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Testing Viscosity of MR Fluid in Magnetic Field

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The purpose of this paper was to determine the coefficient of viscosity of a magneto-rheological fluid for different values of the magnetic field and to determine parameters at which the flow of the fluid through a capillary is stopped. To determine the coefficient of viscosity, a method of indirect measurement was implemented using a reference fluid with the known properties. A test stand with a capillary viscometer was constructed. The measurements showed that the viscosity of the magneto-rheological fluid was linearly dependent in a wide range of values of the magnetic induction.

Keywords: magneto-rheological fluid, viscosity, measurement

1. INTRODUCTION

ONE OF THE METHODS of damping vibrations in mechanical systems is the application of magneto-rheological (MR) dampers.

These dampers make it possible to continuously control the damping rate by changing the viscosity of a fluid. This is possible by proper control of the magnetic field parameters. Ready made damping modules filled with a MR fluid or own designs of dampers may be applied for this purpose. The leading producer of these modules and MR fluids provides little information and data on their properties. In the case of damping modules, given are reaction time on changes in the magnetic field and a dependence of the damping force from the velocity of vibrations [3]. In the case of MR fluids, the producer gives a dependence of the yield strength and magnetic induction from the magnetic field strength [4]. Sufficient data necessary for the viscosity control of a MR fluid are missing.

The objective of this paper was to determine the viscosity of a MR fluid at different values of the magnetic field and to determine the parameters at the value of which the fluid flow through the capillary is stopped. A test stand was constructed and erected to realize this purpose. The method of determination of viscosity with the use of a capillary viscometer was employed.

2. PROPERTIES OF MAGNETO-RHEOLOGICAL FLUIDS

A MR fluid is a colloidal suspension of polarised particles. Its viscosity is close to the viscosity of engine oil. In the presence of the magnetic field this viscosity changes. The carrier fluid is usually mineral or silicone oil which combines low tendency to evaporation with resistance to temperature: depending upon a need, either high or low. Particles distributed in the carrier oil are micro-magnets. These are coated with a surfactant like oleinic acid which prevents the clustering of micro-magnets. MR fluids may operate within a temperature range from - 65°C to 200°C. High temperature causes solidification of the fluid [1].

The properties of the fluid make it possible to use it in two operational modes (Fig.1). The first mode consists in the regulation of the flow resistance (Fig.1a) which is used in vibration dampers (Fig.2). In this case, the fluid flows through holes in coils located on the surface of the piston. In the second mode, the fluid is subjected to shearing stresses (Fig.1b) between two surfaces in a relative motion which is used in the design of clutches and brakes.

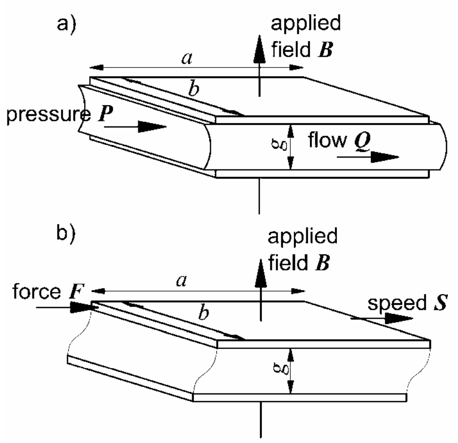

Fig.1 Basic operational modes for controllable fluid devices: (a) pressure driven flow mode, (b) direct shear mode (after [2]).

A scheme of a main, typical damping module with a MR fluid is shown in Fig.2. The damper consists of a cylinder and a piston. A translation of the piston causes the flow of the fluid through axial opening in the coils. The control of the damping properties of the module consists in the control of the feed current to the electrical coils arranged in the piston. Magnetic field generated by the coils directly influences the viscosity of the MR fluid flowing through the holes and causes changes in the resistance to the piston translation. The time necessary to obtain 90% of the final viscosity of the MR fluid at a given strength of the magnetic field is equal to a few microseconds. A gaseous accumulator compensates a difference in the volume of the fluid at the front and backside of the piston (a difference due to design reasons: the presence of a one side piston rod).

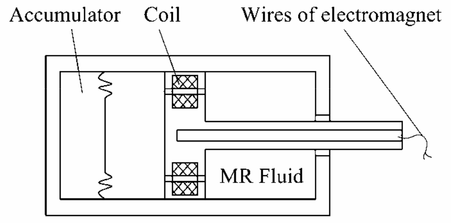

Fig.2 MR Damper RD_1005-3 cross section.

3. CONSTRUCTION OF THE STAND AND A METHOD FOR THE MEASUREMENT OF THE VISCOSITY OF A MAGNETO-RHEOLOGICAL FLUID

To determine the influence of the magnetic field strength on the viscosity of a fluid, a test stand was constructed, the scheme of which is show in Fig.3. The component parts of the stand are: glass capillary (1), electrical coil (2) mounted coaxially with the capillary, DC power adapter (3) making it possible to regulate voltage and current, and a manual stop watch (4) for the measurement of time with 0.2 s accuracy. The stand is additionally equipped with a magnetic field strength gauge (5) for measurements in the capillary, inside the electrical coil.

The coefficient of the viscosity of the magneto-rheological fluid was determined by an indirect method, using glycerine as a reference fluid of the known properties. A formula derived by Poiseuille (1) was used for this purpose. [5]:

$$\eta = \frac{\rho \cdot t}{\rho_g \cdot t_g} \eta_g \tag{1}$$

where:

ρ – density of the magneto-rheologic fluid,

t – outflow time of the magneto-rheologic fluid from the capillary,

ρ_g – density of the reference fluid,

t_g – outflow time of the reference fluid from the capillary,

η_g – viscosity coefficient of the reference fluid.

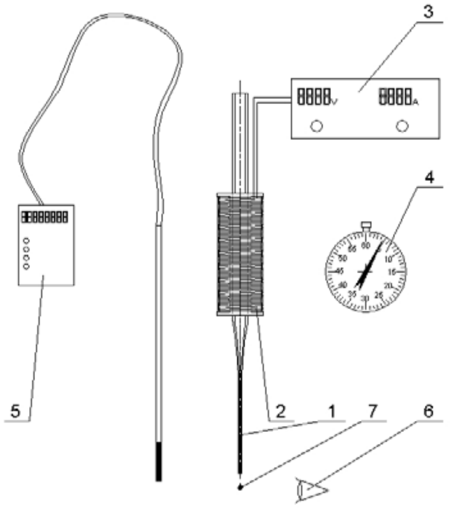

Fig.3 Scheme of the test stand: 1) glass capillary, 2) electric coil, 3) DC current source with means to control voltage and current, 4) manual stop watch, 5) gauge of the magnetic field strength with a Hall's probe, 6) observer, 7) a drop of the fluid.

4. EXPERIMENTAL

The experiments were carried out in two stages. In the first stage, a relationship between the strength of the magnetic field in the coil and the supply current parameters was found. In the second stage, the viscosity of the fluid at the same supply current parameters was determined. Measurements of the magnetic induction were made, using a Hall's probe located inside the pipe with the capillary and filled with the MR fluid. The results of these measurements are shown in Fig.4. When compared with the results of induction measurements made without the MR fluid, the value of the magnetic induction is two times higher.

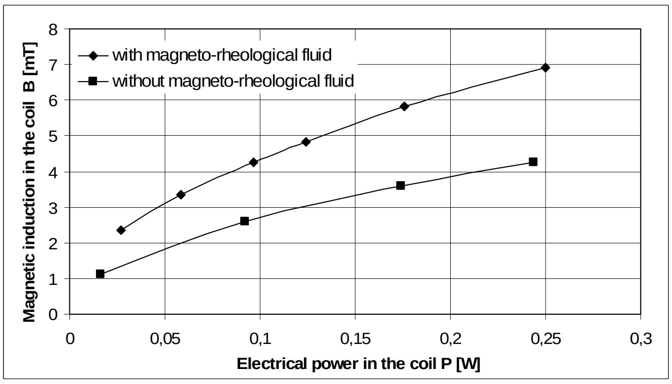

Fig.4 Value of the magnetic induction in the capillary with the MR fluid and without the MR fluid.

The next stage of investigations was a measurement of the magneto-rheological fluid viscosity flowing through the glass capillary located in the coil. To determine the viscosity, the outflow time of 50 drops of the MR and the reference fluids were taken. The density and viscosity coefficient of glycerine were taken from tables, and the density of the MR fluid was taken from the manufacturer's specifications. The results obtained were substituted to formula (1) and a dependence of the MR fluid viscosity from magnetic induction was found (Fig.5).

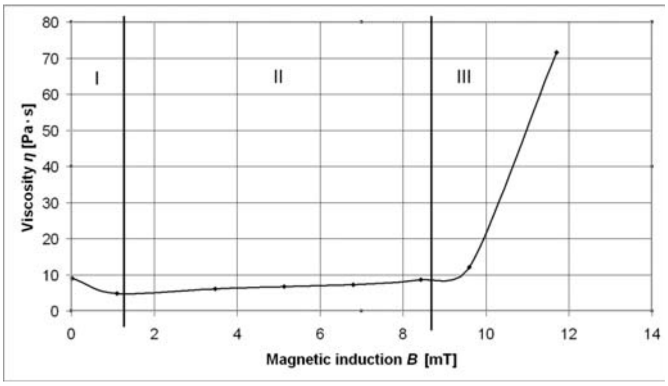

Fig.5 Plot representing a dependence of the viscosity from the magnetic induction

Three different ranges of the magnetic induction may be recognised in the plot. In the first range (Fig.5), with the rise in the magnetic induction, the viscosity of the MR fluid slightly decreases. In the second range, the increase in the viscosity is proportional to changes in the magnetic induction. This is the most useful relation that could be easily implemented to the active control of the fluid properties. In the third range, a considerable increase in the viscosity was observed. The reason is a partial clogging of the flow.

5. SUMMARY

The aim of this research was to determine the viscosity of a MR fluid at different values of the magnetic field. The theoretical objective of the work was to determine this range of viscosity variations that is useful for control purposes. A practical result was the finding of the value of current that locks the flow for different parameters of the coil. This current lies in a range from 1.5 to 3A. The results of this research will be used to control the damping properties of a robot used in the glass industry.

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