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The influence of the current intensity on the damping characteristics for a magneto-rheological damper of passenger car

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Abstract. Due to their simplicity and controllability, adaptive dampers became very popular in automotive engineering industry, especially in the passenger cars industry, in spite of technological obstacles inherent and the high cost of the magnetic fluid. "MagneRide" is the first technology which uses smart fluids in the shock absorbers of the vehicles adaptive suspensions. Since the discovery of the magneto-rheological effect there is a consistent progress regarding the control algorithms and hardware part itself. These magneto-rheological devices have a major potential which can be explored in various fields of applications. At present many companies make researches for the improvement of the response time and for obtaining a better response at low frequency and amplitude of the body car oscillations. The main objective of this paper is to determine the damping characteristic of a magneto-rheological shock absorber of a passenger car. The authors aim to observe how to modify the damping characteristic by changing the intensity of the electric current. The experimental researches have being carried out on a complex and modern test bench especially built for testing shock absorbers, in order to compare the damping characteristic of the classical damper with the magneto-rheological damper.

1. Introduction

A suitable suspension determines the increase of the car and its components durability, and provides comfort for the occupants. The implementation of the adaptive suspension based on the magneto-rheological dampers use, constitutes a modern and efficient solution from the substantially improvement of the comfort on board of the car and, also, of its stability.

The construction of the adaptive shock absorbers is based on the concept of a variable orifice or on smart fluid concept. The first concept is an extension of the passive dampers with electro-mechanical valves, continuously variable while the second concept varies the damping force resultant through adjusting the viscosity of a smart fluid by the action of a magnetic or electric field.

The major advantages of the magneto-rheological shock absorbers are: mechanical simplicity, continuous change of damping characteristics, high dynamic range (turn-up ratio), fast and noiseless work, robustness, and low power demands controllability [1]. Nevertheless, magneto-rheological devices remained a challenge due to the nonlinearity of the damping force and its dependence on the relative velocity and respectively of control. Because of the nonlinearities involved, the optimal control strategies are uncertain.

For optimize the magneto-rheological shock absorber it must be taken into account: the price and weight of the fluid, particles fluid sedimentation and oxidation, the safety in function and so on. To increase the safety in use, the magneto-rheological dampers must be conceived with a breakdown mode, which is able to generate sufficient forces in case of electric circuit falls [2].

The magneto-rheological shock absorber has the damping force controllable with a fast response, therefore being ideal for the control of the vibrations [3]. The magneto-rheological shock absorbers are slow devices. Therefore, they are not reliable in high frequency applications [4].

The magneto-rheological shock absorbers contain fluids which make part from the class of smart materials as electro rheological fluids, whose properties can vary in a controllable mode. The magneto-rheological fluid has the ability to change reversibly the state from viscous to semi-solid with controllable yield strength when it is subjected to an external magnetic field. The magneto-rheological shock absorbers can be used in vibration control systems, from automobiles to civil structures such as buildings or bridges [5, 6]. The primary electrical difference between these fluids is that the magneto-rheological fluid shock absorber uses a power supply voltage from 2 to 25 Volt while the electro-rheological fluid shock absorber uses a power supply voltage from 2000 to 5000 Volt [7].

The primary advantages of the magneto-rheological and electro-rheological shock absorbers are: very less control power, have simple constructions, fast response to control signal and very few moving parts. [8]. The primary difference between ferro and magneto-rheological fluids consists in the size of the polarizable particles. In ferro fluids, these particles are an order of magnitude smaller than magneto-rheological fluids thus they are 1-2 μm, in comparison to 20-50 μm for magneto-rheological fluids [8, 9].

2. Stand description

The testing stand is composed of the resistance structure, which is provided at the top with a slot for mounting the damper, and on the bottom with a slot for mounting the electrohydraulic servomechanism (figure 1). The servomechanism is composed from a hydraulic cylinder and a servo-valve. To measure the damping force of the shock absorber a force piezo-ceramic transducer was used, while for measuring the velocity of the piston an inductive transducer was used.

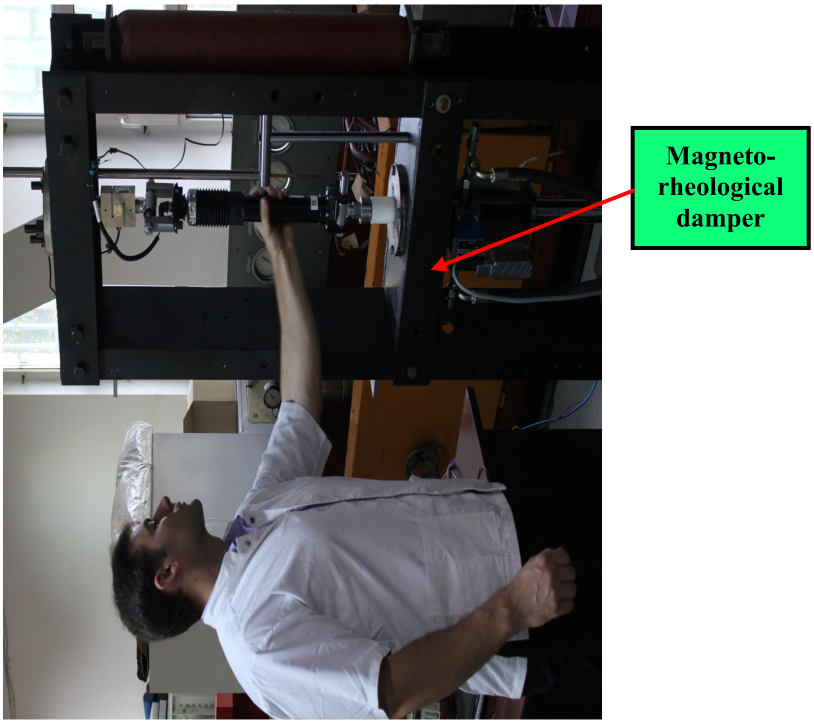

Figure 1. Partial view of the test bench for testing the magneto-rheological shock absorbers.

For commanding the servomechanism and for the acquisition of the measured dates a PXI type electronic industrial computer is used, equipped with a data acquisition board produced by

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NATIONAL INSTRUMENTS Corporation. The excitation of the damper was done with a position signal, similar to the real conditions of working. The input signal can be: sine, triangular or compound. The test bench output is the damping force developed by the damper for different values of the velocity.

For testing of the magneto-rheological damper the same stand shown in figure 1 has being used, to which it was added a control source that can change the current intensity. The tested magneto-rheological and classical dampers equipped the Chevrolet Corvette car (figure 2).

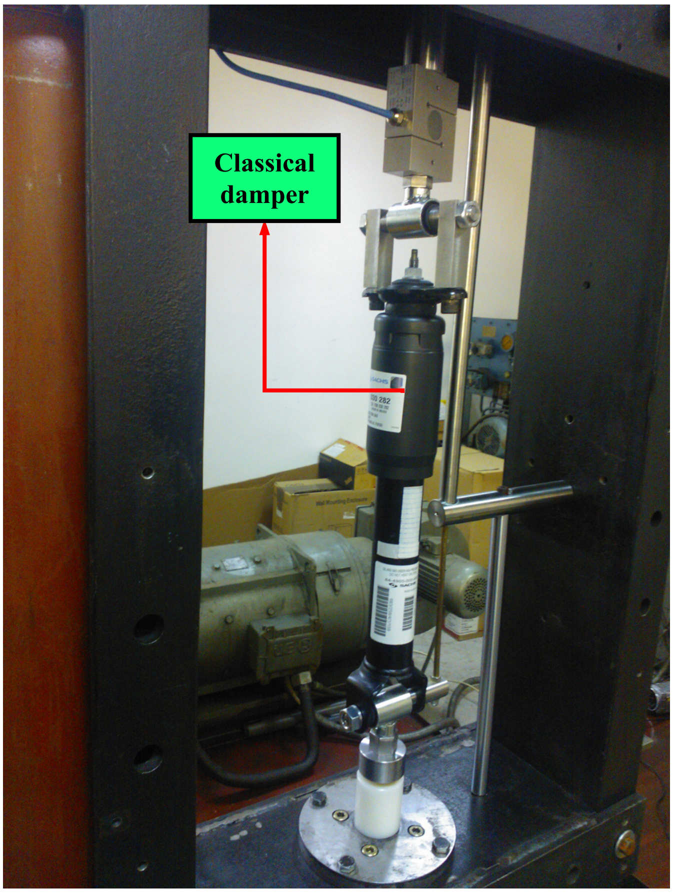

Figure 2. The classical shock absorbers tested.

3. Experimental results

The experimental researches contain preliminary tests emphasizing the dynamic behavior of the classical and magneto-rheological shock absorbers. The primary damping characteristics which define the dynamic behavior of the shock absorber are the diagrams in coordinate force-displacement F(x) and force-velocity F(v). The two damping characteristics for a classical damper are presented in figures 3 and 4. The damping characteristics were determined for different frequency values, using a sine signal input. The damping characteristics were determined directly, correlating the piston velocity with the damping force developed by the shock absorber.

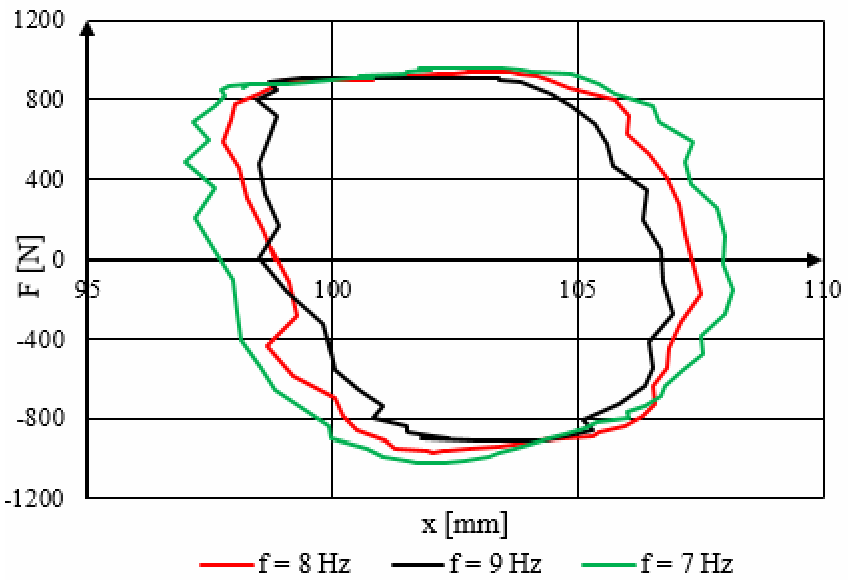

Figure 3. The damping force depending on the displacement, for a classical damper.

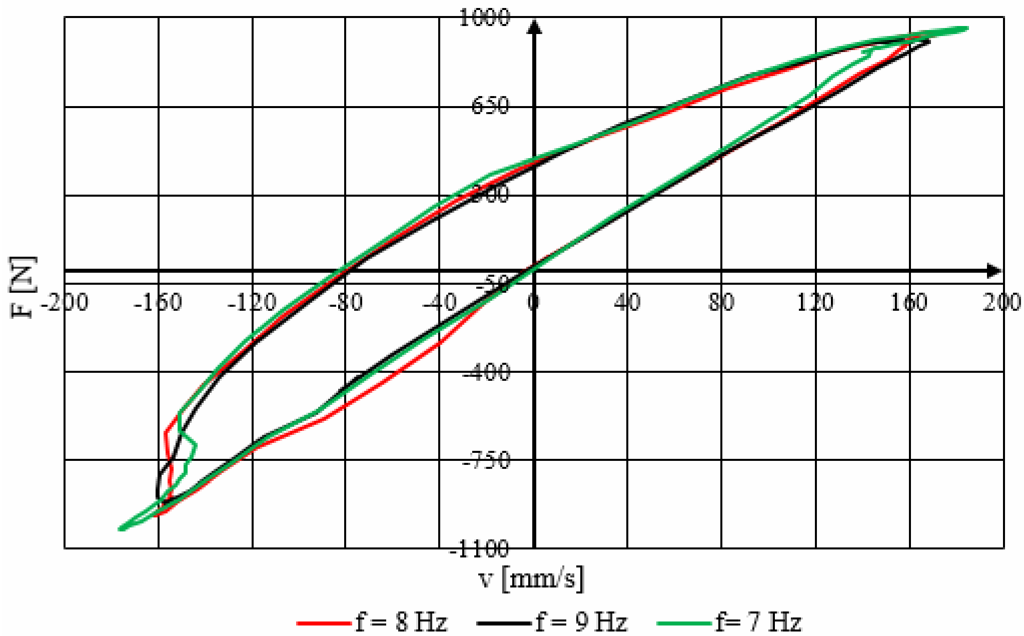

Figure 4. The damping force depending on the velocity, for a classical damper.

The damping force for a sine input signal varies in range (-1000…+1000 N) for a velocity of the piston situated in the interval (-160 mm/s…+160 mm/s).

In the following will be presented the damping characteristics of a magneto-rheological shock absorber, for a sine input signal with the frequency f = 0.5 Hz, at different intensity current values (figure 5 and 6).

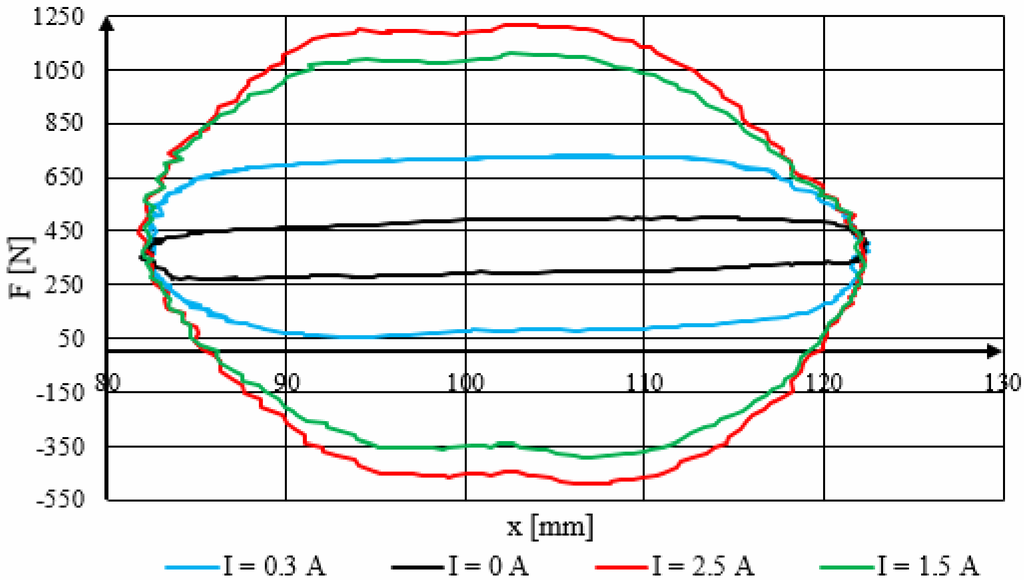

Figure 5. The damping force depending on the displacement, for a magneto rheological damper.

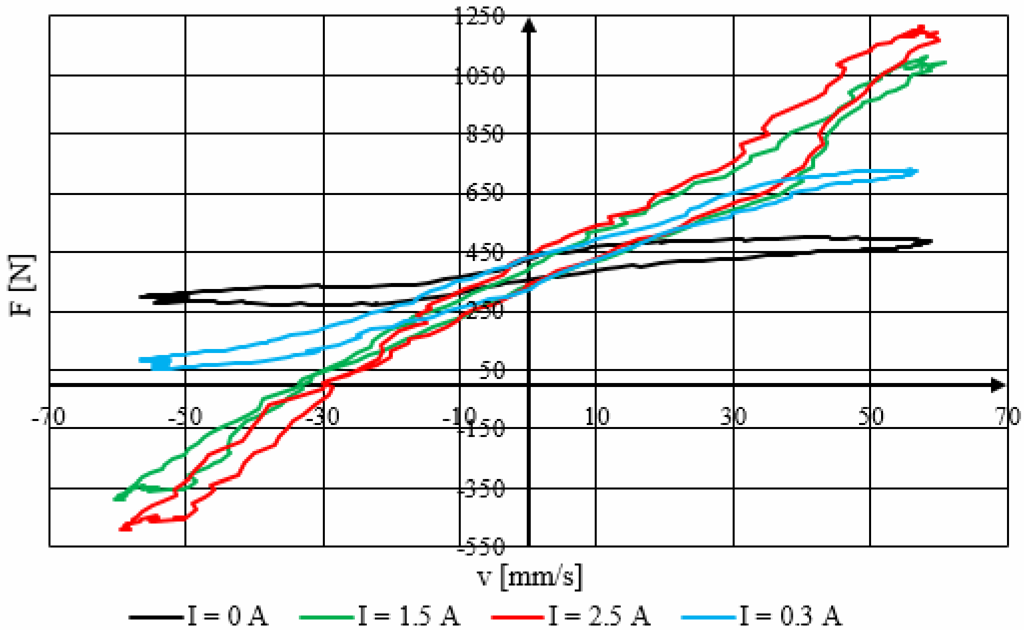

Figure 6. The damping force depending on the velocity, for a magneto rheological damper.

The damping force developed by the magneto-rheological damper increased compared to the classic, the maximum value being almost 1200 N, for a velocity of approximately 60 mm/s. At the increase of the electric current value, the damping force developed by the magneto-rheological damper increases, thereby improving the comfort of the passengers (figure 7). The growth of the intensity current changes significantly the hysteresis loop of the damping characteristic of the magneto-rheological shock absorber. Experimental researches undertaken allowed the determination of the real damping characteristics and revealed the current intensity influence on these characteristics.

In figure 8 it can be observed how varies the damping force developed by the magneto-rheological shock absorber in time, for different intensity current values. The maximum force was around 1.2 kN at a maximum velocity of 0.06 m/s.

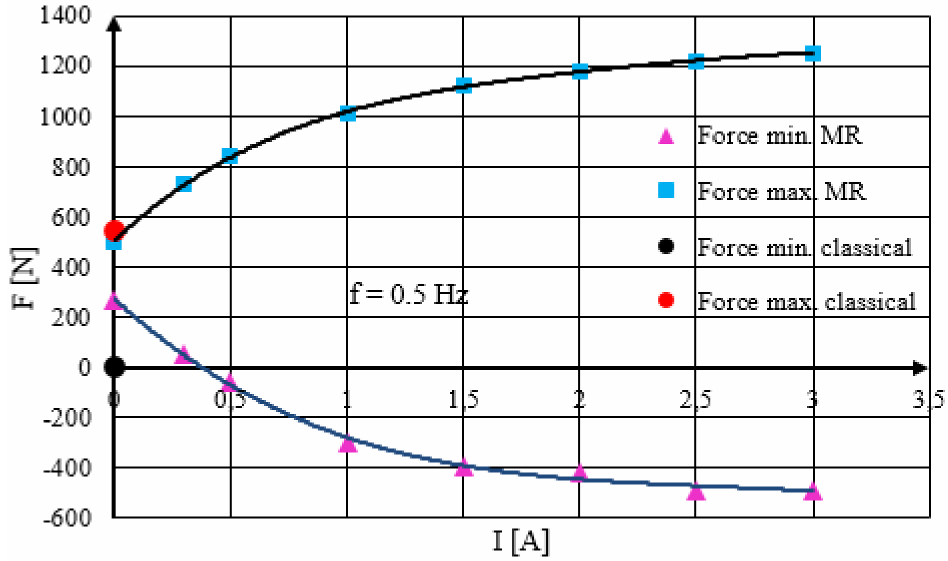

Figure 7. The maximum and minimum damping forces depending on the current intensity, for a magneto-rheological damper.

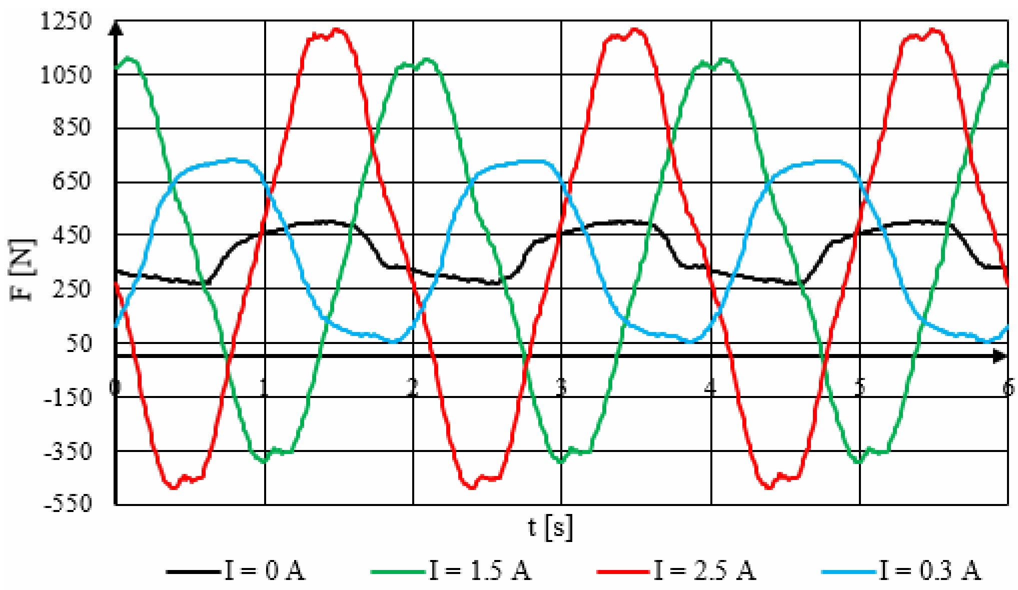

Figure 8. The damping force depending on the time, for a magneto-rheological damper.

4. Conclusions

The dynamic behavior of the magneto-rheological shock absorber was improved comparatively to a classic one, helping to increase the passengers comfort and the car's stability because of its ability to control the damping force. The damping characteristic can be modified by changing the current intensity, which changes the damping force. The increased frequency of the signal produces the growth of the hysteresis loop for a magneto-rheological shock absorber.

When using magneto-rheological shock absorbers, the suspension function can be comfortably controlled when an automobile is driven both, in urban condition at a speed of 54 km /h or on an extra-urban road at a speed of approx. 110 km /h. In these cases, the longitudinal profile of the road shows sinusoidal irregularities with a period of 30 m and, respectively 60 m. Such situations may be found relatively frequently in practice.

5. References

[1] Gołdasz J and Sapiński B 2015 *Insight into Magnetorheological Shock Absorbers* (Publishing House Springer, Swiss)
[2] Dobre Al 2015 The mathematical modeling, numerical simulation and experimental identification of the automotive suspensions (The Faculty of Engineering and Management of Technological Systems, Department Materials Strength, "Politehnica" University of Bucharest)
[3] Yao K, Zhao X and Hou Z 2009 Damping characteristics modeling and simulation of MR damper *Information Management, Innovation Management and Industrial Engineering International Conference* **2** pp 492–495
[4] Naserimojarad M M, Tadayoninejad A and Eghtesad M 2011 An innovative design of fast current controller circuit for MR dampers *Control, Instrumentation and Automation (ICCIA) – 2nd International Conference* pp 1086 – 1090
[5] Sapiński B 2006 Magnetorheological dampers in vibration control *AGH University of Science and Technology Press*, Cracow, Poland
[6] Kasprzyk J, Wyrwał J and Krauze P 2014 An innovative design of fast current controller circuit for MR dampers *Advanced Intelligent Mechatronics (AIM)* pp 500–505
[7] Mahmoud El-Kafafy, Samir M. El-Demerdash, Al-Adl Mohamed Rabeih 2012 Automotive ride comfort control using MR fluid damper, *Engineering* **4**(**4**) pp 179-187
[8] A Ashfak, K K Abdul Rasheed and J Abdul Jaleel 2013 Modeling, simulation and experimental validation of magneto-rheological damper *Advanced Nanomaterials and Emerging Engineering Technologies (ICANMEET)* pp 267–274
[9] Seung-Bok Choi, Young-Min Han 2015 *Magnetorheological Fluid Technology-Applications in Vehicle Systems* (Publishing House CRC Press)

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