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AUTOMOTIVE MAGNETIC SUSPENSION: MAGNETO-RHEOLOGIC DAMPING

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Abstract: The use of passive suspension systems is an already established concept and generates good results in everyday life, however the use of a system that corrects its damping according to the speed used could be advantageous, with regard to the drivability comfort of the common fleet. The comparison between the sets is made through equations that demonstrate and characterize the components and the reaction felt in the passenger compartment, where, through the calculations used, a difference between the two was found, which would result in unfeasibility in the application, as in general, no would be viable in an economic sense. Furthermore, it would present difficulties for the repair sector, due to the tools to be used in diagnoses, spare parts and knowledge about the new system, where many would probably be inflexible to make changes, creating more obstacles in the use of the set. Despite this, it is a promising system, not for the common fleet, as was evaluated and shown, but the racing area or even luxury vehicles can implement it, as well as specific projects, as they would present a larger dimension in their construction. accurate and with a higher percentage of efficiency.
Keywords: Suspension. Fleet. Economic. Magneto-Rheological.

INTRODUCTION

The use of automobiles has become indispensable for today's society, providing efficient transportation in a short space of time. Always being the target of studies for improvements, one of its aspects under analysis is the suspension, which "[...] establishes the connection between the vehicle body and the wheels with the tires and, essentially, allows the vertical movement of the wheels to compensate for irregularities in the track [...]" (BOSCH, 2004), having the function of maintaining the stability and comfort of the set, in addition to supporting the structure.

The suspension set is classified according to its type/functioning, being: passive, active and semi-active, in which the most common employability is that of the passive system, which can be defined, according to Picado (1998), as those that the properties of the Mechanical components are not changed in real time by external factors, in the vast majority of vehicles in circulation today, basically consisting of: shock absorber, spring, scale and bushing. However, the passive system has limitations in its operation, as it only works reactively to vibrations, with no corrections to improve stability and comfort, therefore, on routes where there are high oscillations, it is not smooth and vibrations are sometimes felt in the vehicle, which makes handling challenging.

There are in circulation, in a reduced form, active and semi-active suspension systems with different behavior and elements in their construction, with parameter corrections (damping factor, characteristic present in the shock absorber, which generates a suspension with softer or stiffer behavior) during the operation (PICADO, 1998), since these systems have control centers, which, through sensors, obtain analyzed data, with the aim of acting, through actuators, to correct possible deviations in the established parameters. Their innovative design makes them more difficult, economically, to be used by the "common fleet" of vehicles, being restricted to luxury vehicles.

Given the above, the following question arises: Is the magnetorheological (MR) system more efficient than the conventional (passive) one for the common fleet?

Therefore, this work aims to:

GENERAL ISSUES

To present some data and information that can answer the problem question and demonstrate, through a basic statistical curve analysis, the improvement (or worsening) of the implementation of the MR set in common vehicles.

SPECIFIC GOALS

- Identify factors in the area of repair that may create obstacles to implementation.
- Verify, through the data obtained by the methodology, the economic viability.
- Present, in a theoretical manner, alternatives for improving the system under study, for possible work.

Thus, using a methodology based on explanatory, comparative research, and a bibliographical survey, in which some specific books, scientific articles, among other sources, on the topic discussed were analyzed, the mathematical software MatLab will be used, where the calculations considering initial data, and thus, with the Excel software, the graph of the results obtained for the graphic analysis was assembled and plotted.

More "sophisticated" suspension systems are already in use in some segments or even luxury vehicles, in any case, taking this technology to the common fleet would be worthwhile, as it would present more static behavior and drivability comfort, not to mention that with the vehicle prices are increasingly high, components that can improve the feeling of comfort end up standing out, especially because we spend a lot of time in vehicles and feeling good and comfortable in them has its benefits.

However, new systems bring with them new problems for the repair area, as mechanics would be faced with diagnostic challenges, both of a technical nature in itself, and of a personal nature, with regard to "acceptance" by old mechanics. and their quirks, as they would be more complex and detailed systems. Despite this, semi-active systems present a more economical solution with a considerable percentage of efficiency, according to their definition, presented by Picado (1998), it is a system in which control is carried out in just one component, the damper and its damping factor, which generates positive effects on the vehicle and its behavior.

The implementation of more effective suspension systems must consider the environment in which it will be put into operation, as it is observed in Brazil that, according to (FERREIRA LV; FERREIRA VA, 2019), in some sectors of cities there are streets with wear and tear. and problems of cracks, unleveled patches, erosion, among other problems arising from rain, constant traffic and lack of maintenance, in addition to many rural locations, or not, with unpaved roads. These are factors that the use of a semi-active suspension, for example, would provide smoother handling for the driver, self-correcting and preventing vibrations from reaching the cabin.

THEORETICAL FOUNDATION

SUSPENSION

The suspension, as a set of components, has the main function of supporting the vehicle's chassis, with the transmission system and passenger compartment (closed compartment for the driver and passengers), therefore, in operation it is subjected to several variations in movement, namely: pitching (sway in the longitudinal direction), rolling, axial, radial, torsional. Its composition, in general, is made up of: shock absorber, spring, stopper, swinging arm, pivot, bushing, steering knuckle and, in some cases, torsion bar, as shown in Figure 1.

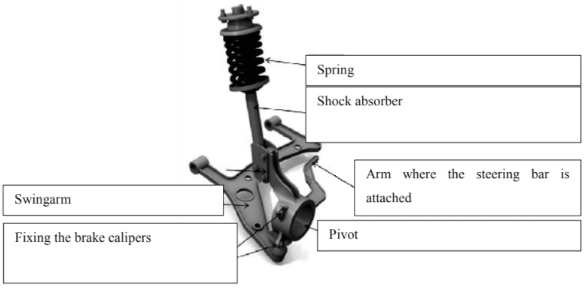

Figure 1 – Vehicle suspension: *McPherson*

Source: (CARVALHO; FARIA, 2010)

Each component mentioned above has a specific function, with the aim of minimizing movement variations and providing the driver with full control of the vehicle while driving.

The steering knuckle is the interconnection link between the suspension components: swinging arm, steering bar, spring-shock absorber assembly, stabilizer bar (if equipped), in addition to bearing mounting (CARVALHO; FARIA, 2010).

1. The swinging arm plays a similar role, but generates the connection between the chassis/suspension assembly and the assembly.

2. The pivot has the function of fixing the swinging arm to the steering knuckle, in addition to allowing the angular movement of the wheels. (NAKATA, 2019).

3. The spring absorbs the energy from the oscillation and releases it in the form of frequency, in addition to providing traction, compression or torsional force. (NORTON, 2013).

4. The bushings generate torsional resistance in the balance and absorb oscillations, as they are made of rubber, located at the connection points between it and the chassis.

5. The stop is located on the shock absorber rod and has the function of limiting its work, preventing it from reaching a critical working region, commonly called "end of stroke", which can cause premature wear.

6. The cushion is located on top of the shock absorber and has the function of preventing it from touching directly against the bodywork, serving as a means of fixing the assembly to the upper part of the chassis and helping to absorb impacts.

7. The shock absorber has the role of containing/minimizing the oscillation frequency employed by the spring after an excitation.

8. The stabilizer bar, when equipped, it has the function of absorbing irregularities from the pavement in its own composition material, it has a similar function to the torsion bar, the oldest and simplest suspension system (GUERRA, 2018).

There are several suspension systems, this one is the most widespread and used, the *McPherson*, due to its great versatility and efficiency for light vehicles has become widely used, other systems are efficient in every aspect for which they were designed, we can mention the independent (oscillation actions caused on one side will not transfer to the other) and dependent (oscillation actions generated on one side will affect the other), as shown in Figure 2.

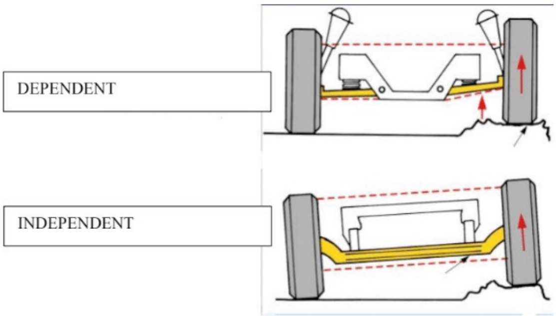

Figure 2 – Suspension difference

Source: Adapted from Automotive Education (GUERRA, 2018)

Double A differentiates itself from the System: *McPherson*, in short, by using two swinging arms and the shock absorber is connected to the upper arm instead of the body, in the Multilink system the axle knuckle is connected by several arms, which generates a geometry with more precise control of the wheels (SHARP, 2018), as shown in Figure 3.

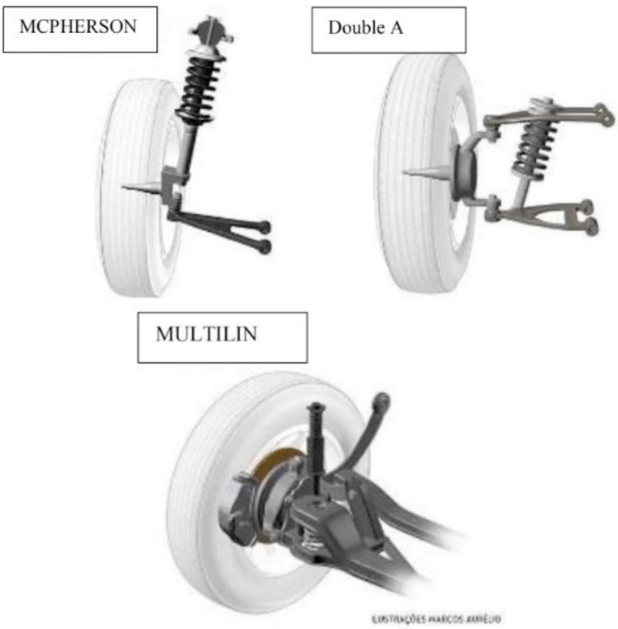

Figure 3 – Independent Suspensions

Source: Quatro Rodas, (SHARP, 2018)

TYPES OF SUSPENSION

PASSIVE SUSPENSION

It is the most common system currently used, due to its versatility and production cost, composed of the previously mentioned components, all mechanically actuated and only react to the vibrations generated by the pavement that will pass, there is no addition of external energy for any control category. (PICADO, 1998). The spring receives and converts the radial force generated into frequency, the shock absorber comes into action to absorb and dissipate this force in the form of heat, thus generating comfort by containing the spring frequency, the other components also assist in this absorption, each one retains a certain amount to maximize comfort.

SEMI-ACTIVE SUSPENSION

It is an intermediate system between passive and active, employing part of both systems, the components are the same as the previous system, but they differ in terms of the damper, which receives external action to control its damping factor. Normally, a central unit is used to analyze the data coming from the sensors, and after this procedure, a signal is sent to the actuator. In the case that will be discussed in this work, the action would be to generate a magnetic field with the aim of changing the damping constant of the shock absorber with rheological fluid.

ACTIVE SUSPENSION

The denomination of asset varies from some authors, however the basic idea for a system to be considered active, according to (LIMA, 2011), is the replacement of some mechanical components with robust processing and control systems and covers all parameters of the vehicle and which still have an external power source. In which, the correction and processing of data is superior to the semi-active system, as it is a central that receives data from the entire vehicle and makes the necessary changes during the operation, for such an action to be carried out correctly, there is a need to make calibrations of sensors and parameters within the appropriate period.

SHOCK ABSORBERS

Conventional shock absorbers, according to (BOSCH, 2004), convert the energy coming from the wheels and bodywork into heat, in their design they closely address the concept of pressure, which assists in its operation and in controlling oscillations, with various types and forms, Figure 4 demonstrates the telescope type, but with similar operation.

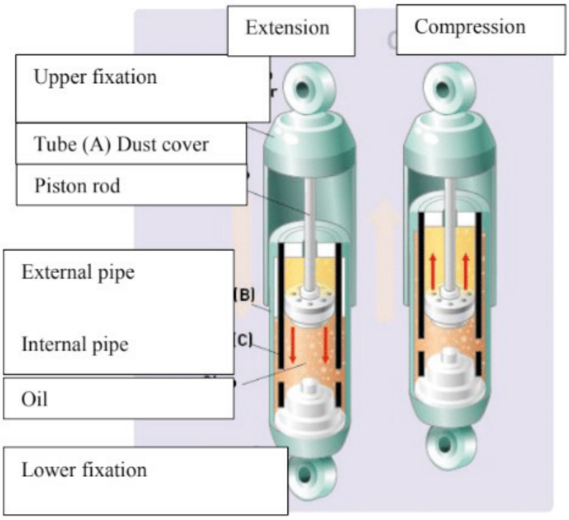

Figure 4 – Telescope Hydraulic Shock Absorber

Source: Google Images (2021).

In this case, it can be observed that as the fluid is pressed, a portion of oil is displaced into the external tube and as it fills, the fluid becomes increasingly difficult to compress, the pressure becomes increasing, making it difficult to compress. descent and given that the fluid force overcomes the work force, or it ceases, the rod returns to position.

The damping constant for a piston shock absorber, according to (SINGIRESU, 2008), depends on the physical characteristics and the fluid, as can be seen in Equation 1 as such factors influence the behavior:

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

In which:

— c is the damping constant;

— µ is the viscosity of the fluid;

— l is the length;

— D is the diameter of the piston;

— d is the clearance between the piston and the cylinder wall;

In general, the study on shock absorbers is not limited to fluid compositions, there are also studies on the use of permanent magnets, such as the one developed by (KIM et al., 2001). However, the objective of this work is based on the study of magnetorheological fluids as opposed to conventional ones that are already widespread.

According to Lima (2011), the fluid to be used would be composed of polarized particles immersed in oil, for example, consequently when a magnetic field is generated outside the tube, the metallic particles will soon rearrange themselves so that, in Over a short period of time, the fluid will become considerably more solid, thus generating a change in the damping constant. As already presented, the constant is based mainly on the viscosity of the fluid, if this viscosity were changed, as in these conditions, this change in the factor would also cause a significant difference in the overall behavior of the vehicle.

RHEOLOGICAL MAGNETO FLUID

"A magnetorheological fluid (MR) is a dispersion of magnetic molecules in a magnetically inert liquid, generally a low-viscosity Newtonian inorganic oil [...]" (SANDOVAL; CARRILLO; DONADO, 2010, p. 123), this is the basic definition of a magneto-rheological fluid, but its study goes much further, as the behavior between a non-magnetic fluid and magnetic microparticles, which generally have a size between 1 and 10µm (SOUSA, 2019), can vary according to with many factors, and as they can be controlled through an external magnetic field, they open up a wide range of applications, both automotive and industrial, among others. Its orientation, composed of 20% to 40% particles (ABREU; RIBEIRO, 2014), is quickly changed between a liquid state and a solid state with the presence of this magnetic field, as shown in Figure 5.

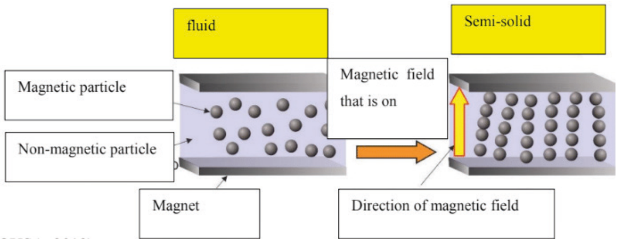

Figure 5. Particle orientation scheme.

Source: (SOUSA, 2019)

However, as analyzed by Sousa (2019), magneto-rheological fluids have the problem of sedimentation of the metallic material, after a period of waiting, the microparticles will be deposited at the bottom, with the action of gravity, as the fluid does not have enough viscosity to keep particles in their places.

A viable solution is to change the fluid, from liquid to gel, in which the magneto-rheological gel, in addition to solving this problem, provides the material with freer movement and easier alignment and misalignment when excited, which also reflects on the greater efficiency in the magnetic pulse generated by the external field. Its properties, both of the fluid and the gel, depend on factors such as: particle size, fluid volume, container roughness, fluid viscosity and temperature. The purpose of building the component is to obtain a material that, when there is no field generation, the fluid/gel is less viscous, behaving like a Newtonian fluid (LIMA; PINTO, 1981), allowing the damper to work freely, and when in operation, with field generation, the viscosity is higher, restricting the movement of the damper and making it firm.

VIBRATIONS

"Any movement that is repeated after an interval of time is called vibration or oscillation [...]" (SINGIRESU, 2008, p.6), the concept of vibration shows that even the simplest movements seen in everyday life, such as that of a pendulum, fits this description, its elementary parts are: spring (responsible for storing potential energy), mass (responsible for storing kinetic energy) and the damper (responsible for energy loss). The focus of this work is to analyze the oscillation resulting from external forces applied to the wheels and suspension system as a whole, in the various existing classifications, the ones that best fit are:

1. Forced vibration: it occurs when external forces are applied to the system, which generate oscillations.

2. Damped vibration: are those in which there is a loss of energy, which may be gradual or abrupt, due to friction.

3. Nonlinear vibrations: basically, they are those that do not follow proportionality while increasing or losing energy, in the case of suspensions it is due to uneven asphalt.

4. The damping element used is viscous, the most used in vehicles, it is characterized by the use of lubricating oil with high viscosity, in which the friction force is related to the viscosity and the relative speed between them (SINGIRESU, 2008), according to Equation 2.

$$F = c\dot{x} \ ou \ M = c_t\dot{\theta} \quad (2)$$

In which:

— F is the viscous friction force;

— C and C_t is the viscous damping coefficient;

— X and θ are the linear and angular velocities, respectively;

The spring element used is the helical spring, and its shape can vary between cylindrical, banana, barrel, this variation depends on the force that will be used, each with different characteristics, its stiffness, according to (NORTON, 2013), is identified through from Equation 3:

$$k = \frac{F}{y} = \frac{d^4 G}{8D^3 N_a} \quad (3)$$

In which:

— $\underline{D}$ is the average diameter of the turns;

— $\underline{d}$ is the diameter of the wire;

— N_a is the number of active turns;

— $\underline{G}$ is the shear modulus of the material;

To model a vibration system, the physical part is used, which must schematically represent all the important characteristics of the system, and mathematics, which is based on the deduction of differential equations (NORTON, 2013), necessary to reduce the original system, which Most of the time it is presented in a complex way, in a reduced and equivalent form to make visualization and analysis clearer, as shown in Figure 6, taking the system of a motorcycle as an example:

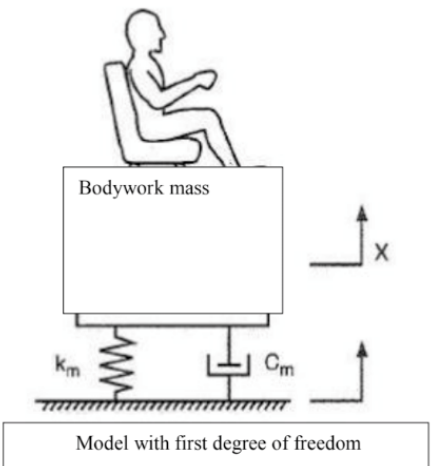

Figure 6: Physical modeling of ¼ of vehicle.

Source: (D'OLIVEIRA, 2014).

Analysis on just one wheel as a sample for the others is a way of simplifying the calculations and the equations, which are described below (SINGIRESU, 2008).

Determining a response for a damped forced vibration system is by applying initial conditions to the general equation, shown in Equation 4.

$$m\ddot{x} + c\dot{x} + kx = F(t) \quad (4)$$

It will change depending on the system used, in this work specifically, the system damped to basic harmonic movement will be used, according to Equation 5, which will demonstrate the jolt that the passenger will feel when traveling on the ground given the speed conditions and change in the terrain. relief, data presented later:

$$\frac{X}{Y} = \left\{\frac{1 + (2\xi r)^2}{(1 - r)^2 + (2\xi r)^2}\right\}^{\frac{1}{2}} \quad (5)$$

RESEARCH METHODOLOGY

Using the types of research: explanatory, comparative, and reviewing the bibliography/literature on the topic addressed, taking into account books, articles and other sources, in order to analyze the factors that make the magnetic system more efficient than conventional ones, data will be obtained in an arbitrary manner using a generic modeling system, similar to that presented in Figure 6, in which the vehicle's overall mass values, spring dimensions and other factors presented in Table 1 are based on the characteristics of the Sandero Authentic 1.0 16v 2011 vehicle with all seats occupied.

m_v = 1400 kg	v_1 = 40 km/h;	y_1 = 1,5 cm;
G = 207 GPa;	v_2 = 120 km/h;	y_2 = 2,5 cm;
N_a = 4;		y_3 = 5 cm;
d = 1,41 cm;		y_4 = 7,5 cm;
D = 12,305 cm;		y_5 = 10 cm;
Cycle = 2 m;		

Table 1: Initial data

Source: Own authorship (2021).

Therefore, using Equation (3) we have the damping constant:

$$k = \frac{F}{y} = \frac{d^4 G}{8D^3 N_a} = \frac{(0{,}0141^4) * 207 * 10^9}{8 * (0{,}12305^3) * 4} = 137{,}23\ kN/m$$

In order to simplify the calculations, only ¼ of the total weight of the vehicle, thus using a part to analyze the behavior, the damping coefficient for a conventional system will be:

$$C = \sqrt{2km} * \xi = \left(\sqrt{2 * (137{,}23 * 10^3) * 350}\right) * 0{,}7 = 6{,}86\ kNs/m$$

As it was discussed by D'Oliveira (2014), and other authors in the automobile industry, the use of this damping factor (ξ = 0,7) is the most suitable for vehicles, being rigid enough for performance and also "soft" for comfort, Figure 7 shows the different responses of a system with a unitary pulse.

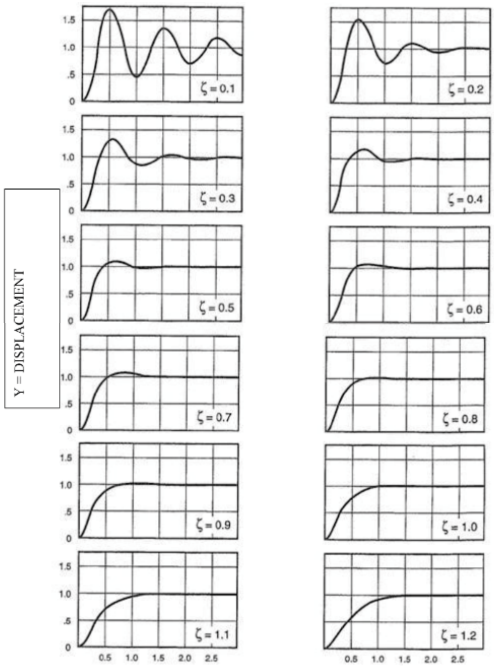

Figure 7: System response to unit pulse.

Source: (D'OLIVEIRA, 2014).

For the magnetorheological system, the damping factor is a phenomenon that varies according to the applied electrical current and the fluid to be used, in a generic way, and also for the purposes of simplifying calculations, two different damping factors will be used for the two situations used in the simulation: high and low speeds.

- Low speeds, simulating a situation with greater rigidity (ξ = 0,8);

$$C = \sqrt{2km} * \xi = \left(\sqrt{2 * (137{,}23 * 10^3) * 350}\right) * 0{,}8 = 7{,}84\ kN/m$$

- High speeds, simulating a situation with less rigidity (ξ = 0,6):

$$C = \sqrt{2km} * \xi = \left(\sqrt{2 * (137{,}23 * 10^3) * 350}\right) * 0{,}6 = 5{,}88\ kNs/m$$

Once the data has been collected and the equation that describes the vibration movement has been assembled, using the scheme in Figure 6 as a basis, the MatLab mathematical simulation software will perform the calculations for both the conventional system and the magnetic system, and will present the results from the arbitrary inputs regarding the level of oscillation of the surface on which the systems under test are located. At the end, tables will be presented that demonstrate such behaviors in the face of unevenness.

To determine the displacement felt by the driver, it is necessary to use a series of equations, starting with the ratio between the frequencies (natural and base), to determine the base frequency, you can consider the speed of the vehicle and the length of a terrain irregularity cycle, as shown in Figure 8 in a simplified and direct way.

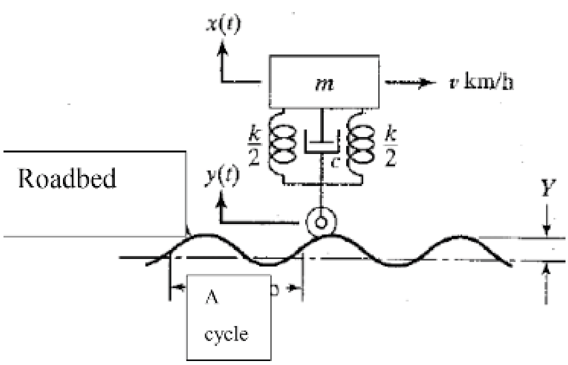

Figure 8: Model simplification

Source: (SINGIRESU, 2008)

To determine the frequency ratios, it is necessary to use intermediate equations where the values for each vehicle speed are obtained, using Equation (6) and Equation (7).

$$\omega_n = \frac{2\pi f}{2} = \frac{2 * \pi * \left(\frac{v_n}{3{,}6}\right)}{2} \quad (6)$$

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$$\omega_n = \sqrt{\frac{k}{m}} \tag{7}$$

Thus:

$$\omega_1 = \frac{2\pi f}{2} = \frac{2 * \pi * \left(\frac{v_1}{3,6}\right)}{2} = 11,63\, rad/s$$

$$\omega_2 = \frac{2\pi f}{2} = \frac{2 * \pi * \left(\frac{v_2}{3,6}\right)}{2} = 104,71\, rad/s$$

$$\omega_n = \sqrt{\frac{k}{m}} = \sqrt{\frac{(137,23 * 10^3)}{350}} = 19,80\, rad/s$$

Therefore, the ratios between frequencies are:

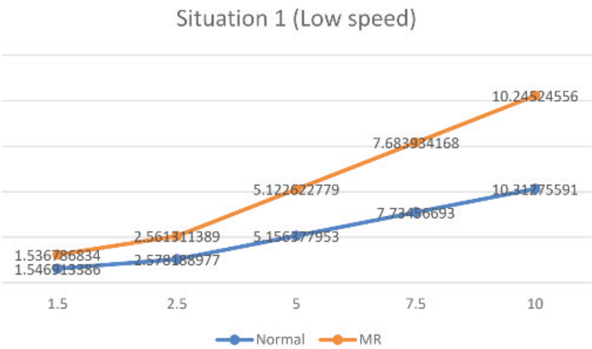
$$r_1 = \frac{\omega_1}{\omega_n} = 1,76$$

$$r_2 = \frac{\omega_2}{\omega_n} = 5,28$$

Later apply these data to the equation of the damped system with basic harmonic motion, Equation (5).

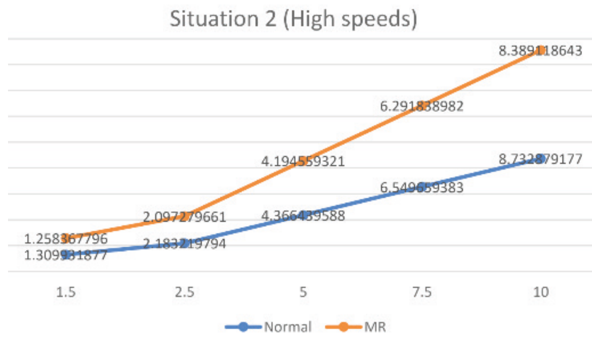
SEARCH RESULTS

After using the software for the iterations and obtaining the results, Tables 2 and 3, as well as Graphs 1 and 2 below, demonstrate the respective values for the terrain situations.



Graph 1: Data plot of the first terrain situation.

Source: Own authorship (2021)



Graph 2: Data plot of the second terrain situation

Source: Own authorship (2021)

As it can be seen in Graphs 1 and 2, and Tables 2 and 3, in the first situation the differences between the systems are negligible up to the parameter of 2.5 centimeters, which changes as the unevenness of the terrain increases, since at high speeds, this difference can be noticed right from the beginning and becomes clearer as the parameters progress. Generally, there is little difference in relation to both systems, which may or may not be noticeable in the passenger compartment, it can be concluded that, with the established parameters of damping factor for the magnetorheological system, there is no considerable advantage to justify the use of this system in the common fleet.

CONCLUSIONS

Despite the use of a data set that simplified the calculations, it is clear that the magnetorheological system is more effective, even though it is not a big difference, as seen in Graphs 1 and 2, due to the parameters used for the MR system in this work. The system works with adjustable damping coefficient parameters depending on speed and other factors, so, in addition to continuously adjusting, it can be designed to generate less vibration for the passenger compartment and consequently for the driver.

Analyzing the results acquired, it is not productive to exchange the conventional set

Situation 1 (Low speed)					
Y	1,5 cm	2,5 cm	5 cm	7,5 cm	10 cm
Normal	1,546913 cm	2,578189 cm	5,156378 cm	7,734567 cm	10,31276 cm
MR	1,536787 cm	2,561311 cm	5,122623 cm	7,683934 cm	10,24525 cm

Table 2: Data from the first field situation.

Source: Own authorship (2021).

Situation 2 (High speeds)					
Y	1,5 cm	2,5 cm	5 cm	7,5 cm	10 cm
Normal	1,309932 cm	2,18322 cm	4,36644 cm	6,549659 cm	8,732879 cm
MR	1,258368 cm	2,09728 cm	4,194559 cm	6,291839 cm	8,389119 cm

Table 3: Data from the second terrain situation.

Source: Own authorship (2021)

for the magnetorheological one, because due to the difference in construction between them, the MR system is significantly more expensive, where within its construction, in addition to the damper, there would be a need for a control module interconnected to the BCM (Body Control Module) which would adjust the damping factor depending on the signal received by the vehicle speed sensor, and it would not be viable given the range of values presented, on the other hand, if the design of the set presented greater efficiency in its operation and parameters, a difference could be clearer, and this change would lead to a significant improvement, demonstrating and presenting reasons why the replacement must already be carried out for the entire fleet.

As it is a more complex system and contains sensitive electronic components, the usability of this system can currently be a problem, where unpaved streets, critical differences in level (potholes), recklessness or even carelessness on the part of the driver, can cause damage to the system, which depending on, they will be serious enough to render some components unusable, resulting in a very high maintenance cost, as they will be complex and expensive components, original or second-rate.

Considering the professionals in the repair area, where they would need training to adapt to the new system, some would resist this new knowledge and carry out maintenance carelessly or even with neglect, in other cases, the difficulty in obtaining the necessary equipment to data analysis and reprogramming would be an obstacle for some workshops, the tools to carry out the service with quality and without unforeseen events would be very expensive and sophisticated, generating major headaches for them and the customers, on the other hand, those who would embrace the changes and would take the courses, they would see themselves more prepared and would not make silly, precise and concise mistakes in the diagnoses, for these the data and equipment, as mentioned, would be available due to the location and ties where they work, in dealerships, obtaining machinery It is done very easily, as at an affordable price from suppliers than a workshop owner.

In line with these factors, the values of automobiles are relatively high for the few resources currently used, and with the implementation of a more sophisticated system for the common fleet, their prices would increase too much, becoming almost unaffordable for a large part of society, as current vehicles considered “basic” come with a high price, and the addition of accessories makes it increasingly higher, reaching exorbitant values.

As previously presented in this work, the magnetorheological system works with magnetic particles immersed in a rheological fluid, thus its damping coefficient is variable within a range of action of the set (fluid and particles), these parameters, despite not be considered in this work, is best presented in reference materials and other authors. Thus, it can be seen that the results did not come out as theoretically established, the difference between the systems was small, as the main intention was to present the behavior of both systems in different types of relief and with certain differences in level.

Taking into consideration, the data, an option for improving them would be the use of the damping factor best adapted for each level of speed used, being a system that continuously presents the correction of its parameters, better adjusting the comfort that will be transmitted to the driver. passenger compartment. Another option to consider is the use of other components of the suspension assembly, some with better or more resistant materials and absorb vibrations in their own structures or bushings.

The semi-active suspension system has its particularities, which demonstrate greater efficiency during operation in relation to the passive system used in vehicles, generates greater comfort, better drivability in uneven environments, greater stability, among other factors, but its employability requires a cost, which may be disadvantageous overall.

It was demonstrated in this work that the semi-active system presents little advantage in relation to the conventional one, in that in everyday use such differences will probably not be noticed, making the vehicle more technological without necessarily using this resource, something that the passive system can perform normally and, with some changes to the components that make up the suspension, obtain better results with relatively lower implementation costs, it can currently be observed that some vehicle features end up not being as useful for some drivers, remaining unused.

Finally, the use of the magnetorheological damper as a correction agent has the potential to be explored for other "levels" of vehicles, luxury, racing, among others, in which the implementation is done specifically for a use, such as Therefore, the benefits that may come from your employability will be better, as they will be designed with more precise dimensions and parameters.

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