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Investigation of Magnetorheological Shock Absorber Used in Semi-Active Suspension

Ramazan Ferik
Maysan Mando A.Ş.

Murat Yazici
Bursa Uludag University

Orhan Kurtulus
Maysan Mando A.Ş.

Abstract: The automotive industry is rapidly moving towards autonomous vehicles. In this case, the answers of the vehicles can be change in different scenarios. At this point, the suspension system must be semi-active or fully active. Magnetorheological shock absorbers can be used in semi-active suspension systems. In this study, studies were carried out on the examination and testing of magnetorheological shock absorbers. These systems can change the stiffness of the shock absorber with the effect of magnetic field depending on the data coming from the road and the condition of the vehicle. It does this by changing the viscosity with the nano powders affected by the magnetic field. Ferromagnetic nanoparticle additives are used in the shock absorber. However, one of the biggest risks in these shock absorbers is the precipitation of nano powders in the oil. If this happens, it starts to fail to fulfill its shock absorber feature. To prevent this, oil density and nano powder density should be close. In this study, low density polystyrene coated with magnetic material and these particles was added to the oil in the shock absorber. As a result, particles with a density of 0.877 gr/cm3 were obtained and oil with a density of 0.971 gr/cm3. As a result of the observation, no significant precipitation was observed in the liquid formed. A prototype MR damper was produced using this mixture. In the next step, the effects of the electromagnetic field on the shock absorber were investigated and the shock absorber is controlled by electromagnetic field. As a result, the piston velocities of the damper in response to the force were measured under 3 different forces, without magnetic particles and at different current values after the magnetic particle was added. Damper hardening with current was observed.

Keywords: Shock absorber, MR damper, Semi-active suspension system, Nanocomposite

Introduction

The suspension system is located between the vehicle body and the wheel carrying the vehicle, and usually includes shock absorbers, springs, arms, bushing connections, etc. These are systems that provide comfort, safety and performance for the vehicle. As the automotive industry develops, suspension systems also constantly evolve. The main reason for better optimizing these systems in the development of the suspension system is to ensure safe driving by keeping the communication between the vehicle and the driver at a high level. The automotive suspension on a vehicle typically has the following basic tasks (Rajamani, 2012; Isermann, 2005):

1) To isolate a car body from road disturbances in order to provide good ride quality.

Ride quality in general can be quantified by the vertical acceleration of the passenger locations. The presence of a well-designed suspension provides isolation by reducing the vibratory forces transmitted from the axle to the vehicle body. This in turn reduces vehicle body acceleration.

2) To keep good road holding

The road holding performance of a vehicle can be characterized in terms of its cornering, braking and traction abilities. Improved cornering, braking and traction are obtained if the variations in normal tire loads are minimized. This is because the lateral and longitudinal forces generated by a tire depend directly on the normal tire load. The road holding performance of a suspension can therefore be quantified in terms of the tire deflection performance.

3) To provide good handling

The roll and pitch accelerations of a vehicle during cornering, Braking and traction are measures of good handling. Half-car and full-car models can be used to study the pitch and roll performance of a vehicle. A good suspension system should ensure that roll and pitch motion are minimized.

4) To support the vehicle static weight

This task is performed well if the rattle space requirements in the vehicle are kept small. The short working range of the suspension can play an important role in ensuring the weight balance of the vehicle.

As the automotive industry progresses, customer demands have also increased proportionally. Among these requests, there are issues that will take the safety and comfort of the vehicle to the next level. In addition to these requests, raising and lowering options that will improve visuals or hardness settings that will increase performance have also been added. Although all these adjustment parameters reveal weaknesses in strength, this weakness can be overcome with the development of technology and production methods.

Vehicles are exposed to impact and vibration due to the vertical movement of the wheel due to irregularities on the road. The first suspension system elements that absorb these vibrations are the springs, and preventing the vibrations from being transmitted to the chassis is possible by compressing the springs. After this compression, the aim is for the springs to relax slowly and slightly so that they do not continue the movement. Shock absorbers perform this task in the suspension system (Dixon, 2007).

Considering these and other functions of shock absorbers, their structural integrity must be preserved under operating conditions in order to continue their function. For this reason, the physical behavior of the lower parts of the shock absorber under different conditions should be examined and necessary precautions should be taken during the design phase. (Güney & Tüfekçi, 2016).

Suspension systems used in automobiles continue to become more complex as autonomous vehicle technology advances. The main reason for this situation is that different responses are expected from the vehicle under different conditions. In this case, the suspension must be activated. This need can be met with fully active or semi-active suspension. Fully active suspensions can change the operating parameters of the suspension system automatically or at the user's discretion. However, semi-active suspensions affect the operation of the suspension by changing the operating parameters of a component on the system, not all the parameters of the system. In this case, fully active suspensions have more variability, but are more expensive and can fail more often due to the more complex parts. Semi-active suspensions are relatively less complex, more reliable and less costly. Examples of fully active suspension systems include air suspension and electromechanical suspension. Examples of semi-active suspensions are active valve technology and magnetorheological shock absorbers.

Objective

Magnetorheological shock absorbers are becoming common in semi-active suspension systems in automobiles. In mr shock absorbers, magnetic particles added to the oil can change the viscosity of the oil with the effect of a magnetic field. Electromagnets are used to create a magnetic field. Accordingly, a magnetic field of a magnitude directly proportional to the magnitude of the electric current in the system will be generated. In this case, the magnetic particles will start to fulfill their task. Also, one of the biggest advantages of mr shock absorbers is that even if it loses its active feature, it can continue to work like a passive shock absorber. This increases the structural reliability of the shock absorber.

Method

This study was conducted in collaboration between Maysan Mando Turkey R&D Center and Uludağ University Automotive Engineering. In this study, the structure, working principle and usage areas of the MR shock absorber were examined in order to complete the deficiencies of passive shock absorbers. After this, an experimental investigation of the mr shock absorber was carried out with the prototype shock absorber produced. Experimental conditions are shown in Table 1.

Table 1. Force and magnetic field combination table

	MAGNETIC FIELD EFFECT			
FORCE VALUES	0.72 N. Force without Magnetic Field	0.72 N. Force with 0.2 Ampere Current	0.72 N. Force with 0.3 Ampere Current	0.72 N. Force with 0.4 Ampere Current
	4 N. Force without Magnetic Field	4 N. Force with 0.2 Ampere Current	4 N. Force with 0.3 Ampere Current	4 N. Force with 0.4 Ampere Current
	7.1 N. Force without Magnetic Field	7.1 N. Force with 0.2 Ampere Current	7.1 N. Force with 0.3 Ampere Current	7.1 N. Force with 0.4 Ampere Current

An electromagnet was used in the experiment. It is aimed to observe the change in the magnetic field according to the current given on the electromagnet. Some of the prototype shock absorber parts were produced with a 3D printer. This gave the work an advantage in rapid prototyping. Polystyrene foam with low density was used to prepare magnetic particles. In this way, the density of the composition using metal powder could be controlled.

Material

Silicone oil was used as the carrier phase and polystyrene foam and iron powder were used for magnetic particles.

Carrier Phase (Oil)

Silicone oil was used as the carrier phase. It is colorless and odorless. Usually easy to find on the market. They have different properties according to their varying viscosity values and chemical structures. It can protect its physical properties between -700 ˚C and 2500 ˚C. For these reasons, silicone oil would be ideal for the experiment. The specific properties of silicone oil are shown in Table 2.

Table 2. Specific properties of silicone oil

Silicone Oil	DM1000
Viscosity (cst)	1000
Flash Point (˚c)	> 300
Freeze Point (˚c)	-50
Density at 25 ˚C(gr/$\boldsymbol{cm^3}$)	0,971
Surface Tension (mN/m)	21,2
Refractive Index (25 ˚C)	1,403

Magnetic Particles

Polystyrene grain with relatively low density was used in the experimental shock absorber. Contrary to common usage, polystyrene was coated with metal powder in this study. In this way, the density of the mixture could be controlled. This is important to prevent the particles from settling or floating in the oil.

Table 3. Specific properties of polystyrene

Specific properties of polystyrene	Value
Density (gr/$\boldsymbol{cm^3}$)	0,02814
Thermal Conductivity (W/m.K)	0,037-0,039
Water Absorption (%; 24 hours)	0,03-0,1
Particle Diameter (mm)	1,5-2
Bending Strength (kPa)	75-125
Compression Stress at 10% Deformation (kPa)	1,403

Polystyrene

It is a synthetic and aromatic polymer obtained using styrene monomer, a liquid petrochemical. It can be hard or foamy. It is a polymer with low unit cost. While transparent in its natural state, color can be added using colorants. Specific properties of polystyrene are shown in Table 3.

Carbonyl Iron

Its grain structure is very small. This will make it easier to coat the polystyrene. It is mixed with the adhesive to form a resin, which is then applied to the polystyrene and magnetizes the polystyrene. polystyrene material will be more in volume, the density will remain low. Specific properties of carbonyl iron are shown in Table 4.

Table 4. Specific properties of polystyrene

Specific properties of polystyrene	Value
Density (gr/$\boldsymbol{cm^3}$)	7,86
Particle Diameter (µm)	5
Iron percentage (m/m, %)	> 97

Magnetic Particle Production

When polystyrene material interacts with some liquids, it dissolves on its surface and becomes sticky. Acetone (C3H6O) is one of these liquids. The surface of the polystyrene material in contact with a small amount of acetone erodes and becomes sticky. This allows iron dust to adhere to the surface of the polystyrene. In this way, the magnetic particles are ready. Figure 1 shows these coating stages.

Figure 1. Stages of coating polystyrene with iron powder

Magnetic Particle Addition

In order to observe whether these magnetic particles would decompose in silicon, the particles were kept in silicon liquid for 3 days. In this mixture, 70% oil and 30% magnetic particles were used by volume. No significant segregation of the particles or precipitation in the liquid was observed at the end of the expected time. The magnetic particles obtained were examined under a microscope. Diameter values are between 1.7 and 2.7 mm.

Electromagnet

Electromagnets are made by coiling insulated thin wires around matter. When current is applied to this coiled cable, a magnetic field is created. The gravitational force of the electromagnet will increase or decrease in direct proportion to this current. The operating voltage of the electromagnet gives us information about the ranges in which we can work. In this study, a 20 mm. high, 25 mm. diameter electromagnet was used. This magnet works with DC current. Specific properties of electromagnet are shown in Table 5.

Table 5. Specific properties of electromagnet

Specific Properties of Electromagnet	Value
Work Voltage (V)	12
Work Area (A)	0,3
Power (W)	4
Retention Force (N)	50
Magnet Diameter (mm)	10

Prototype Mr Shock Absorber

Some parts of the prototype shock absorber were produced using a 3D printer. This technology was utilized in the rapid prototyping part. The requested design was also achieved in this way. Figure 2 shows the visuals of these parts.

Figure 2. Shock absorber parts produced with 3D printer

The produced parts were then assembled and the experimental setup was prepared. The fluid used in the prototype shock absorber contains 65% silicone oil and 35% magnetic particles by volume. Figure 3 shows the experimental setup prepared. The quantity of magnetic particles used is about 16 ml. In return, around 30 ml. of silicone oil was used.

During the test, a force of 0.72 N, 4 N and 7.1 N was applied to the shock absorber. The speed of the piston in response to these forces will give information about the stiffness of the shock absorber. The lower velocity at high force can be considered as an increase in hardness.

Figure 3. Test setup

Results and Discussion

In the experiments for comparison, the velocity, was first measured without the addition of magnetic particles for reference. Afterwards, particles were added and experiments were carried out under a current of 0.2 A, 0.3 A and 0.4 A. The achieved test results are shown in Table 6.

Table 6. Test results

	No magnetic field No particles	0.2 Amper	0.3 Amper	0.4 Amper
0.72 N.	0.179 cm/sn	0.047 cm/sn	0.054 cm/sn	0.062 cm/sn
4 N.	1.101 cm/sn	0.406 cm/sn	0.531 cm/sn	0.772 cm/sn
7.1 N.	2.083 cm/sn	0.550 cm/sn	0.954 cm/sn	0.973 cm/sn

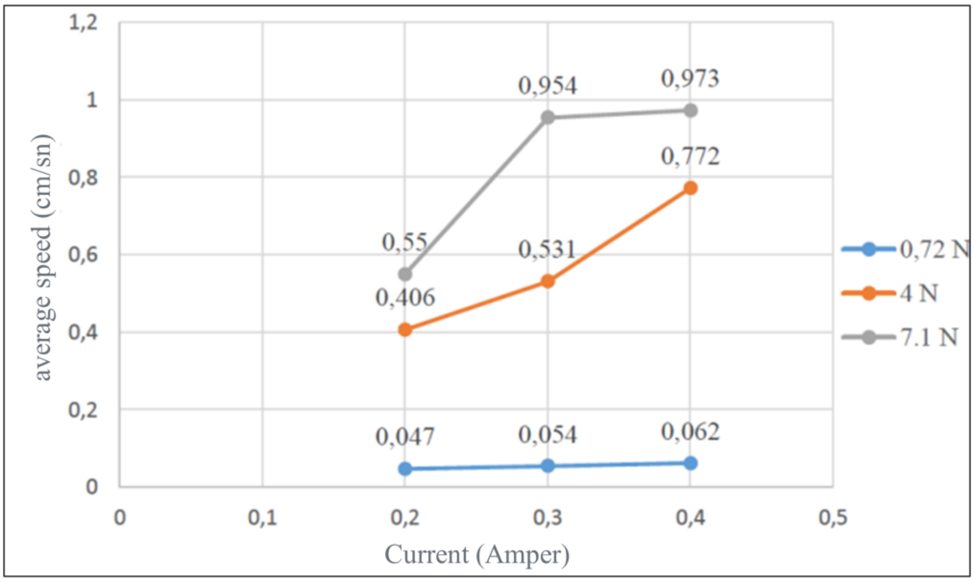

Figure 4. Graph of velocities obtained in test results

As seen in the results, the velocity values obtained after the addition of magnetic particles decreased significantly compared to the previous situation. The increase in velocity as the current increases is also due to some wear and tear in the setup due to the experimental conditions. In the next stages of the study, this situation will be prevented and more accurate control will be ensured depending on the current.

Another important issue, the problem of precipitation in mr shock absorbers, has also been prevented. The oil has a density of 0.971 gr/cm^3, On the other hand, the average density of the particles produced from polystyrene and iron powder was 0.877 gr/cm^3. In this case, due to the close densities, problems such as sedimentation or floating are not encountered.

As seen in the study, mr dampers provide an increase in force. However, the control of this increase is not always as planned. This may be due to inadequate test conditions or particle size. After this study, the test shock absorber will be prepared with more accurate materials in the following stages. In this way, more stable operation can be achieved. By reducing the particle structure, the test can be repeated with a piston with a better groove structure.

The magnetic particles have a density close to the carrier liquid, preventing precipitation or floating. This is important for the shock absorber to give the correct performance after a longer period. These characteristics are also mentioned in different scientific publications. Sedimentation stability is also mentioned in the scientific publication by Ergin & Altıparmak (2013). In the study, experiments were conducted with particles with different settling rates. As a result, it was decided to use the least settling particle.

In the scientific publication by Söylemez (2018), another study on this subject, the effect of different temperature values on the magnetic field was examined. the related study, experiments were carried out with different temperatures under the same conditions. Different evaluation criteria such as temperature can be added to our study. This allows more comprehensive correlations to be made and the correct operating position for the shock absorber to be found by controlling temperature and current.

Conclusion

In conclusion, there is still room for improvement in the field of Mr shock absorbers. With advancing technology, different manufacturing methods and composite materials can be used to increase both the structural strength and operational stability of shock absorbers. We will continue our efforts to take important steps by working to make developments even faster.

Scientific Ethics Declaration

The scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to Ramazan FERİK as the main author.

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References

Dixon, J. C. (1999). *The shock absorber handbook*. SAE International.

Ergin T., & Altıparmak D. (2013). Karbonil demir ve manyetit esaslı manyetoreolojik sıvıların sönümleme performansı ve katkı maddesi olarak silika dumanı kullanımı. *Gazi Üniv. Müh. Mim. Fak. Der. Cilt 28*, No 4, 695-703.

Güney S., Tüfekçi M. (2016). Hafif ticari araç amortisörünün çalışma koşulları altındaki yapısal analizi, testleri ve sonuçların korelasyonu, *IMSEC*; 4224-4232

Isermann, R. (2005). *Mechatronic systems fundamentals*. Springer, New York.

Rajamani R. (2012). *Vehicle dynamics and control, mechanical engineering series*, 2nd edition. Springer, New York.

Söylemez M. E., (2018). *Farklı sıcaklık şartları altında manyetoreolojik sıvılı bir sönüm elemanının dinamik karakterizasyonunun elde edilmesi* (Master's thesis, Sakarya Üniversitesi).

Author Information

Ramazan Ferik
Maysan Mando A.Ş.
Bursa/TURKEY
rferik@maysanmando.com

Murat Yazici
Bursa Uludağ University
Bursa/TURKEY

Orhan Kurtuluş
Maysan Mando A.Ş.
Bursa/TURKEY

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