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STUDY AND TESTS OF A SEMI-ACTIVE DAMPER USING COMPLEX MEDIA.

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Abstract: Insulation of vibration and their damping is a commonly used method in mechanical systems where it is desired a sensible protection of structures. The vehicles, and specially the cars, are systems that, by adaptive suspensions can reduce the vibrations and, respectively, to assure a high level of comfort, no matter the load and road conditions. To reduce the vibrations of structures and machines, the most used are the insulation materials and active and semi-active dampers. The main goal of the paper is the study and testing of a semi-active damper in order to establish the behavior of this kind of equipment as vibration damper.

1. INTRODUCTION

The magnetorheological fluids (MR) are considered as controllable fluids because their rheological properties (elasticity, plasticity and viscosity) depend on the applying of a magnetic field. They consist in a carrier fluid, usually silicon or synthetic fluid and ferromagnetic particles (20-50 μm as diameter) [1]. In the absence of the magnetic field, the magnetorheological fluid flows in a state of linear viscosity. However, in the presence of magnetic field, the particles are aligned and form linear chains, parallel to the magnetic field lines (figure 1). The chains impede the fluid motion and solidify the suspension. With a magnetic field, adequately designed, the yield stress of the magnetorheological fluid is changed in a few milliseconds. The most important change is usually remarked when the magnetic field has the normal direction to the flow of magnetorheological fluid. In the design of magnetorheological dampers, it can be obtained damping forces, increased up to 10 times more than in passive state [2]-[5].

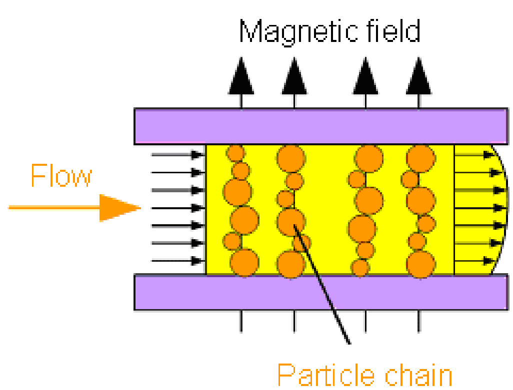

Fig.* 1. *Work of magnetorheological fluid by flow control.

2. STUDY OF A SEMI-ACTIVE DAMPER, USED TO REDUCE VEHICLE VIBRATIONS

For the experimental study of a semi-active damper, it was used a high performance magnetorheological damper RD-1005-3, commanded by a controller RD-3002-03, produced by Lord Rheonetic Company, USA, http://www.lord.com/.

In figure 2 it is presented the catalog product and in figure 3, there is presented the main component parts.

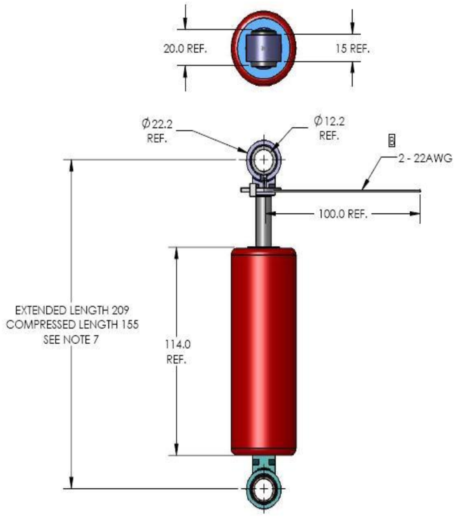

Fig. 2. ***Magnetorheological damper***

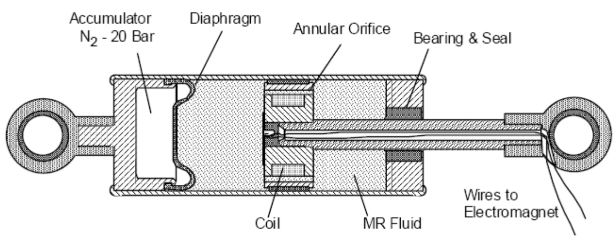

Fig. 3. ***Cross section of RD-1005-3***

The working principle of the damper with MR liquid is as follows: by applying a magnetic field, the MR liquid in the interior of cylinder, rapidly modifies its mechanical characteristics, and the time response is very short (10 ms), the control of damper being very rapidly realized. In the interior of the cylinder chamber there are a piston, a magnetic circuit composed by a coil and a feromagnetic core, a nitrogen accumulator, the MR fluid, diaphragm, electromagnet power cables, a sliding bearing and an oil-tight packing.

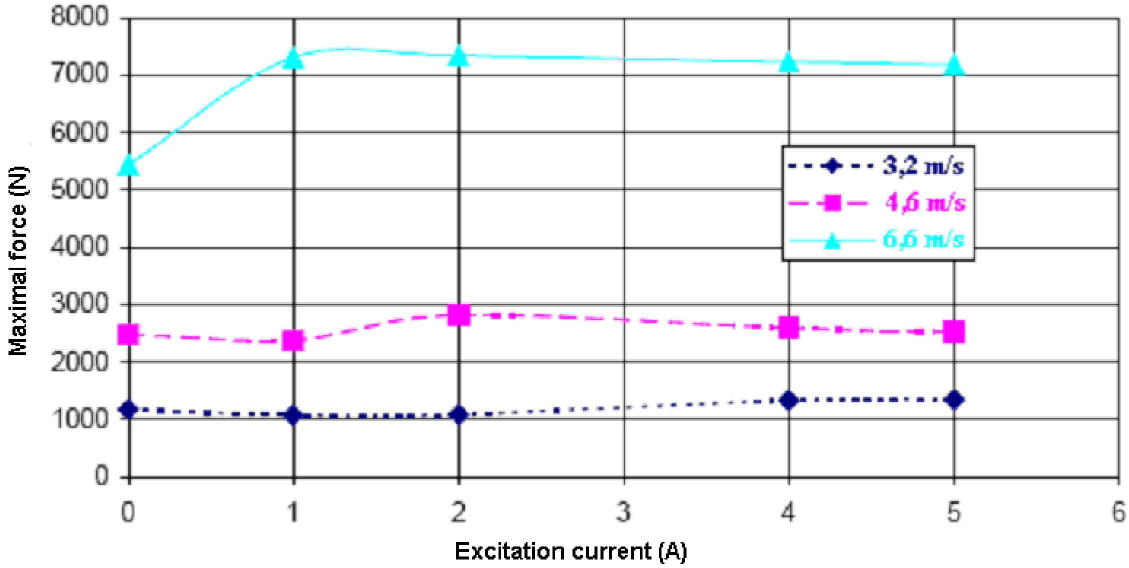

Fig. 4. ***Maximal force transmitted to the magnetorheological damper as a function of excitation current***

The obtained diagrams are in discordance to the anticipated behavior of a MR liquid. If the yield stress increases with the current it would suppose that the transmitted force must increase too with the current intensity. However, it is find that the maximal transmitted force seams to be independent on the current intensity. By considering these discordances it was admitted the hypothesis that the initial forces and high velocities, corresponding to the percussion, force the fluid to enter in a region where the yield stress does not depend on the applied magnetic field.

3. TEST BENCH CONSTRUCTION AND DAMPER TEST

Within the framework of Vibration and Vibroimpact Laboratory, it was designed and constructed a test bench for the test of a damper with MR fluid (figure 5).

The experimental test bench was obtained by modifying a Charpy pendulum. In order to obtain different impact velocities the pendulum can be launched at different angles; in this way it is modified the kinetic energy before the impact, which can be considered as input energy in the system.

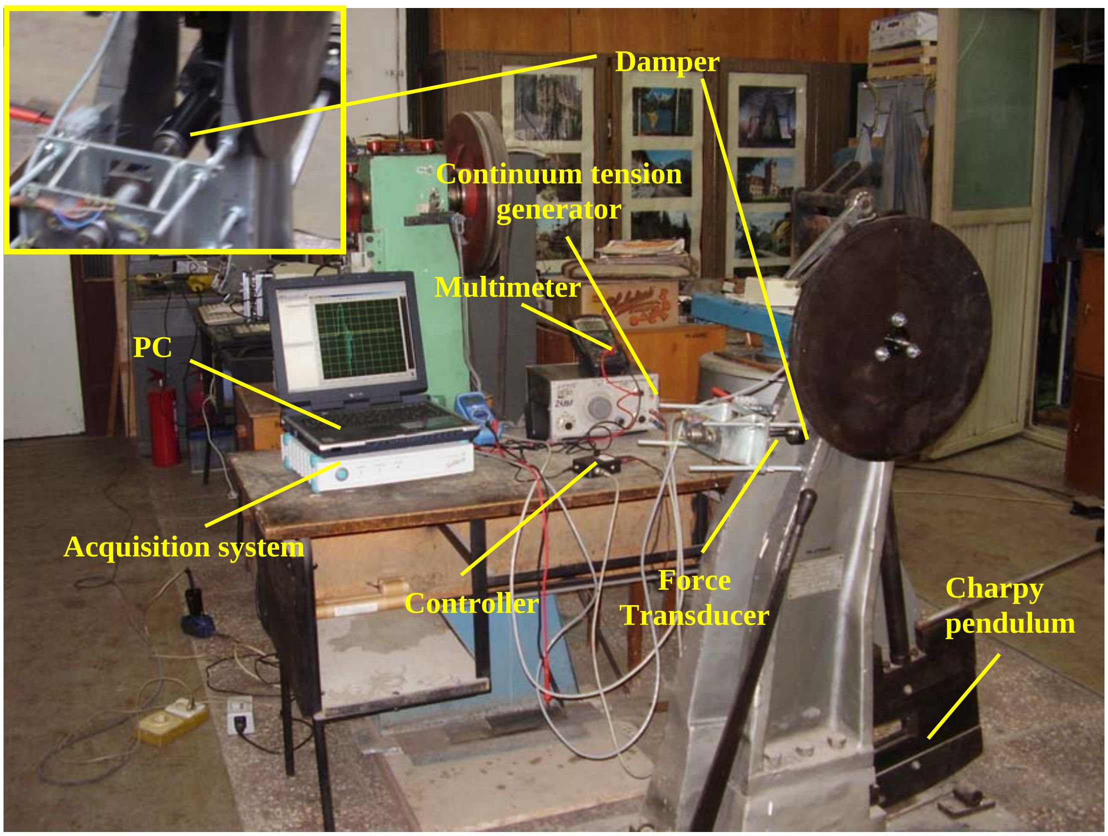

Fig. 5. Experimental test bench

In addition to the Charpy pendulum, the test bench comprises the following equipment and apparatus:

- ✓ MR damper
- ✓ Controller
- ✓ Force transducer
- ✓ Displacement transducer
- ✓ Acquisition system

- ✓ Digital multimeter
- ✓ Portable computer

4. ESTABLISHING OF WORKING CHARACTERISTICS OF DAMPER AS A FUNCTION OF THE PERTURBING SOURCE.

The experimental test bench, designed and constructed in the Vibration and Vibroimpact Laboratory of the Department of Mechanics and Vibrations of “Politehnica” University of Timişoara, it was used for the study of the dynamic response, but also, for the determination of the dissipated energy. It can be done two categories of experiments: determination of the dynamic response on the basis of free excitation, respectively when the damper is submitted to the action of impulsive forces. On the basis of modifying of the height from which the pendulum is released, it can be controlled its kinetic energy before the percussion, energy that represents, in fact, the input energy in system.

By supposing that the pendulum in freely launched from the rest position, the relations between the kinetic and potential energy can be written:

$$mgh = \frac{mv^2}{2},\ h = l(1-\cos\alpha),$$

where m is the pendulum mass, v is the velocity before the impact, g is the gravity acceleration, h is the height from which the pendulum is released, respectively l is the pendulum length, and α is the angle between the pendulum and vertical. The velocity before the impact is determined:

$$v = \sqrt{2gl(1-\cos\alpha)}.$$

From this moment, the phase of energy dissipation begins. During this process it can be determined the value of average force, developed in the damper.

$$E_d = \int_0^{\delta} F(x)dx = F_{med}\cdot\delta$$

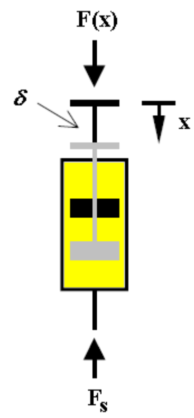

Fig.* 6. *Force representation during the damping process

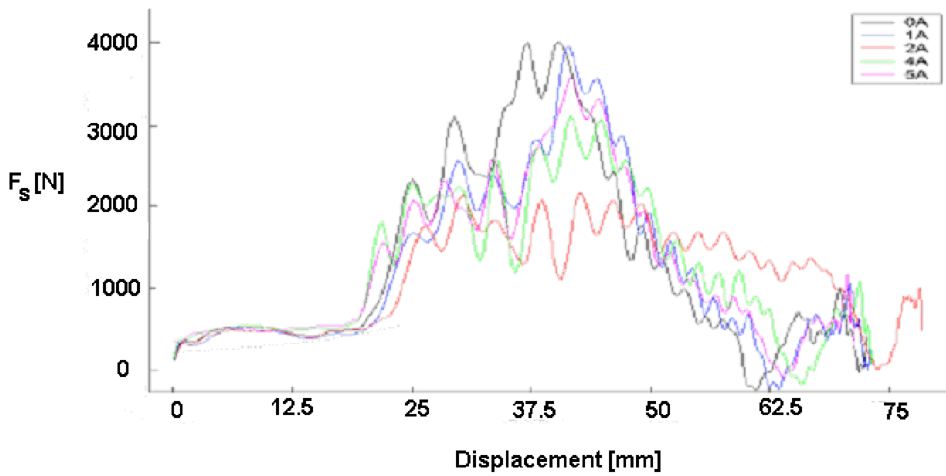

Fig. 7. Transmitted force from the damper to the base, as a function of displacement

In figure 7 it is represented the transmitted force to the base, for a velocity of the Charpy pendulum of 6.7 m/s, before the impact, as a function of displacement, for different values of currents, given by the controller.

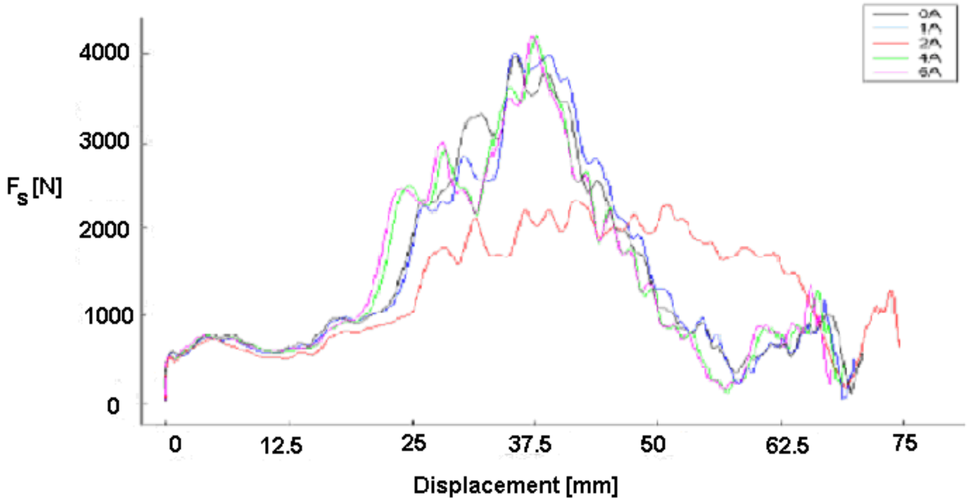

Fig. 8. Transmitted force from the damper to the base, as a function of displacement

In figure 8 it is represented the transmitted force to the base, for a velocity of the Charpy pendulum of 5.8 m/s, before the impact, as a function of displacement, for different values of currents, given by the controller.

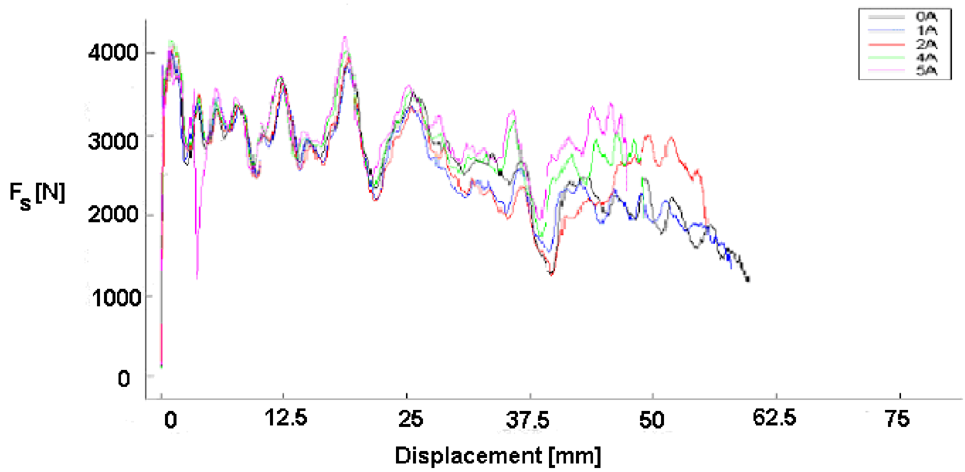

Fig. 9. Transmitted force from the damper to the base, as a function of displacement

In figure 9 it is represented the transmitted force to the base, for a velocity of the Charpy pendulum of 2.1 m/s, before the impact, as a function of displacement, for different values of currents, given by the controller.

5. OPTIMAL DESIGN OF DAMPING SYSTEMS, USED TO VEHICLES AND OTHER STRUCTURES SUBMITTED TO VIBRATION AND SHOCKS

Initially, the optimal design of a damper needs to define the time constant of device and the consumed electric power. It is also necessary to know the maximal force that can act on the damping system, the overall size of device and its electric characteristics. As a function of these parameters it can be determined the length of poles, the number of coils, the number of helix in a coil, the cross section of wire, the interior coil diameter and the density of magnetic flux in the flowing orifice.

It is very important that in the design of a damping system with MR fluid to take into account the type of used fluid, its availability, the presence of some commercial components and also the possibility to adjust the damping in the absence of magnetic field.

To characterize the efficiency of a damper, i.e. for its optimal design, it is introduced the ratio between the dissipation energy of damper and the input energy:

$$\eta = \frac{E_d}{E_i}.$$

The input in damper energy can be determined on the basis of force-displacement diagram. The dissipated energy in the MR damper can be considered as a measure of its performances. It can be determined by the calculus of the aria, included in the force-displacement diagram. By considering the force-displacement diagram for the classical behavior of a viscous damper, the dissipated energy is given by the aria, included in the interior of ellipse (figure 10).

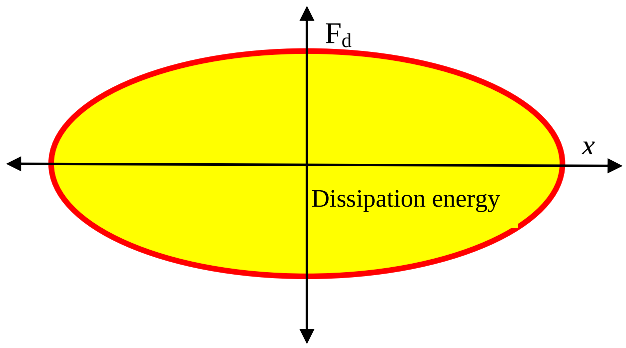

Fig.* 10. *Force-displacement diagram

The calculus of area, included in the force-displacement diagram can be expressed on the basis of integral:

$$E_d = \int_0^T F_d(t)dx$$

where $T = 2\pi/\omega$, and F_d is the force, generated by the damper.

By digitization, it can be written

$$E_d = \sum_{n=1}^{N} F_d(n)\Delta x(n)$$

where N is the sample number in a period, Δx is the displacement variation along the damper.

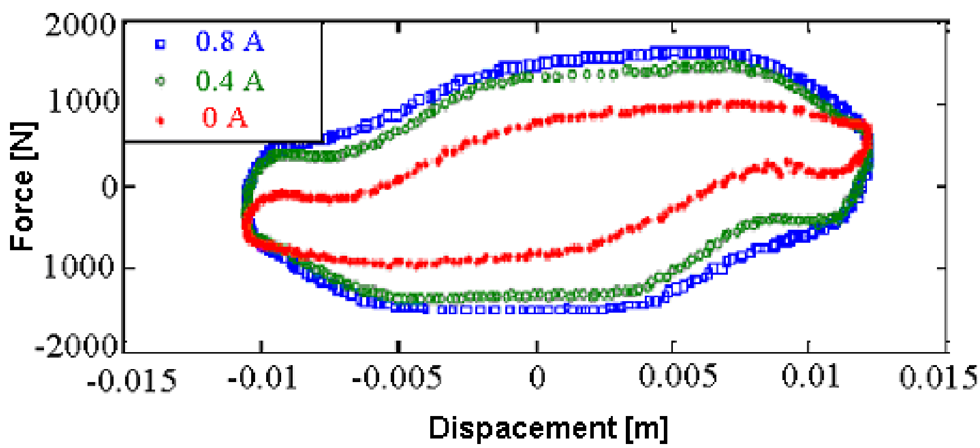

Fig.* 11. *Force-displacement experimental diagram

In figure 11 there are represented the experimental force-displacement diagrams for different values of current intensity. The red diagram corresponds to the passive work of damper (in the absence of magnetic field), and the blue and green diagrams correspond to the work of damper by exciting the magnetic coil with 0.8 A, respectively 0.4 A

6. CONCLUSIONS AND REMARKS

The main objectives of the study were as follows:

1. Design and construction of an experimental test bench for the study of dynamic behavior of a MR damper. The Charpy pendulum has a proper mass to which a supplementary 20 kg mass was added. In order to obtain different impact velocities,

the pendulum can be released from positions comprised between 0 and 180^0, the length of arm being of 1.2 m.

2. Behavior of MR fluid in the case of impulsive solicitations, with the aim of the optimal design of damper. It was studied the fluid response in the case of some impulsive solicitations, by modifying the supply current of the damper coil.
3. The MR fluid is not rapidly enough to follow the piston motion, in the case of impulsive solicitations.
4. It was realized an equipment with the possibility of real time acquisition and signal processing.

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