Research Article

EXPERIMENTAL INVESTIGATION OF MAGNETIC SUSPENSION SYSTEM

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ABSTRACT

This project is based on suspension system of an automobile vehicle. This report gives information about electromagnetic suspension system. The aim of this project is to study and investigate the response of system, when it is subjected to road surface irregularities with the hope that it would help automobile industry. This project presents design, construction and working of one wheel vehicle electromagnetic suspension system. This system uses electromagnets as passive dampers, which is used to reduce displacement and acceleration of sprung mass in order to improve ride comfort. Main performance parameter of suspension system is vertical acceleration of chassis.

Problem definition

"Design and development of suspension system to minimize road shocks"

The aim of any suspension system is to provide a vehicle with a suspension that simultaneously resists dive, squat and roll, provides a comfortable ride with extensive axle articulation whilst maintaining equal pressure on all wheels as far as possible. In suspension system, there is always compromise between stability and comfort. So, suspension systems cannot offer all of the above requirements and have to compromise on ride quality which is associated with spring stiffness and damping coefficient. Springs that are too stiff springs provide a harsh ride and impede axle articulation. Soft springs provide a softer ride but cause unwanted effects on the handling of the vehicle, such as too much dive, squat and body roll. It is also not possible to use very soft spring in the suspension system as it reduces the ground clearance too much when loaded heavily. Another disadvantage of soft spring in suspension systems is the building up of high kinetic energy as the springs compress and the subsequent release of this energy when the springs return to their original state. This causes chassis twist and wheel bounce. Therefore, it is required to use dampers of high damping coefficient to gradually dissipate kinetic energy of spring. Again, these dampers oppose the spring to deflect effectively and hence deteriorate the comfort. So, it is required to develop a system that can improve comfort.

DESIGN OF EXPERIMENT

Project Concept

As discussed earlier, hydraulic dampers of conventional suspension system oppose the spring to deflect effectively and hence deteriorate the comfort. So, ride comfort of vehicle may be improved by introducing such type of dampers, which can help the spring to deflect properly and gradually dissipate the kinetic energy due to deflection of spring. In this project, electromagnet is used as damper to fulfill above objective.

Construction of suspension system

Purposed suspension system is modelled as shown in Figure. Since the model represents a suspension from one of the four corners of the vehicle, this system is referred as the "quarter-car" model. The lower mount is connected to the upper mount through the suspension spring. Sprung mass is placed on upper mount. Two electromagnets are mounted both on upper and lower mount.

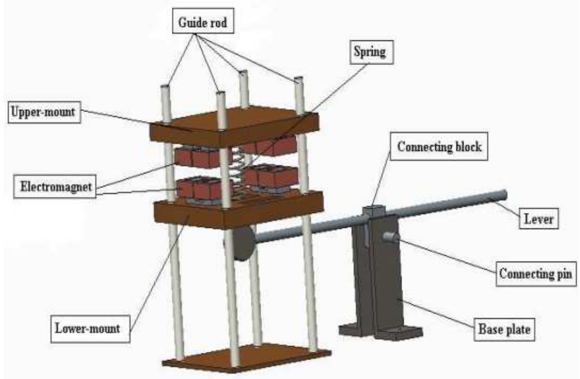

Fig Components used in Setup

Components used in suspension system are as follows:

- Upper-mount
- Lower-mount
- Spring plate
- Spring
- Electromagnet
- Battery

1) Upper-mount:

The function of upper mount is to accommodate sprung mass and electromagnet. It is made up of wood. One end of spring is also connected to upper mount through spring plate. Dimension of upper mount: 38cm X 38cm X 3cm. There is one square hole at the center of upper mount having dimension: 10cm X 10cm X 1.2cm. The reason behind providing square hole is to constraint the horizontal movement of spring plate.

2) Lower-mount:

The jerk is applied to lower mount by lever, which is then transferred to suspension system. It is made up of wood. Two electromagnets are also mounted on upper side of it. Lower end of spring is connected to the lower mount through spring plate. . Dimension of lower mount: 38cm X 38cm X 4.8cm. There is one square hole at the center of lower mount having dimension: 10cm X 10cm X 3cm.

3) Spring plate:

The main function of spring plate is to connect spring with upper and lower mount. It is made up of Mild steel material. Both ends of spring are welded to spring plate. Both spring plates are connected to upper and lower mount through bolted joint. Dimension of spring plate: 10cm X 10cm X 1cm.

4) Spring:

Springs act as reservoirs of energy in suspension system. They store the energy due to the sudden force, when the vehicle encounters a bump or road

surface irregularities. This energy is released subsequently with the help of shock absorber.
Dimensions of spring are as follows:

Spring material	**Spring steel grade 2**
Wire diameter	**6.3mm**
Inner diameter	**41.4mm**
Outer diameter	**54mm**
Mean diameter	**47.7mm**
Free length of spring	**190mm**
Pitch	**19mm**
Number of turns	**11**

5) Electromagnet:
The role of electromagnet in this suspension system is as a damper. Core of electromagnet is made up of Mild steel in U shape. Coil of electromagnet is made up of copper having SWG 18. There are two electromagnets, which are mounted on both upper and lower mount through aluminum strips as shown in figure. Both coils are connected in parallel configuration with battery.

Core material	**Mild steel**
Coil material	**Copper**
Height of limb	**50mm**
Width of limb	**50mm**
Thickness of limb	**50mm**
Distance between two limb	**40mm**
SWG	**18**
Number of turns	**275 per limb**

Experimental setup
It is the mechanism constructed to provide jerk to the suspension system. Purposed suspension system is constructed as shown in Figure. Jerk is applied at the one end of lever, which is than supplied to lower mount of suspension system through circular plate. As we know that shock absorbed by suspension system is proportional to reduction in acceleration of upper mount with respect to lower mount, shock absorbed by the suspension system can be determined from the accelerometer sensor.

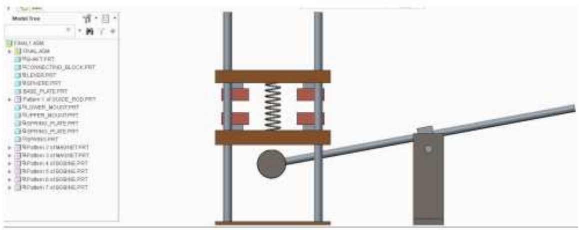

Fig Experimental setup

Components used in experimental setup are as follows:

- Base plate
- Connecting pin
- Connecting block
- Lever
- Circular plate
- Guide rod
- Accelerometer monitor

1) Base plate:
The main function of base plate is to provide rigid and stable base. It is an L-shaped plate having hole on its vertical face to support connecting pin. Vertical height of plate is 32cm and hole of 3.2cm is located 8cm below top surface.

Fig: Base plate

2) Connecting pin:
The main function of connecting pin is to support connecting block. It is circular rod in shape. Its diameter is 25mm and length is 20cm. It is supported in hole of base plate. Oiling is also carried out between connecting pin and connecting block to reduce friction.

Fig: connecting pin

3) Connecting block:
It is the link between connecting pin and lever. It is solid block of dimension: 5cm X 5cm X 10cm. there are 2 through holes of diameter 25mm at right angle as shown in figure.

Fig: connecting block

4) Lever and circular plate:
It is circular rod in shape. Lever is supported in connecting block. Load is applied from one end of lever, which transmits to suspension system through other end. One circular plate is welded at other end of lever. The reason to use circular plate is to have line contact between lever and suspension system.

Fig: lever and circular plate

5) Guide rod:
The main function of guide rod is to constrain horizontal movement of suspension system and allow only vertical movement of system. Guide rod is PVC plastic pipe. Its diameter is 25mm and length is 100cm. There is one hole at each corner of upper and lower mount, from which guide rod passes.

6) Accelerometer monitor
As we know that shock absorbed by suspension system is proportional to reduction in acceleration of upper mount with respect to lower mount, shock absorbed by the suspension system can be determined from the acceleration, which is measured by accelerometer monitor.

Fig: Accelerometer monitor sensor

Design of spring:
Material of spring: Spring steel grade 2
Modulus of Rigidity G = 79.3 X 10^3 MPa
Wire diameter d = 6.3 mm
Outer diameter of spring D_O = 54 mm
Mean diameter of spring D = 47.7 mm
Deflection of spring δ = 10 mm
Load W = 20 kg
Length of spring L_f = 190 mm

$$\delta = \frac{8WD^3 n}{Gd^4} \qquad \text{……3.5}$$

$$\therefore 10 = \frac{8 \times 196.2 \times (47.7)^3 \times n}{79.3 \times 10^3 \times 7^4}$$

$\therefore n = 8.9$

$\therefore n \approx 9$

Now, total number of turns for square and ground end N = n+2= 9+2
= 11
So, actual deflection of spring = 9.84 mm

Now, stiffness of spring $K = \frac{W}{\delta} = \frac{196.2}{9.84} = 19.99 \frac{N}{mm}$

Pitch $P = \frac{L_f}{N-1} = \frac{190}{10} = 19mm$

Dimensions of spring are as follows:

Design of electromagnet:

Attraction force per limb $F = \frac{B^2 A}{2\mu_0}$, N

Attraction force per electromagnet $= \frac{B^2 A}{\mu_0}$, N……3.6

Now, magneto motive force =

$$NI = \frac{Bl_g}{\mu_0} + 20\% \text{ of NI}$$

$$\therefore 0.8NI = \frac{Bl_g}{\mu_0}$$

$$\therefore NI = \frac{Bl_g}{0.8\mu_0} \qquad \text{...3.7}$$

Here,
Number of turns N=275
Absolute permeability $\mu_0 = 4\pi \times 10^{-7}$ N/A^2
Cross sectional area A=25mm^2
Following graph represents change in magnetic force with respect to change in current and air gap.

Spring material	**Spring steel grade 2**
Wire diameter	**6.3mm**
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Outer diameter	**54mm**
Mean diameter	**47.7mm**
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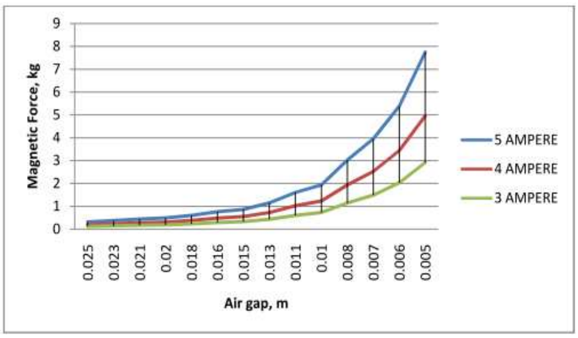


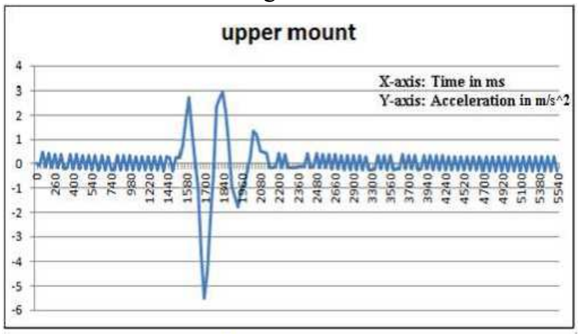
Fig Magnetic force at different air gap

Working:
As 196.2N static load is placed over the upper mount of suspension system, spring is compressed by an amount equal to 10mm. Circular plate is placed below the lower mount in such a way that line of action of force passes through centre of gravity of suspension system. As electric supply is given to the electromagnets by battery, opposite poles are generated on electromagnets facing each other on. Now, force is applied to the centre of lower mount by circular plate through lever in such a way that lower mount is lifted by 2 cm. Due to application of impact force, spring is compressed. As there is attraction force between electromagnets, it helps the spring to compress effectively. Due to compression of spring, kinetic energy is stored in it. This kinetic energy of spring is gradually dissipated by attraction force of electromagnets during retraction of spring, which results in smooth movement of sprung mass.

RESULT AND CONCLUSION

Result

Below graph represents acceleration of upper-mount and lower-mount with respect to time. When jerk is given to lower-mount in upward direction, there is change in acceleration of lower-mount according to Newton's second law of motion F=ma. This force is transmitted to upper-mount through suspension spring, which can be measured in terms of acceleration by accelerometer sensor. From this graph, we can observe change in acceleration of upper-mount and lower-mount, which is an ultimate criterion to decide the degree of comfort.



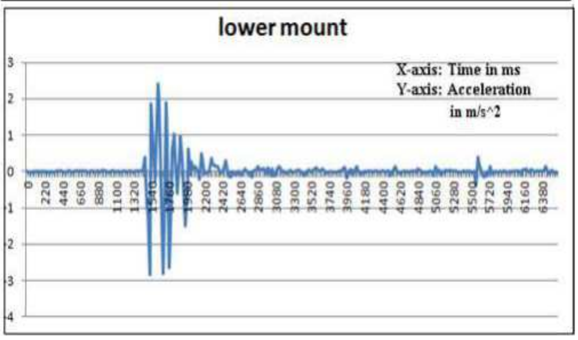
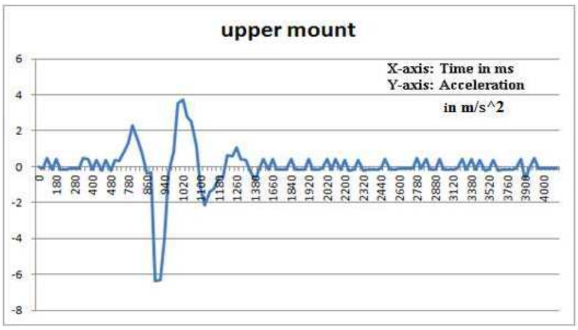


Fig: Graph of acceleration vs time when electromagnets are not active



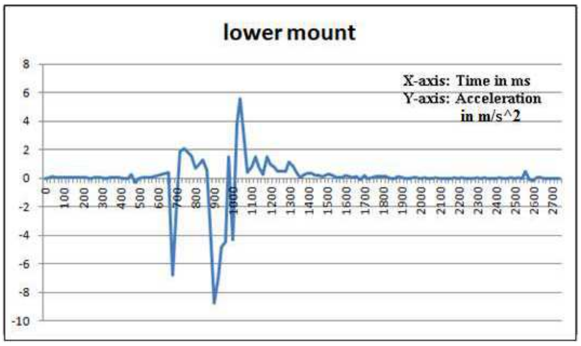


Fig: Graph of acceleration vs time when electromagnets are active

CONCLUSION:

From above figure, it is observed that vertical acceleration of upper-mount is less with respect to lower-mount when electromagnets are active as compared to the case in which electromagnets are not active. So, it is concluded that vertical acceleration of sprung mass is reduced and comfort is improved by using purposed magnetic suspension system.

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