Experimental Identification of the Automotive Magnetorheological Shock Absorbers

Nicolae Vasiliu, Anton Hadăr, Alexandru Dobre, Constantin Călinoiu and Cristian Andreescu

Abstract The effectiveness of the shock absorbers in terms of comfort and automotive manoeuvrability is closely linked to the free and forced vibrations generated by the road irregularities and the driver's orders (acceleration, braking etc.). The passengers mass, the sprung mass parties (car body), the free parties mass (wheels and a part of the suspension), the stiffness and the damping coefficient of the various elements of the car are involved in this process. In the road vehicles' suspensions field, the dampers control through the valves is an extremely difficult target due to the unpredictable flow's variation and the pressure difference generated inside them. This was the main reason for developing and using magneto rheological fluids as dampers fluids. The authors have designed and built a complex test bench in order to compare the behaviour of a classical dampers and a magneto rheological one. A high speed National Instruments data acquisition system was used to obtain information about the correlation between the damping force, stroke, and speed, control current, temperature etc. The results were compared with the similar ones supplied by some top level manufacturers.

Keywords Magneto rheological shock absorbers (MR) · Experimental identification · Numerical simulations · AMESIM

Introduction

The damper is an important component of any suspension system, because it determines the damping level of the vibrations of the car body generated by the irregularities of the road. A magneto rheological (MR) damper has the ability to change the viscosity of the fluid, when it is subjected to the action of a magnetic

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field. The development of this relatively new technology wasn't easy. The first commercial use of the magneto rheological fluid in a semi-active suspension system was implemented on passenger cars at the beginning of the 2000s: MagneRide™ developed by Delphi Automotive Systems and Corp/BWI Group. The first passenger car, equipped with such a shock absorber was Cadillac Seville STS in 2002, followed by Audi A8 in 2006.

There are a lot of papers concerning the MR dampers. Different kinds of models have been developed: quasi-static and dynamic, parametric and non-parametric, phenomenological and heuristic ones, based on a set of well suited functions (Kasprzyk et al. 2014). An extensive overview on different types of models of the MR damper as well as some identification and validation methods can be found in Wang and Liao (2011). In a simple MR damper, the variation of the electric current in a coil placed in the piston changes the physical properties of the fluid. MR dampers are widely used in vibration control systems: from automobiles to civil structures such as buildings or bridges (Sapinski 2006).

Test Bench Description

The test bench is composed of a high stiffness frame, which at the top level is provided with a flexible bushes for connecting the force transducer with the damper, and on the bottom with another flexible bushes for coupling with the hydraulic servo cylinder (Fig. 1).

Fig. 1 The frame of the test bench for shock absorbers

The driving system was designed by the authors and manufactured by AEROTEH SA from ROMANIA. It can use any type of high speed servo valves (aerospace, industrial, proportional type etc.). A high speed piezo ceramic force transducer (MTS) is used to measure the damping force developed by the shock absorber. The velocity of the stroke piston is measured by an inductive contactless transducer (SCHEWITZ). The test bench control is performed by NI LabVIEW software set up on a NI PXI high speed controller. The driving system can supply 21kN for a maximum speed of 1 m/s, working at 21 MPa.

Preliminary Experimental Results

The first step in defining the behaviour of a *classical* damper is the use of a sine input signal with a small frequency, for example f = 0.5 Hz (Fig. 2). Some of the experimental results are presented in the Figs. 2, 3 and 4. The damping force follows and velocity with some distortion generated. The maximum force reaches around 550 N for a velocity of 60 mm/s.

The main features which define the behavior of a hydraulic shock absorber are F (x) and F(v), shown in Figs. 3 and 4 for different frequencies.

A high frequency signal leads to the increasing of the hysteresis loop of the damping characteristic of the shock absorber.

For the behaviour of the magneto rheological damper study was used a sine signal having the frequency f = 0.5 Hz. A part from the experimental results are presented in the Figs. 5, 6 and 7. In Fig. 5 it can be observed how varies the damping force in time for different values of the electric current.

The main features which define the behaviour of a MR shock absorber are presented in Figs. 8 and 9, for a sine input signal of 0.5 Hz. Naturally, this kind of damper generates an increased force compared to the classical one considered as reference.

Most of modern researches concerning the complex behaviour of the MR dampers (Savaresi et al. 2010; Gołdasz et al. 2015; Choi et al. 2015; Laura et al. 2000) show similar results. The maximum damping force depends in a parabolic manner on the electric current. The control damping force is always increasing with

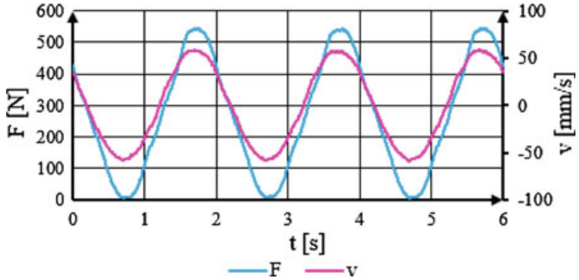

Fig. 2 The damping force and velocity depending on the time, for a classical damper

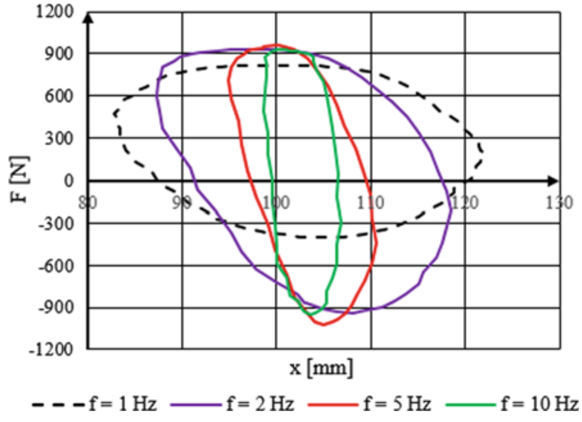

Fig. 3 The damping force and displacement depending on the time, for a classical damper

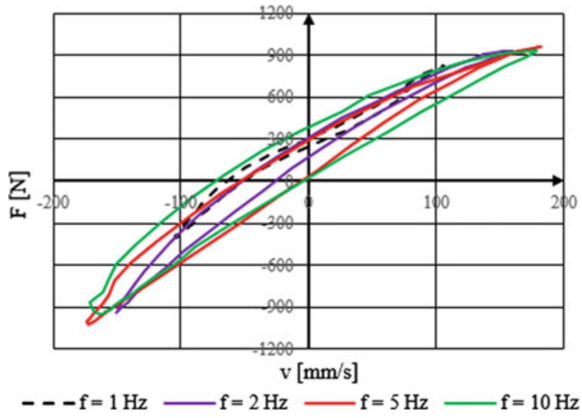

Fig. 4 The damping force depending on the velocity, for a classical damper

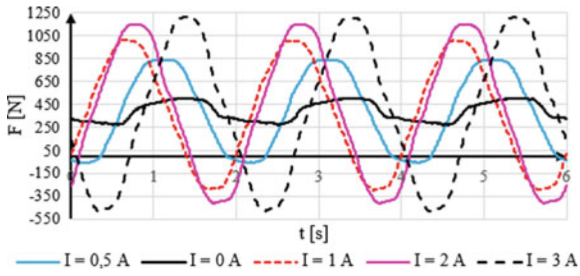

Fig. 5 The damping force depending on the time, for a MR damper for different values of the electric current

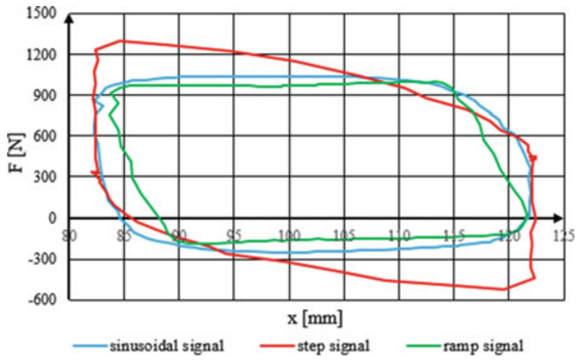

Fig. 6 The variation of damping force according to the displacement for different types of signals, f = 1 Hz, I = 0.5 A

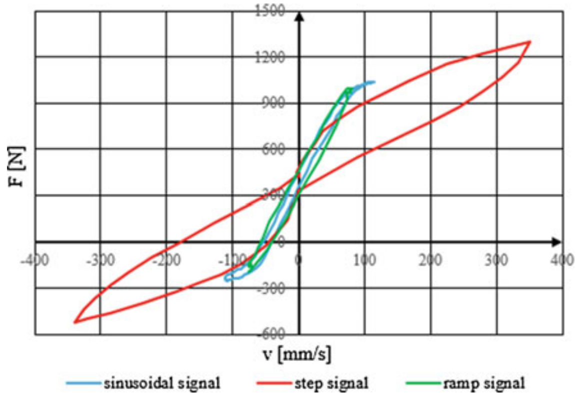

Fig. 7 The variation of damping force versus velocity for different types of signals (f = 1 Hz, and I = 0.5 A)

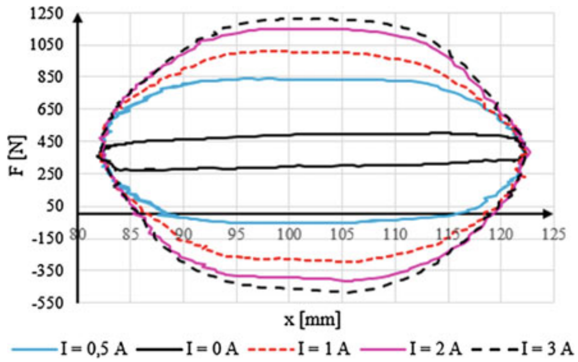

Fig. 8 The damping force versus the displacement generated by a MR damper supplied by different currents

the current value, but the fluid magnetic saturation limits the force. For a coil impedance of about 1 Ω, the saturation occurs when the current reaches about 3 A (Fig. 10).

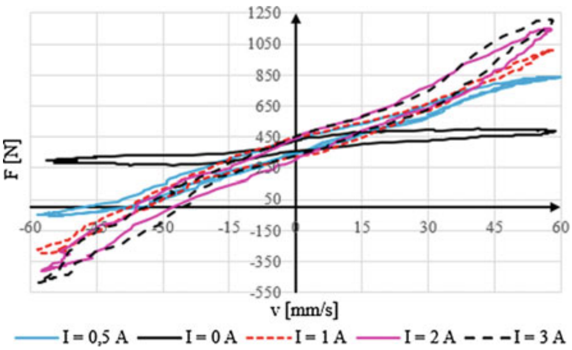

Fig. 9 The damping force versus velocity, for a MR damper supplied by different current

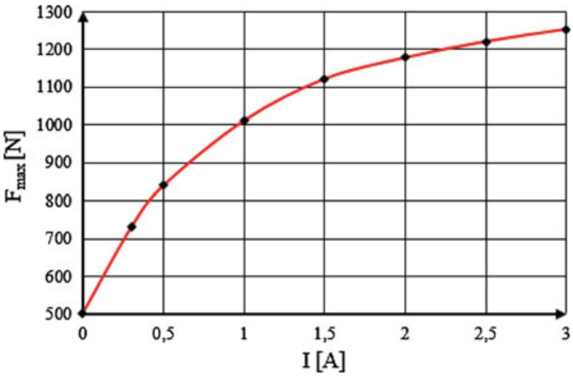

Fig. 10 The maximum damping force depending on the electric current

Conclusions

The behaviour of the MR dampers can improve the passengers comfort and the holding road in a significant measure. The damping force can be increased using a MR damper in the same mechanical conditions as the classical one. Usually, the control of a MR damper is done by changing the average electric current value by the aid of a PWM controller. This control manner avoids the shocks introduced by the sudden changes of the current. The average value of the current during a sine or ramp control signal seems to be the best control strategy.

A lot of problems have to be solved in the implementation of the MR technology in a series of cars. A strong improvement of the passengers comfort needs a very sophisticated fuzzy controller.

Increasing the intensity of the electric current applied to the magneto rheological shock absorber leads to the damping force increasing, improving the comfort. For example, for a sinusoidal input signal with a frequency of 0.5 Hz and a current of 3 A, the damping force increased by 2.4 times compared with the case "unpowered".

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References

Choi SB, Han YM (2015) Magnetorheological fluid technology-applications in vehicle systems. CRC Press, Boca Raton, ISBN:978-1-4398-5673-4

Gołdasz J, Sapiński B (2015) Insight into Magnetorheological Shock Absorbers. Springer, Berlin, ISBN:978-3-319-13232-7

Jansen LM, Dyke SJ (2000) Semi-active control strategies for mr dampers: a comparative study. ASCE J Eng Mech 126(8):795–803

Kasprzyk J, Wyrwał J, Krauze P (2014) Automotive MR damper modelling for semi-active vibration control. In: 2014 IEEE/ASME international conference on advanced intelligent mechatronics (AIM), Besançon, France, July 8–11, 2014

Sapinski B (2006) Magnetorheological dampers in vibration control. AGH University of Science and Technology Press, Cracow, Poland

Savaresi SM, Poussot-Vassal C, Spelta C, Sename O, Dugard L (2010) Suspension control design for vehicles. Elsevier, Amsterdam, ISBN:978-0-08-096678-6

Wang DH, Liao WH (2011) Magneto rheological fluid dampers: a review of parametric modelling. Smart Mater Struct 20(2):023001