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Design and Performance Analysis of an Electro Rheological Damper

Engineering

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ABSTRACT

This paperis presenting the design, fabrication and performance analysis of an Electro-Rheological (ER) damper prototype, The characteristics of the used electrorheological (ER) fluid are experimentally obtained.The ER material is the one of which any of the rheological properties is depending upon the Electric-Field as in (volts/meter), this means, a material with a viscosity or shear stress which depends on the Electric-Field. A twin tube cylindrical ER damper type is designed and fabricated, then its damping force is evaluated experimentally, which the design method of the ER damper is based on thedamping system requirements, such as,the controllable damping force. Which is obtained through load cell and a motor.

By applying different voltages (from 1KV to 3 KV), damping coefficient at each voltage value is obtained from the load setup.

INTRODUCTION

Vibration is the most undesired motion in vehicles, structures and most of machines, and there were continuous research and development in vibration absorption systems, such as suspension systems in vehicles, through springs and dampers, which dampers are considered more important because they are primary responsible of ride stability and comfort.

With the discovery of the Electro-Rheological fluid in 1947 by (Winslow), Which is a fluid that change its properties such as apparent viscosity and shear stress when exposed to electrical field, and with the development of the ER fluid in the 1990s , The idea of using this fluid have become more familiar and many scientists and research teams have researched in this field and in the behavior of the Electro-Rheological fluid in different applications and designs.

Electro-rheological, named [ER] fluids are non-conducting suspensions of very fine particles [with size to 50 micro-meters diameter] in a fluid which is electrically insulating. The apparent viscosity of those fluids is changing reversibly with response to an Electric-Field. That gives the typical ER fluid a capability to go from the consistency of liquid to the consistency of Gel, and reverse back, with times response in the order of milli-seconds.

This practical application is to use an ER fluid damper that can be used in various applications including vehicle suspension or vehicle seat damping, The experimental results is to be discussed in this paper.

In this research, we are going to design, manufacture and analyze a damper model containing the ER fluid as damping medium and this model will be as a base design for further development in the future.

The design

The damper is a twin tube design which contains of two tubes one inside the other, and each one of the tubes is serving as an electrode which conducts electricity and the ER fluid flows between the tubes, making the design as a flow mode ER damper, in the OFF state; the fluid flows almost freely at given viscosity and a relatively low damping coefficient, and in the ON state; the electrical current is applied, and the electrodes conduct the electrical field to the fluid, the electro-static forces cause the formation of chains of particles in the electric field direction of which makes the small fluid particles rearrange due to the dielectric mismatch between the suspended particles and the solvent, makes a structured chains as one form of polarization, which increase the yield stress, thus increasing the viscosity, all this happens within milliseconds.

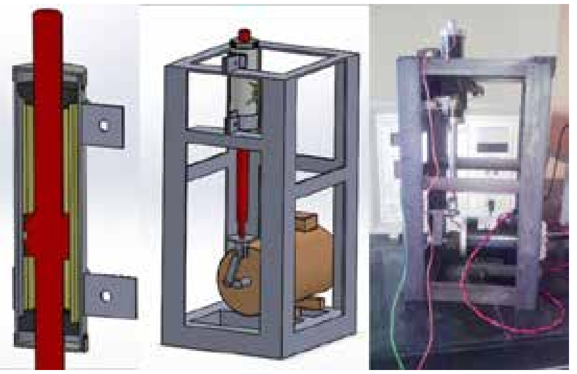

Figure 1: ER damper design and testing setup

The design was based on mathematical formula of pressure drop from "**Poiseuille equations**" flow in between two concentric cylinders, which yields:

Where , is the damping coefficient,

is the area of piston head minus area of rod,

is the distance from center of damper to the gap,

is the electrode length,

is the viscosity,

is the gap between electrodes,

The damping coefficient value from the design is (601 N.s/m), which suitable as testing setup for the purpose of studying the ER effect.

The important factors that control the damping coefficient is the design characteristics and dimensions of the whole design, as well as the fluid properties, both of them can be utilized according to the application intended for use.

Fluid preparation:

The fluid was chosen based on the break down test and also the yield shear stress test, which are both a good indications to determine how the fluid will behave in this design, also based on temperature effect on the fluid viscosity.

The used fluid composition contains of silicon oil with a 20% **Strontium Titanyl Oxalate**, which is having a breakdown voltage between (3KV/mm to 4 KV/mm) and this voltage range is ideal for the design, as the design is having 1.5 mm clearance between the electrodes

The properties are listed in the flowing graphs:

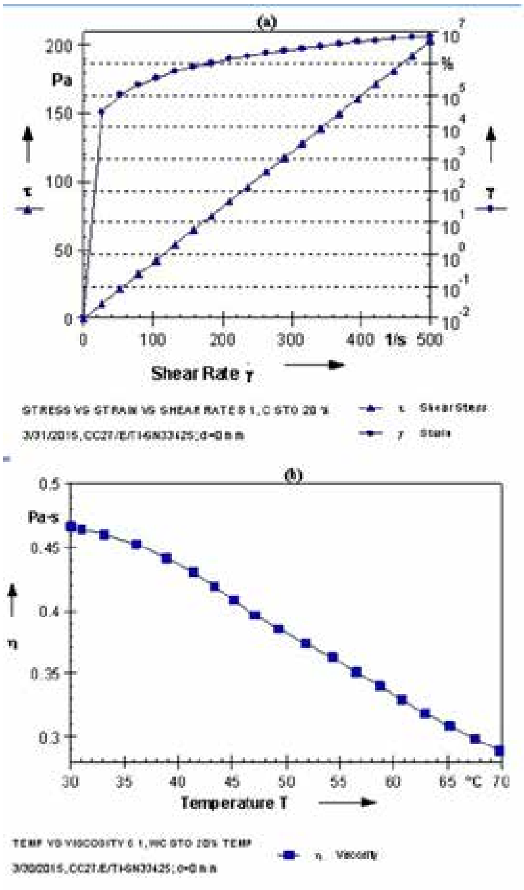

Figure2: Shear stress vs. strain vs. shear rate (a), Temperature (b).

The fluid was tested in a rheometer and was validated to use within the given voltage range.

Testing Of Damper:
The testing was done through load cell as Electro-mechanical testing method, which contains of a motor with a given power, and it is connected to a crank-slider mechanism with a connecting rod, this gives a reciprocating motion to the damper, the motion is considered as a sinusoidal motion, and with the variation of the acceleration and velocity, it is possible to find the mean speed of the damper, also with a controlled speed of the motor, it is possible to maintain accuracy of the input power.

The damping coefficient can be calculated from the power input of motor ,torque and RPM, through torque, the force applied to the damper obtained through the crank displacement, which is (20mm), thus, gives a displacement of (40mm), and with the force applied, the damping coefficient can be calculated by knowing the speed of the damper, and since the speed is changing as a sinusoidal wave, the mean speed is calculated for each of the tests at every voltage value, thus giving the desired results for the damping coefficient.

The used motor is having (0.25 HP) or (0.1864 KW) and (1500 RPM). The torque of the motor is given by:

,T= 1.187 N.m

And force on piston is given by:

,Where damping coefficient, velocity of piston.

Where

We have:

The resulting mean force on piston = 126 N

And the resulting mean velocity of damper piston is:

, where St is piston stroke=

And by applying the Electrical field on the damper, we get different rotation per minute for each voltage amount, thus, it is possible to calculate the damping coefficient through the velocity of the damper shaft from equation (3). Note that the motor torque in the PMDC motor is having a steady torque, and the only change the power supply is controlling is the RPM of the motor, and in our testing, we are only using steady power input that gives 1500RPM without load.

The analysis of testing gave the following RPM results, and also the damping coefficient as:

	ER fluid 0kv	ER fluid 1kv	ER fluid 2kv	ER fluid 3kv
RPM	132	114	96	85
C	717	831	986	1114

Figure3: Damping coefficient results

Conclusions:
The ER fluid damper consisting of silicon oil with a 20% **Strontium Titanyl Oxalate** were evaluated and tested in the flow mode.

It is shown that the resulting shear stress from the flow mode is relatively high with low electric field intensity applied , compared to most of other ER fluids.

The method of designing of [ER] dampers is based on technical requirements of the dampers and their intended use, e.g, controllable damping coefficient, An [ER] damper is tested on a single degree of freedom exciting system, with a setup for controlling the velocity, for evaluation of the effectiveness of the [ER] damper when applying an electrical field for controlling the vibration of the system through experiments.

And for purpose of the designing of the Electro-rheological fluid shock absorber-damper, a good knowledge of mechanical properties of the [ER] fluids is required, This study is showing that the set of parameters obtained from the rheometer and from the tests, which are in flow mode can be sufficient for predicting the [ER] fluid behavior in other modes and in the combined mode as well.

In this study, there are main three feature results:
(1) The damping coefficient of the ER damper which is controllable, is higher than that of conventional damper.
(2) The fluid chosen for the experiment is having considerable effect on the damping coefficient, with a lower breakdown voltage than most of ER fluids.
(3) The appropriate design of the size and geometric dimensions of electrodes can be designed for maximum controllable ratio of fluid flow and also the needed damping force.

This [ER] damper is able to produce a relatively high damping coefficient with medium stroke and low [ER] fluid effectiveness, this is done by selecting appropriate gap between electrodes and electrode length.

In addition, Electro-mechanical control systems for vibration which are equipped with the [ER] dampers and also controllers of motion, are designed for performance evaluation of the [ER] dampers. Also, the results of experiments of the Electro-mechanical testing system is demonstrating that the velocity is reduced significantly with Electrical-Field applied on the ER damper.

The optimal design, and also the applications of [ER] dampers as well as their optimal control algorithms for road vehicle suspension system is the aiming for future research topics.

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