetic particles increases. Thus the friction increases. Figure 7 shows the resistance force - displacement curves under constant magnetic field. When the air pressure is high in fluid-1 and fluid-2, longer displacement is necessary till the resistance force becomes constant. This phenomenon results from the decrease of the friction. As the load increases, the displacement speed increases. Therefore, the viscosity increases, and effect of friction on total of the resistance force decreases.

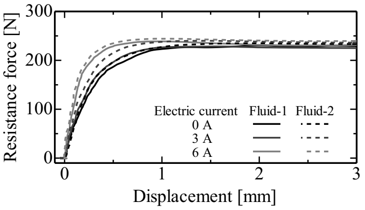


Fig.6 Resistance force – displacement curves
(Air pressure: 0.6 MPa)

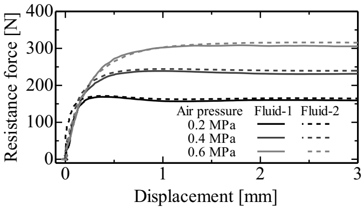


Fig.7 Resistance force – displacement curves
(Electric current: 6 A)

4. Conclusions

Effect of composition of the magnetic functional fluid, the magnetic field and the load on resistance force properties of the shock absorber using magnetic functional fluid were investigated experimentally. The following results were obtained. (1) The resistance force of the shock absorber consists of viscosity and friction. (2) As the volume fraction of the nanometer-sized magnetic particles in the magnetic functional fluid increase, the friction increases under weak magnetic field. And as the volume fraction of the micrometer-sized magnetic particles in the magnetic functional fluid increase, the friction increases under rather strong magnetic field. (3) As the magnetic field decreases or the load increases, longer displacement is necessary till the resistance force becomes constant.

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