

# Contributions to modeling functionality of a high frequency damper system

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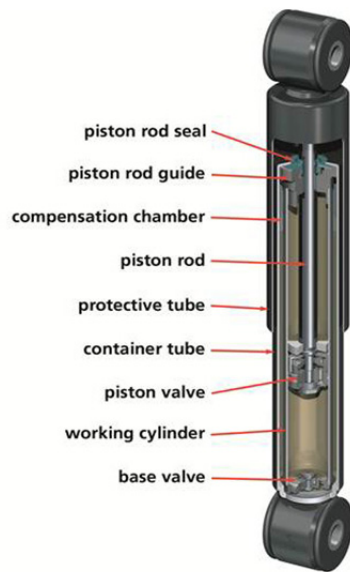
**Abstract.** Due to the necessity of improving the handling performances of a motor vehicle, it is imperative to understand the suspensions properties that affects ride and directional respons. The construction of a fero-magnetic shock absorber is based on two bellows interconnected by a pipe-line. Through this pipe-line the fero-magnetic fluid is carried between the two bellows. The damping characteristic of the shock absorber is affected by the viscosity of the fero-magnetic fluid. The viscosity of the fluid, is controlled through a electric coil mounted on the bellows connecting pipe-line. Modifying the electrical field of the coil, the viscosity of the fluid will change, finally affecting the damping characteristic of the shock absorber. A recent system called „CCD Pothole Suspension” is implemented on Ford vehicles. By modifying the dampning characteristic of the shock absorbers, vehicle daynamics can be improved; also the risk of damaging the suspension will be decreased. The approach of this paper is to analyze the behaviour of the fero magnetic damper, thus determining how it will affect the performances of the vehicle suspensions. The experimental research will provide a better understanding of the behavior of the fero-magnetic shock absorber, and the possible advantages of using this system.

## 1.Introduction

In its essence, the shock absorber is very similar to an oil pump. A piston is attached to the end of a rod, which presses against a hydraulic fluid in a pressure sealed tube. While the suspension has an alternative up and down movement, the hydraulic fluid forcibly enters through small orifices in the piston. These orifices allow only a small quantity of fluid to pass, therefore creating a braking effect on the piston, resulting in damping of the spring and suspension oscillations.

The shock absorber used in the suspension of vehicles has the purpose of rapid dissipation of the energy created by the vertical oscillations of the car's body and wheels, transforming it into caloric energy which is transferred to the surrounding environment [1]. They are mounted in parallel with the main elastic elements of the suspension, and represents the base element in ensuring the comfort and road safeness [2]. The degree of resistance produced by the shock absorber, depends on the speed of the suspension system, the number and size of the orifices in the piston, together with the quality and thickness of the disc valve. Suspension springing and damping operate especially on the vertical oscillations of the vehicle. As a result, the shock absorber and the spring reduce the amplitud and frequency of the vehicles oscillations, such as: swinging, front leaning on braking or back leaning on acceleration. As the universal principle of physics states that " the energy cannot be created or destroyed, but only can be transformed ", the shock absorber converts the kinetic energy, stored by the spring in its oscillating state, in heat.





**Figure 1.** Construction of a classic damper

The magnetoreologic shock absorbers are created the same as the hydraulic ones, the only difference is the fluid used in the cylinder, in this case being a ferromagnetic fluid. The ferromagnetic fluids are magnetic particles suspended in a base fluid. Each particle inside the ferromagnetic fluid is a permanent magnet that has the tendency to align with the direction of the magnetic field. With a new design and a new construction of the magnetic shock absorber, the aim is to eliminate the use of valves, seals and to reduce the wear.

The design of the shock absorber implies that a number of factors need to be taken into consideration; these factors will affect the shock absorber capabilities, statement that is highlighted by the next relationship (1):

$$F = \frac{3\pi D^3 l \left(1 + \frac{2d}{D}\right)}{4D^3} \mu V \quad (1)$$

F- damping force [N]

D- piston diameter [mm]

l - piston height [mm]

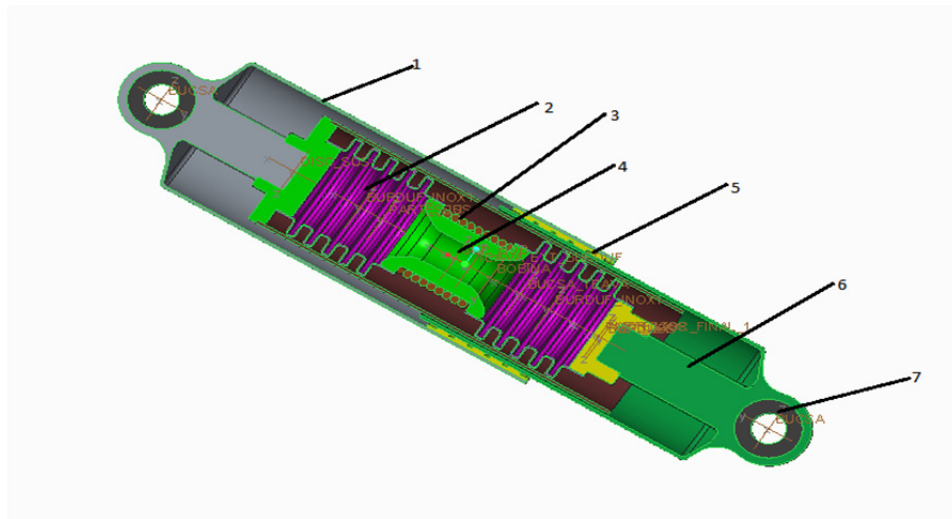
d - the diameter of the hole in the piston(lamination holes) [mm]

$\mu$  - fluid viscosity [N/m.s]

## 2. Magneto- rheological damper design

An important step to control the dynamic behavior of a vehicle is to control the suspension, which means to control the dampers behavior.

A method to control the response of the dampers is represented by the use of ferromagnetic fluid in the damper [3][4]. In figure 2 it is presented the shock absorber design; the construction is based on two bellows filled with ferromagnetic fluid; the fluid passes from one bellow to the other one when the shock absorber is compressed.



**Figure 2.** Magnetorheological damper design elements

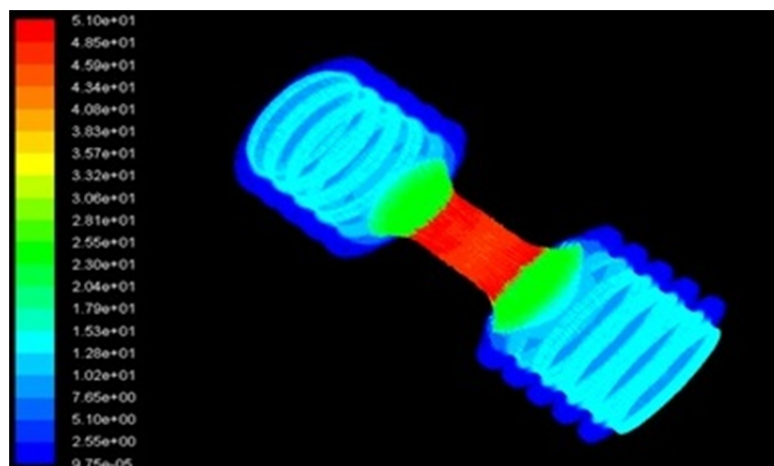
1.Housing, 2.Bellows, 3.Coil, 4.Dynamic viscous-throttle, 5.Bush guide , 6.Elastic support and magneto-rheological volume regulator, 7.Clamping sleeve

### 3. Design analysis of the Magnetorheological damper

The analysis performed on the 3D-model presents: the behavior of the ferromagnetic fluid flow through the viscous-throttle, bellows critical stress areas and the displacement of the bellows during the oscillations of the shock absorber. Following the simulations, the results were satisfactory. Based on the results, the model will be improved in the future, thus obtaining a better dynamic response.

#### 3.1. Magnetorheological Fluid flow

Figure 3 presents the variation of the magneto - rheological fluid velocity through the dynamic viscous-throttle. In red the high velocities, green the velocities to entrance and exit, from and to the bellow. The simulation corresponds to the system dynamics.

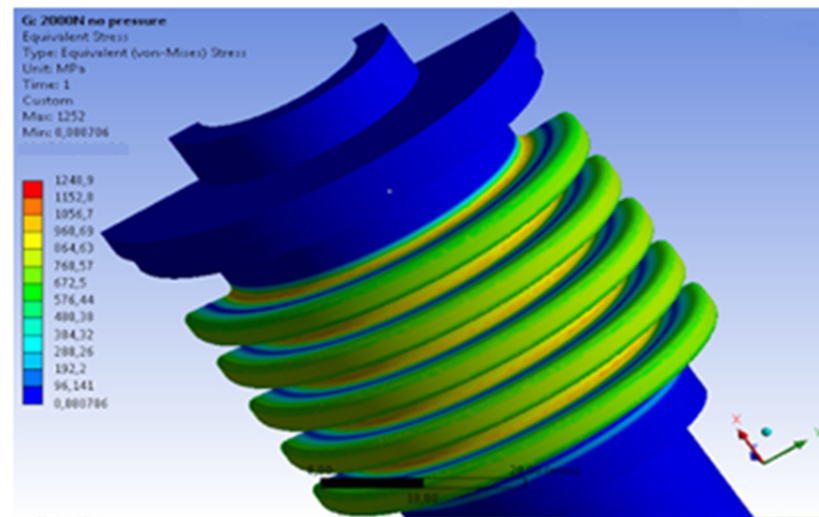


**Figure 3.** Velocity of the viscoelastic fluid flow through the damper

#### 3.2. Stress simulation

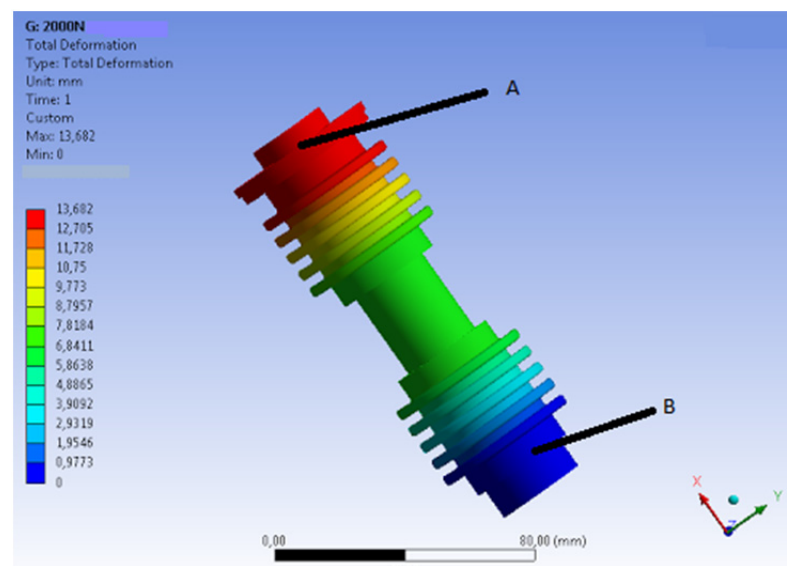
The next step represents the behaviour of the bellow when a force of 2000 [N] is applied on the top surface of the damper (Figure 3 and Figure 4). By loading the shock absorber with a force of 2000 [N] the simulation revealed the possible areas of the bellows that are subjected to a greater stress. Such

areas will need to be carefully design to maintain the stress values as low as possible, according to the material stress-strain curve.



**Figure 4.** Bellows Stress simulation

### 3.3. Bellows displacement after applying a force.

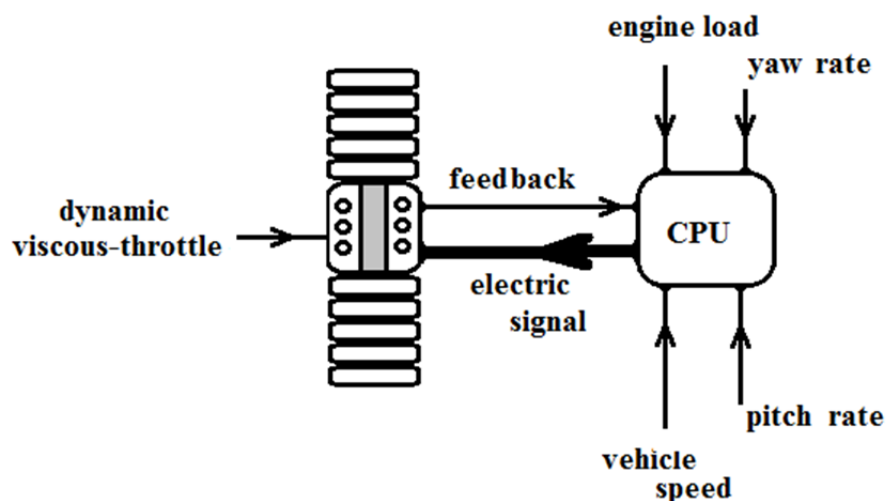


**Figure 5.** Displacement of the bellows

Figure 5, represents the deformation amplitude of the bellows; The force has a value of 2000[N ] and it is applied on the bellow „B”. The displacement of bellow „B”(compression) is transmitted through the fluid to the bellow „A”, which tends to become longer than in neutral state.

## 4. System-control Block diagram of bellow dumper

The dynamic “viscous – throttle” behavior is controlled as follow:



**Figure 6.** The system-control Block diagram of a magneto-rheological damper

The CPU collects signals from the dynamic behavior sensors of the vehicle, as pitch rate, jaw rate and vehicle speed combined with the engine load (Figure 6). The CPU generates an electrical signal which is transferred to the dynamic viscous-throttle that controls the flow of the magneto-rheological fluid, by means of an electro-magnetic field; this electro-magnetic field determines the viscosity of the fluid passing from a bellows to the other, depending of the working orientation of the damper. In this way, the response of the damper can be modulated (soft or hard) depending on the road condition, vehicle weight, or speed.

## 5. Conclusion

The dynamic behavior and performances of this type of ferromagnetic damper are better, compared to a classic damper [5]. This new type of damper increases vehicle stability, controls the inclination angle when cornering, improving the general dynamics of the vehicle and increasing the passengers comfort. The viscosity characteristic of the magneto-rheological damper changes depending on the characteristics of the electric supply applied to the command coil of the damper. The electrical current characteristics is done by the CPU and depends on the dynamic behaviour of the vehicle. Ferromagnetic shock absorber provides a better and improved ride behaviour of the car, both at low speeds and at higher speeds. The ferromagnetic damper has a simple construction, removing the out-valves, the seals and reducing the wear.

## 6. References

- [1] Bastow D 1990 *Car Suspension and Handling, Second Edition* (Pentech Press, London)
- [2] Shorp R S and Crolla D A 1987 Road Vehicle Suspension System Design- A Review *Vehicle Systems Dynamics* vol. 16 no.3
- [3] Kasprzyk J, Wyrwał J and Krauze P 2014 An innovative design of fast current controller circuit for MR dampers *Advanced Intelligent Mechatronics (AIM) International Conference* pp 500 – 505 DOI: 10.1109/AIM.2014.6878127
- [4] Sapiński B 2006 *Magnetorheological dampers in vibration control* (AGH University of Science and Technology Press Cracow, Poland)
- [5] Seung-Bok Choi and Young-Min Han 2015 *Magnetorheological Fluid Technology-Applications in Vehicle Systems* (Publishing House CRC Press)

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