Assessment of Damping Effect as Applicable to Automobile Shock Absorber systems and related damper Systems.

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Abstract
This study seeks to review the theories behind the effect of damping in harmonic oscillator and suggest improvement in its application in an automobile shock absorber system as well as other related damper systems. An experiment was conducted to investigate damping effect in three media (air, water and 50w engine oil). The results were presented in tables and graphs to analyze and compare the rate at which the amplitude decaying with time in media investigated which invariably used to validate field measurements. A critical damping was found in 50w engine oil and it is suggested to be excellent to automobile engineers in order to improve the passenger's comfortability in an automobile system. The critical damping was found would give more comfortability and healthier due to its rapid decay in vibration coming to passenger seat. Consequently, it provides an alternative support to the automobile shock absorber system in the passenger seat constructions to reduce the vibrational impact in human body and the design of the vehicle body (chassis) together with engine components.

Keywords: Damping effect, shock absorber, critical damping, amplitude decay, comfortability, vibrational impact

1. Introduction

Vibratory systems is very important in modern technology and engineering. Though undamped system could be hazardous to human body. Vibratory system transfers energy between the potential and kinetic energies alternatively. In a damped system, some energy is dissipated at each cycle of vibration and must be replaced from an external source if a steady vibration is to be maintained [1], [2]. All vehicles especially those plight on roads are subjected to dynamic forces which cause vibrations. One of the important factors in vehicle design is the performance of vehicle dynamic systems [3]. Though, most of automotive manufacturers have tried to improve on the automobile shock absorber response to the rough surface. This is because when vehicle is moving on the roads, the vibrational impact from the road rough surface could damage the vehicle and human health as well as affecting the vehicle balance and speed. According to [4], [7], vehicles are exposed to vibration because of roughness of the roads and design of the vehicle body (chassis) together with engine components. These negativities of vibration can cause a significant damages in human body and mental health. Hence this uncomfortable situation could be reduced by damping the oscillatory motion. Damping is a phenomenon associated with oscillating system and vibrating systems. The term damped simply means loss of energy in oscillating systems or is the reduction of amplitude of oscillating systems [2]. The vibration isolation is of great importance for the vehicles. Depending on the material used in vehicle shock absorber and seat design, reduces drastically the vibrational impact reaching the drivers and passengers. For this purpose, automobile shock absorber system of vehicles is to reduce uncomfortable vibrational impact transferred from the uneven road surface through the tires and to transfer the forces back to the tires in order to help the driver to keep balance and the vehicle under control.

However, according to [4], many studies on vibration and movement has shown that the frequency of the vibration between 1.0 Hz and 100 Hz has a significant effect on human body. Though, vibration effect leads to an increase in deformation and distortion of body shape and size [7]. Despite of the positive utilization of on-vehicle damping systems in order to decrease these forces, vibrational impacts in human body can cause seriously health damage such as distortion of body tissues, increase the rate of respiration, trigger energy consumption, increase the consumption of oxygen, shoot up heartbeat, increase in blood pressure, decrease in performance, and it also affects the central nervous system

[5], [6]. Despite these health damages and enormous studies and researches on vibration, the amount of vibration cannot be decreased to desired levels. This is because vibration is virtually the source of energy in all sinusoidal motion and waves.

In this work, the investigation shall be narrowed to damping effects in oscillating systems using a loaded helical spring in three media since damping occurs widely in nature and is exploited in many manmade devises, such as clock, radio circuit and automobile shock absorber. Thus, it is targeted at reviewing the theories behind damping effect of harmonic oscillator systems in different media and affirming it by experiment to describe and compare the behaviour of damping effect and the rate at which the amplitude of the oscillating systems decay in three different media such as air, water and 50w engine oil.

2. Materials and Method

Measurements were obtained using a simple harmonic motion (SHM) kit. A 200g load hung on the 21.0cm spring was displaced from its equilibrium position and allowed to oscillate freely in air and the amplitude was recorded at different time with respect to equilibrium position using stop watch and meter rule. The procedure was repeated in water and oil respectively. The values obtained in each medium (air, water, and 50w engine oil) were tabulated in table 1, 2, and 3 respectively. It works on the principle of classical mechanic where a harmonic oscillator system is displaced from its equilibrium position, and experience a restoring force, F, proportional to the displacement, x, $[F - kx]$; where k is a positive constant. If F is the only force acting on system, then the system is called a simple harmonic oscillator (SHO) and it undergoes simple harmonic motion (SHM) sinusoidal oscillations about the equilibrium position with constant amplitude and a constant frequency [2]. If a frictional force (damping) proportional to the velocity is present, the oscillation is described as a damped oscillation. Depending on the frictional coefficient, the system can oscillation with a frequency smaller than in the non-damped case, and an amplitude decreasing with time and it can also (damped oscillator) and it can also decay exponentially to the equilibrium position, without oscillation (over damped oscillator) [1], [2].

An example of damped harmonic oscillator is shown in Fig. 1. When an object moves through air or viscous fluid, it experienced a frictional force; this force dampens the motion. The higher the velocity the greater the frictional force.

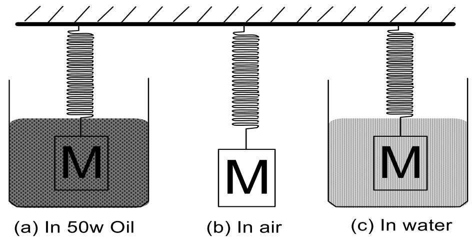

Fig. 1: Damped Mechanical Oscillator

The force F acting on the mass m is proportional to its velocity (x'). That is;

$$F = -kx' \quad (1)$$

Where the minus sign indicates that the force is always acts in the opposite direction of the motion and constant s depend on the mass m. The presence of resistance in the motion means that another force is active, which is taken as being proportional to the velocity; like the stiffness force, it always act in a direction opposite to that of acceleration term, for a system in which these two forces are present [2], the Hooke's law gives;

$$F = -kx' - rx' \quad (2)$$

Where r is the constant of proportionality and has the dimension of force per unit velocity and x^{11} is the acceleration, x^{1} is the velocity and x denotes the displacement [1]. To find the behaviour of the system in question, we suggest the solution to equation (2) as;

$$x = Ce^{\alpha t} \quad (3a)$$

$$x' = C\alpha e^{\alpha t} \quad (3b)$$

$$x'' = C\alpha^2 e^{\alpha t} \quad (3c)$$

Substituting equation (3) into (1) then;

$$Ce^{\alpha t}(m\alpha^2 + r\alpha + k) = 0 \quad (4)$$

For non-trivial solution, $Ce^{\alpha t} \neq 0$ and

$$m\alpha^2 + r\alpha + k = 0 \quad (5)$$

Using standard formula:

$$ax^2 + bx + c = 0; \quad (6)$$

Where the standard formula is given as;

$$x = \left[-b \pm \frac{\sqrt{b^2-4ac}}{2a}\right].$$

Thus; $\alpha = \left[-\frac{r}{2m} \pm \sqrt{\frac{r^2}{4m^2} - \frac{s}{m}}\right]$

Substituting the value of α we have

$$x = Cexp\left[-\frac{r}{2m} \pm \sqrt{\frac{r^2}{4m^2} - \frac{s}{m}}\right] \quad (7)$$

Thus: let $\left(\sqrt{\frac{r^2}{4m^2} - \frac{s}{m}}\right) = \omega \quad (8)$

Equation (7) has different solutions depending on the degree of damping involved. For the solution, it shall be considered in three cases as follow;

(i) Bracket negative $(\omega < 0)$: Damping here is light, and is normally considered as the most important case because it involves oscillatory motion where the other two cases involve little or no oscillation [2].

(ii) Bracket positive ($\omega > 0$): Damping here is heavy; this occur when the degree of damping is sufficiently large that the system return sluggishly to its equilibrium position without any oscillation at all. The damping resistance $r^2/4m^2$ dominate the stiffness term s/m and the system does not oscillate [1].
(iii) Bracket zero ($\omega = 0$): Damping here is critical. It is an interesting situation occur when, $\frac{r^2}{4m^2} = \frac{s}{m}$.

3. Results and Discussion

Table 1 – 3 show the result obtained from the harmonics oscillation in three media. In our description a body setting in a simple harmonic motion, the amplitude of the oscillation steadily reduces and the body eventually comes to rest.
From the tables of values, it is clearly seen that the time taken for the oscillations to decay varies from one medium to the other. In air, the time taken for the oscillation to decay is longer than in both water and oil. This is linked with the fact that, when an object oscillate through air or various liquid, it experiences a frictional forces, these forces dampens the motion [6], [7]. That is the density and or velocity of a medium has a direct effect on any object that moves (oscillates) through it. The higher the density/velocity, the more effect it will have on the object. The density/velocity of oil, water, and air is in the following order: oil>water>air. This effect, in our own case, is described in terms of damping effects, as shown in Fig 2, 3 & 4, are in agreement with the above discussion.

The equilibrium position, $x_0 = 21\ cm$

Table 1: Damping Effect in Air

S/N	Time (s)	Position X_n (cm)	Displacement $x = (x_0 - x_n)$ (cm)
1	0.00	29.0	8.00
2	16.42	27.0	6.00
3	32.10	25.8	4.80
4	51.30	24.6	3.60
5	86.20	23.2	2.20
6	113.8	22.2	1.20
7	151.12	21.4	0.40
8	180.11	21.0	0.00

Table 2: Damping Effect in Water

S/N	Time (s)	Position X_n (cm)	Displacement $x = (x_0 - x_n)$ (cm)
1	0.00	29.0	8.00
2	5.20	26.0	5.00
3	15.80	24.0	3.00
4	24.71	22.0	1.00
5	29.31	21.4	0.30
6	33.99	21.0	0.00

Table 3: Damping Effect in 50w Engine Oil

S/N	Time (s)	Position X_n (cm)	Displacement $x = (x_0 - x_n)$ (cm)
1	0.00	29.0	8.00
2	1.10	22.0	1.00
3	1.86	21.0	0.00

In Fig 2, the loaded spring oscillates with much inertia and with little resistance due to the medium (air) and gradually decays after a long period of time.
In Fig 3, although there is oscillation, but the damping effect of the medium (water) is greater and it subsequently overcome of the tendency of the loaded spring to oscillate and causes the oscillation to decay in a very short time.
In Fig 4, however, the damping effect due to 50w engine oil is much greater. Hence, little or no oscillation was recorded because it decays exponentially to its equilibrium position.

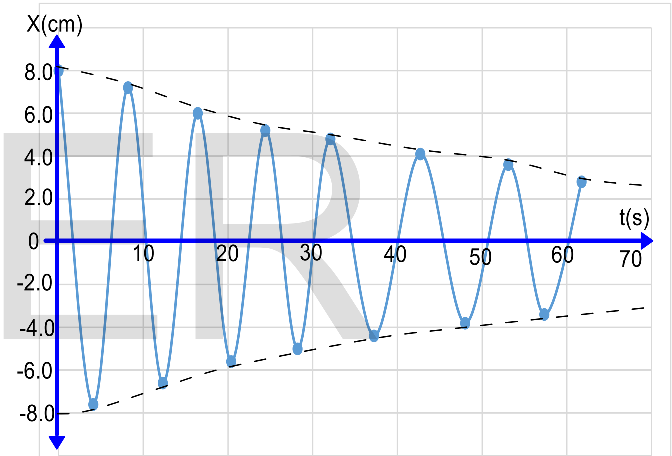

Fig 2: Graph of damping effect in air

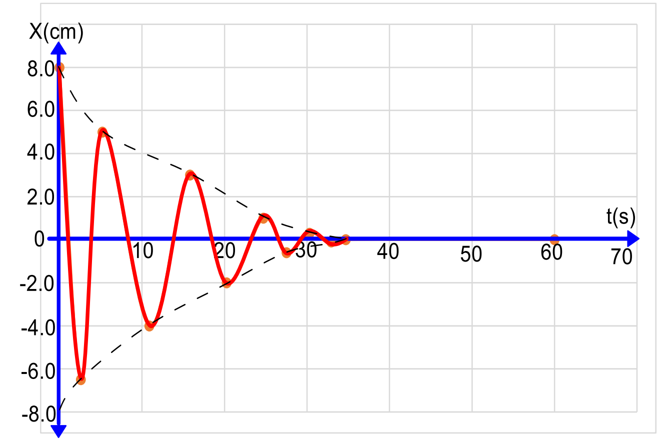

Fig 3: Graph of damping effect in water

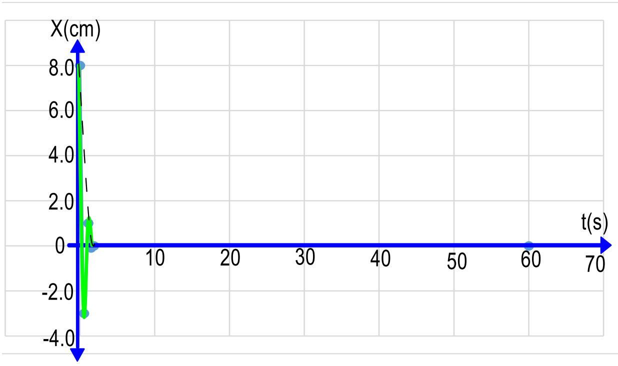

Fig4: Graph of damping effect in Engine Oil

Fig 5 shows the combined damping effects (light, heavy and critical damping) in three media

In air medium, it shows that the spring with air medium as damping factor will takes at least about 180 second before coming to rest. This means, a shock absorber designs with such medium will cause a vehicle to bounce for 130 minutes when it passes over a rough road before maintaining its balance. Hence, as important as this, it is not good enough for damping factor in seat construction.

In water medium, a spring with water medium as damping factor will takes at least about 33 second before coming to rest. This means, designing an automobile shock absorber with water medium will cause a vehicle to bounce for at least 33 second when it passes over a rough road before maintaining its balance. Hence, it cannot be used as damping factor in seat construction.

In engine oil medium, shock absorber spring with engine oil medium as damping factor will takes just 2 second to come to rest. That means, a shock absorber designs with engine oil medium will take a vehicle just 2 seconds it maintain its balance (or passengers if used in seat construction) when it passes over a rough road. Hence, this medium can be recommended for seat construction.

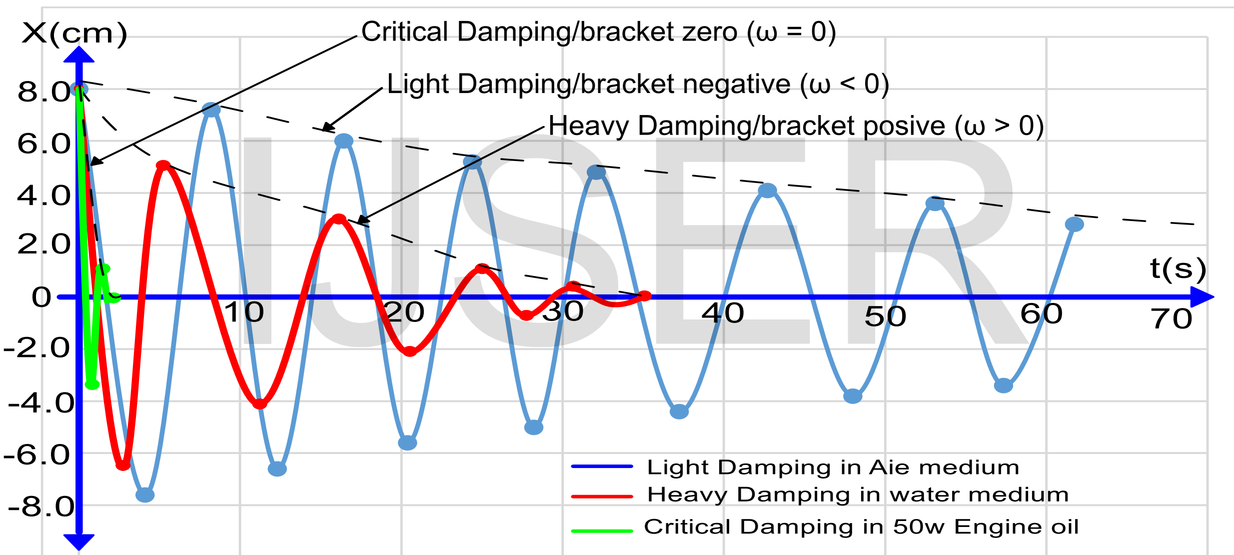

Fig 5: Graph of Combined Damping effect in three media (air, water & 50w Engine Oil)

4. Conclusion and Recommendations

From the results and observations of the experiment, it can be seen that the basis of the theory behind the damping effect has been investigated and confirmed. The time taken for decay in oscillation was found to be higher in air and least oil, with water in between and this was due to the difference in density, viscosity and the media involved. The investigation also shows that damping effect in 50w engine oil was very much and critical which has been recommended for seat construction to support the automobile shock absorber in order to reduce the vibrational impact transmit from the rough roads via the vehicle to the passengers. Consequently, it can be concluded that constructing a damper (using critical damping effect) under the passenger's seat will totally eliminate or reduce the vibrational impact of the vehicle on human body as the result of roughness of road's surface.

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