International Conference on Emerging Trends in Engineering, Science and Technology (ICETEST - 2015)

Magnetorheological fluids examination for antivibration mounts at impact loads

Gordeev B.A.\textsuperscript{a,}\* , Dar’enkov A.B.\textsuperscript{a}, Okhulkov S.N.\textsuperscript{a}, Plekhov A.S.\textsuperscript{a}

\textsuperscript{a} Institute of Electric Power Engineering, NNSTU n.a. R.E. Alekseev, Nichny Novgorod 603950, Russia

Abstract

In this work the question of magnetorheological fluids usage in damping systems of electromechanical power installations and machinery are studied. The physical backgrounds of magnetic fluids characteristics operation with respect to inner magnetic fields are considered. The processes appearing in magnetorheological fluids at impact loads are looked into. These tasks are solved within the frame of magnetorheological fluid only due to the fact that electromagnetic impulses appear on solenoid windings which are meant to create an inner control magnetic field. The amplitude and the impulses duration is an impact load function. Their influence is to be taken into account when developing magnetorheological dampers.

\textsuperscript{a} Corresponding author. Tel.: +0-000-000-0000 .
E-mail address: gord349@mail.ru

© 2016 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Peer-review under responsibility of the organizing committee of ICETEST – 2015

Keywords: magnetorheological fluids; magnetorheological transformers

1. Introduction

Increasing the power of the electromechanical and mechanical equipment causes an increase the amplitude of the vibration, the expansion of the spectrum of vibrations and shocks. This affects the reliability and safety of operation of the equipment. Thus it is necessary to improve the vibration protection systems and to implement new engineering solutions. Developing magnetorheological dampers of impact loads oscillations is a prospective trend nowadays. In these oscillations energy dissipative processes in magnetorheological media [1, 2, 3] take place.

* Corresponding author. Tel.: +0-000-000-0000 .
E-mail address: gord349@mail.ru
This article shows an approach to solve the vital task of magnetic fluids characteristics research under the impact loads with inner and outer electromagnetic fields [4, 6, 7].

2. Main results

The process of integrated dampers (hydromounts) associated with the use of magnetorheological fluids [1, 2, 3]. Thus one of the most vital tasks is to investigate the magnetorheological fluids characteristics at impact loads. The possibility to control the magnetorheological viscosity in magnetorheological transformers (MRT) choking channels at inner and outer electromagnetic fields influence is test-proven [4, 6, 7].

When demonstrating magnetorheological and electrorheological media movement at the magnetic field influence, the following conditions are taken into account [5]

$$\omega_0 \tau << 1,$$

where \( \omega_0 \) - Larmor procession frequency for ionized molecules of the working fluid, \( \tau \) - ionized molecule mean free path time, electrical conductivity - \( \gamma \) too much, thus

$$\frac{\varepsilon}{4\pi} \cdot \frac{\omega}{\gamma} << 1$$

where \( \omega \) – external signal frequency, \( \varepsilon \) – relative dielectric permeability.

During electromagnetic fluid choking, the induction current with current density appears in the magnetic field

$$J = \frac{\gamma}{c} [\varepsilon H]$$

where \( c \) – light speed, \( H \) – external magnetic field strength, \( V \) – the electrorheological fluid flow speed.

To test the mechanical impulse load on a single-channel inductive MRT there has been created an impact loads experimental test unit. Fig.1 shows the test unit.
Fig. 1 shows: 1 – measuring scale; 2 – an altitude indicator with a Nonius; 3 – piston rod; 4 – cylindrical diamagnetic brass freight; 5 – bottom section – Nd permanent magnet; 6 – inductive MRT; 7 – electronic memory oscilloscope; 8 – physical shock vibrorecord; 9 – electrical inductive signal. Under the influence of physical shock mechanical impulse at magnetorheological fluid movement and the movement of screw-cork core in an MRT choking channel and the effect of permanent magnetic field Nd permanent magnet 5 in the solenoid electrical currents are induced which at the solenoid open winding create the voltage difference \( U_1 \). The voltage difference is picked up by an electronic memory oscilloscope.

When tested the inductive electrical signals from the memory oscilloscope screen have been picked up, which indicated the inductive currents, appearing in an MRT solenoid as a result of cylindrical brass freight shocks (Fig. 1).

Fig. 2 shows the inductive electrical signal oscillogram chart at the outlet of the inductive MRT correspondent to the absorbed impact load energy of 2.5 joule (on Y-axis the voltage in mV, on the X-axis the time in ms). This happens at a mechanical shock impact of 1 kg freight. The signal positive amplitude is 620 mV; negative amplitude – 800 mV; electrical impulse period – 2.0 ms.

![Fig. 2. The inductive electrical signal oscillogram at the inductive MRT outlet at a physical shock, the freight drop height 100 mm, the freight weight 1 kg](image)

The positive and negative amplitudes of inductive electric voltage at a physical shock depend on the freight drop height (Fig. 3). Fig. 3 shows the Y-axis - the amplitude of the voltage caused by the impact load in mV, on the X-axis - drop height of load in mm. Thus the freight drop heights determine the impact energy values, damped by a hydromount.

![Fig. 3. Dependence of positive and negative amplitudes of inductive electrical signal at a physical shock from the freight drop height h. The freight weigh is 1.0 kg: 1- the signal maximum negative amplitude; 2 – the signal maximum positive amplitude.](image)
The maximum inductive electrical signal negative amplitude at 225 mm freight drop is explained by an inductive MRT rubber-steel shell return shock. Friction of magnetorheological fluid has a low resistance to magnetorheological fluid flow and the movement of screw-cork core in an MRT choking channel (Fig. 1), as the MRT volume is quickly restored to its initial state. In this case the magnetorheological fluid velocity in a choking channel is at its maximum and at the maximum magnetorheological fluid velocity in a choking channel at permanent magnetic field effect the maximum negative amplitude of an electrical signal is induced in a solenoid.

The magnetic force, created by magnetorheological fluid flow in an MRT choking channel with a permeability \( \mu \) from the pressure in the working chamber and the magnetic induction of the permanent magnet external magnetic field is determined as

\[
J \times B = -\mu \cdot \text{grad} \ p_M,
\]

where \( J \) – magnetic field induction, \( p_M \) – magnetic pressure

The magnetic pressure is represented as

\[
p_M = \left| -\frac{\mu}{8\pi} H^2 \right|.
\]

Herewith \( \mu \) – relative magnetic permeability of the magnetorheological fluid. To satisfy the static terms of the equation it follows that

\[
p + p_M = 0,
\]

\[
p = -p_M.
\]

It means that in static equilibrium conditions any mechanical pressure change \( p \) the magnetorheological fluid must be compensated by an opposite magnetic pressure change \( p_M \).

In a magnetorheological fluid there appears a pressure gradient, balancing the electromagnetic field component

\[
\gamma \cdot v \cdot \mu \cdot B^2 = \frac{\partial p}{\partial z},
\]

where \( \gamma \) [Cm] – electromagnetic fluid conductivity, 1sm = A/B = c^3 · A^2/(kg·m^3); \( v \) [m/s] – magnetorheological fluid speed in a choking channel; \( B \) [tesla] – magnetic flux density, 1tesla = B-s/m^2 = kg/(c^2·A); \( p \) [Pa] = H/m^2 = kg/(c^2·m); \( z \) [m] – choking channel length; \( \mu = 10 \) – relative magnetic permeability of the magnetorheological fluid.

When testing the magnetorheological fluid with magnetite elements (Fe_3O_4) was used in an inhomogeneous magnetic field of an Nd permanent magnet. The magnetorheological fluid elements \( d \) are 60 - 100 Nd.

For a magnetorheological damper the outer magnetic field spring action over the magnetorheological liquid is based on its force impact. Herewith, created by it a magnetic pressure is great, compared to other dynamic factors-hydraulic dynamic pressure and inertial forces, created by the magnetorheological fluid flow in a choking channel when

\[
\frac{\mu \cdot H^2}{8\pi} \gg \frac{\rho \cdot v^2}{2},
\]

\[
\frac{\mu \cdot H^2}{8\pi} \gg p,
\]

where \( \rho \) – magnetorheological fluid density.

Further the magnetic field solenoid magnetic force is estimated, which prevents the magnetorheological fluid mechanical pressure in a choking channel at a physical MRT impact.

The drop-weight force \( m = 1.0 \) kg at the height of \( h = 0.6 \) m at the acceleration of gravity \( g = 9.81 \) m/s² and at the impact duration taken from the oscillogram, which equals \( t_i = 1.0 \) ms (Fig.2) is determined as follows

\[
F = \frac{m \cdot \sqrt{2gh}}{t_i}.
\]
At such impact force the pressure on the MRT shell mount (Fig. 1) at the square of \( S = 0.707 \times 10^{-3} \) m\(^2\) is expressed as follows

\[
P = \frac{F}{S}.
\]

The magnetic force – magnetic pressure created in an MRT choking channel at the magnetic field strength \( H = 20 \times 10^3 \) A/m

\[
p_M = \frac{\mu H^2}{8\pi}
\]

Such magnetic pressure creates the magnetic force which prevents the magnetorheological fluid mechanical pressure at inlet/outlet of a choking channel at the influence of a permanent magnetic field as well as exceeding the magnetorheological liquid hydraulic pressure.

At this pressure ratio \( p_M \) and \( p \) are

\[
\frac{p_M}{p} = 31.
\]

Herewith the magnetic pressure \( p_M \) from a magnetic field permanent magnet is by 31 times higher than the hydraulic pressure \( p \) from inertial load of the drop-weight and equals 30 dB.

The \( p_M \) and \( p \) pressure ratio shows that at magnetorheological damper operation, the maximum magnetorheological fluid magnetization is desirable.

Fig. 4 shows the dependencies of magnetorheological fluid viscosity samples (MRF-1 and MRF-2) for different values of magnetic field strength \( H \).
Acknowledgements

R&D are carried out as a part of a state project in the sphere of scientific research №8.2668.2014/K in Nizhny Novgorod State Technical University n.a. R.E. Alekseev.

References