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Effect of Temperature Variation on Oil in Oscillation of Mass/Load

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Abstract: In this investigation a model was made to replicate the working of a shock absorber and the liquid that is used in place of the hydraulic fluid was vegetable oil. Hydraulic fluid is composed of a mineral oil base stock [1]. The working of the model of a shock absorber was tested at different temperatures. It is studied that the relation between the temperature and the time taken by the load attached to the spring to stop oscillating and presented in graph. An optimum temperature, at which the time taken by the mass of 1.50 kilograms suspended in the vegetable oil to stop oscillating and it is the least mass used in the study. In addition to this, the freezing point of the vegetable oil will also be found. It is found in this study that the two variables that is temperature of the vegetable oil and the mass of 1.5 kilograms at rest is linear.

Keywords: Temperature Variation, Oil, Oscillation, Mass, Load.

I. INTRODUCTION

Oscillation is the repetitive variation, typically in time, of a measure about its equilibrium [2]. This concept of oscillation was necessary to be introduced, as the movement of a mass about its equilibrium position is a concept that has a vital role to play in this investigation.

The reduction in the amplitude of an oscillation as a result of energy being lost from the system in order to overcome the resistive forces is called damping [3]. Damping restrains vibratory motion, like mechanical oscillations, noise, etc. Damping stops the body from vibrating. There are four different types of damping motion, under damped, un damped, Over damped and Critically damped. When a body is under the influence of under damped motion, it oscillates with the amplitude gradually decreasing to zero.

When a body over damped, it returns to the equilibrium position without oscillating i.e. the body doesn't move from its equilibrium position. A body is un damped when it oscillates with constant amplitude, i.e. it never stops. When a body returns to equilibrium as fast as possible without oscillating, it is critically damped. One of the differences between critical damping and over damping is that, in the case of critical damping, the body returns to the equilibrium (i.e. rest) in the least amount of time. Shock absorbers are one of the examples of damping. The shock absorber is an example of a critically damped device. The main purpose of a shock absorber is to bring a body (that is moving) back to its equilibrium position as quickly as possible i.e. by the least time possible. Viscosity is the quantity that describes a fluid's resistance to flow[4]. The damping that occurs in shock absorber is viscous damping that causes the loss of energy for a moving body with the help of a liquid [5]. A hydraulic fluid is pushed through a small opening (the valve) that helps in absorbing the shock that the body goes through. The below Fig.(1) represent to understand the working of a shock absorber, it the figure a shock absorber is added below [6].

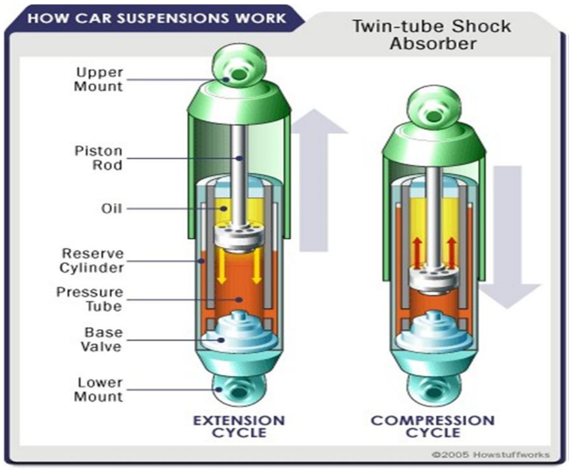

Figure-1 : Working of Shock observer

The shock absorbers work as a simple oil pump that pushes the hydraulic liquid that is stored in the reserve cylinder. The piston inside the shock absorber acts as a pump which eventually comes back to rest after getting compressed. They absorb the energy when the automobiles move on rough surfaces and when they go over bumps. These absorbers help the car to stay stable [7-11]. In this investigation, a mass of 1.50 kilograms attached to a spring suspended inside vegetable oil, and the spring was then extended to make the mass oscillate inside the vegetable oil. This model was just roughly used to compare with the working of the shock absorbers, as damping takes place in both of the situations, i.e. in the shock absorbers, and by the mass attached to the spring suspended in the vegetable oil. The time taken by the mass to stop oscillating in vegetable oil was measured. The time taken by the mass of 1.50 kilograms to stop oscillating was to be measured using a motion detector but this approach of measuring the time was unsuccessful due to various errors, later it was decided that the time was to be measured manually. These errors will be discussed later in conclusion and remarks. For this experiment study, trials were taken at different temperatures and their subsequent time was measured, and the change in the time with the change in the temperature was evaluated as well. The reason for choosing this topic is because of failure in the working of shock absorbers of the cars. The shock absorbers could cause more harm than just the comfort. It can also lead to damaging the brakes and the suspension of the vehicles, which could later contribute to unnecessary accidents. The shock absorbers in the regular vehicles, usually don’t work efficiently at extremely low temperatures. It was found, there’s a hydraulic fluid present inside it.

This fluid is pushed through the valves using a piston when the vehicle moves. When the car experiences a jerk, more of the hydraulic fluid is passed through the valve. Shock absorbers are meant to restrain the vibratory movements. At these, extremely low temperatures the hydraulic fluid present inside the shock absorber would freeze. For the working of the shock absorber, the rod present inside the shock absorber must move, in order to push the hydraulic fluid through the valve If the fluid itself were frozen, then it wouldn’t be possible for the rod to move. Same concept is applied for this work to study the effect of temperature variation on oil in oscillation of mass /load. The mass/ load selected in this study is 1.50 kilograms, to be attached to the spring the results are presented.

Hypothesis: It was hypothesized that the time taken by the load of 1.50 kilograms to stop oscillating would decrease as the temperatures drop and vice versa as the temperatures rise, i.e. the time taken by the oscillating load of 1.50 kilograms to come to rest will be longer as the temperature increases. This is assumed as the vegetable oil becomes more viscous as the temperature drops. The freezing point of the vegetable oil will be around —17.00. C. The vegetable oil that was used was sunflower oil. The freezing point will be calculated by substituting the time taken by the spring to stop oscillating as zero.

A. Model Specifications

Experiment performed using a motion detector: The initial model use for study is shown in below Fig. (2). At the initial stages of the experiment, the motion of the mass of 0.50 kilograms attached to the spring was observed using a motion detector. A disk was connected to the mass of 0.50 kilograms so that the motion detector detects it as it oscillates. The motion detector was placed right above the disk; it was placed at a distance from the detector to avoid it from colliding with the detector. After performing a few trials with this model, it was found that the time taken by the spring to stop oscillating was less than the time recorded by the motion detector.

The reasons for this could have been the natural factors-the room temperature was not controlled; the air pressure was not constant as well. In addition to that, the motion detector was taking readings at an interval of every 0.01 seconds, and at this rate of sample collection, 100 samples were being recorded. The rate could’ve been decreased to 20 samples per second at an interval of 0.05 seconds, but the position of the mass would change drastically in this amount of time. The time was being measured up to two decimal places. The mass of the load in this experiment was 0.50 kilograms, but since the mass was taking almost the same time stop oscillating at different temperatures, it was decided that the mass would be increased from 0.50 kilo grams to 1.50 kilograms. 1.50 kilograms was chosen as the optimum mass for the load that would be attached to the spring as it was showing results with notable difference with the change in temperature and this would be suitable to understand the relationship between the temperature of the vegetable oil and the time taken by the mass to stop oscillating. Also, it was decided that the time taken by the mass to stop oscillating in the vegetable oil, would be measured using a stopwatch. This would be a better alternative as the time taken for the mass to stop oscillating is being measured manually and while recording the time, the minimal uncertainties, like the movement of the mass by 0.0001m would be ignored, whereas while using the motion detector, the movement was measured up to four decimal places.

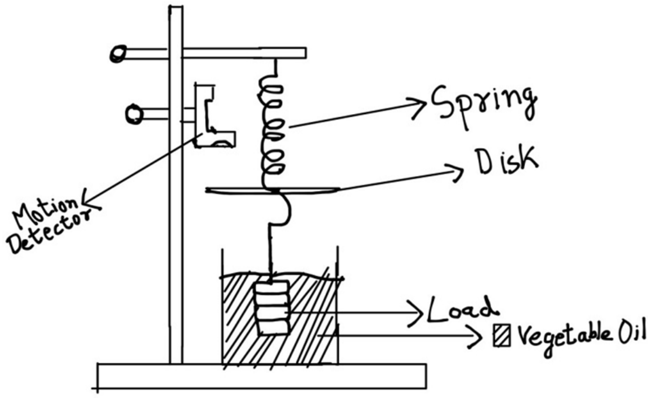

Figure-2: Initial model use for study

B. *Modified Model of the Experiment*

The modified model for this study is shown in below Fig (3). was pretty simple. In this model, the time was measured manually. Even though experimenting with this way had a few errors, it was better than the previous model, as the minimal errors were being neglected. For making this model of the experiment work, the same setup as the previous model was used. Only a few changes had to be made. The changes that were made in the installation were: - that the motion detector and the disk were removed. The time was measured using a stopwatch, so there was no use for the motion detector to be in the modified setup, and the disk was also not required as it was placed to help the motion detector detect the oscillations made by the mass. Keeping the disk would only increase the time taken by the mass of 1.50 kilograms to stop oscillating, as there would be an additional air resistance offered by the disk.

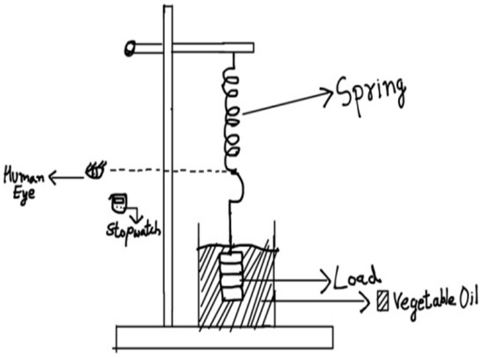

Figure-3: The modified model for this study

C. *Experimental Setup*

Spring: The key apparatus of the model that was used was the spring, which helped in simulating the movement of the automobile shock absorbers.

1) *Vegetable Oil:* This was used as a substitute to the hydraulic liquid that is present inside the shock absorbers.
2) Measuring Tape: A measuring tape was required, as the extension that was being made had been maintained constant throughout the experiment, i.e. during all the trials. The extension was being measured after each trial.
3) *Weights:* 1.50 kilograms of load was used to perform the experiment
4) *Weighing Scale:* This is just used to check the mass of the load that was hang on the spring.
5) *Beaker:* A two-liter beaker was used in this investigation. The beaker was filled with vegetable oil (1750.00 ±2.50 milliliters) and the mass of 1.50 kilograms was suspended in the oil present in the beaker.
6) Water bath- this was used to change the temperatures of the vegetable oil. Thermometer - this was an apparatus that had been used to measure the temperature of the oil.
7) *Measuring Cylinder:* A measuring cylinder (500.00±2.50 mL) was used to measure 1750.00 mL of vegetable oil.
8) *Stopwatch:* This was used in the second model of the experiment, which helped in recording the time taken by the mass attached to the spring to come to rest.

D. Calculations

- The mean time taken by the load of 1.50 kilograms to come to rest was calculated by adding up all the data recorded and then dividing this value by the total number of trials that were performed, and for this experiment, the number of trials was seven. The measured Data is entered in Table 1: Data 1.

It was calculated using the formula

(time in trial 1 + time in trial 2 + time in trial 3 + time in trial 4 + time in trial 5 + time in trial 6 + time in trial 7)/ 7

For example, for 10.00C mean time taken by the load of 1.50 kilograms to come to rest

=(8.80+9.30+8.85+8.62+9.10+8.50+8.23)/7 = 8.77s

- Finding the difference between the highest and the lowest value of the trials taken and then dividing the difference by two calculated the uncertainty in the mean time taken by the load of 1.50 kilograms to come to rest.

  It was calculated using the formula

  = (Maximum measured value − Minimum measured value)/2.00

  For example, for 10.00C

  = (9.30-8.23)/2.00 = 0.54s

The calculated value using the above formula is as shown in Table 2: Processed Data.

Table 1: Data 1

Temperatures of vegetable (C) $(\Delta = \pm 0.01\mathrm{C})$	Time taken by the load to come to rest (s) ($\Delta t=\pm 0.01$s)						
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7
10.00	8.80	9.30	8.85	8.62	9.10	8.50	8.23
20.00	11.06	11.94	10.50	10.87	11.20	11.80	10.20
30.00	14.12	13.66	13.97	14.40	13.88	13.62	14.81
40.00	19.03	18.80	19.70	18.99	19.84	19.64	18.10
50.00	22.75	22.80	23.20	22.40	22.71	23.50	23.60
60.00	25.30	24.60	24.40	24.68	25.50	24.20	24.90
70.00	27.10	28.40	28.10	28.70	27.80	28.20	27.70
80.00	33.30	32.10	31.80	32.60	32.60	33.10	32.10
90.00	36.50	37.20	36.40	35.90	35.40	36.20	36.70
100.00	39.20	37.10	38.40	37.90	38.70	39.90	38.60
110.00	42.30	43.10	41.90	43.40	42.13	41.70	43.30

Table 2: Processed Data

Temperatures of vegetable (C) $(\Delta = \pm 0.01^{!}\mathrm{C})$	Mean Time taken by the load to come to rest (s)	Uncertainty in the mean Time taken by the load to come to rest(Δ)
10.00	8.77	0.54
20.00	11.08	0.87
30.00	14.07	0.60
40.00	19.16	0.87
50.00	22.99	0.60
60.00	24.80	0.65
70.00	28.00	0.80
80.00	32.51	0.75
90.00	36.33	0.90
100.00	38.54	1.40
110.00	42.55	0.85

II. EXPERIMENTAL RESULTS AND DISCUSSION

As we can see in the graph the relationship between the temperature of the oil and the time taken by the load to come to rest is linear, i.e. as the temperature increases the time taken increases. Hence the hypothesis is true that the time taken by the mass of 1.50 kilograms would increase with an increase in the temperature and vice versa.

One of the objectives was to find the relationship between the temperature of the oil and the time was also found out.

There's a positive relationship between the temperature of the oil and the time taken by the mass to stop oscillating, as there is a relationship between the coefficient of viscosity and the temperature of the oil. Coefficient of viscosity is a measure to which a fluid resists flow when acted upon by a force [9]. As the temperature of the oil decreases, the oil becomes more viscous i.e. the coefficient of viscosity increases and the time taken by the mass to stop oscillating decreases. There is an inverse relationship between the temperature and the viscosity of the oil. As the temperature of the vegetable oil decreases, the coefficient of viscosity increases because the bonds between the molecules of vegetable oil get stronger.

The freezing point of the oil can be found using the gradient of the graph.

At the freezing point, the mass will not oscillate in the vegetable oil at all.

$y=0.34x+5.31$

$y= 0.00$

$0.00= 0.3384x+5.327$

$x=-5.31/0.34$

$c=-15.62$ C

Therefore, the freezing point of the vegetable oil that was used was -15.62C The freezing point of the oil cannot be used as an answer as, there would be no oscillations taking place at this temperature. The mass would be overdamped, as the mass would remain at the equilibrium position without oscillating. The objective was to find a temperature where the mass goes under critical damping.

The damping that takes place in the oscillations by the mass attached to the spring is under damped (between the temperatures ranging from 10.00C and 110.00C) because the coefficient of viscosity is low at these temperatures. However for the mass to go under critical damping, I would suggest a temperature ranging from (0.0C) –(-10.00C). At these temperatures, the coefficient of viscosity is high and it would be suitable as at these temperatures, the system would return to the equilibrium position in the shortest time without passing it.

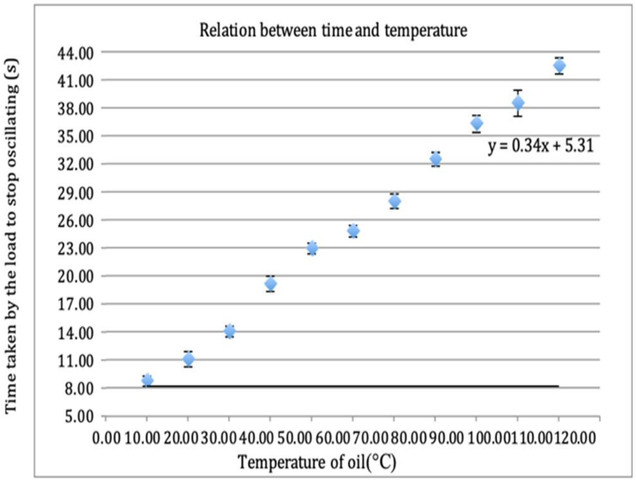

Figure-4: Variation in oil temperature versus time taken by the load to come at rest.

III. CONCLUSION AND REMARKS

The relationship between the two variables i.e. the temperature of the vegetable oil and the time taken by the mass of 1.50 kilograms to come to rest is linear. So it can be concluded that the increase in temperature of the vegetable oil does cause a fluctuation in the time taken by the mass attached to the spring to stop oscillating. The increase in temperature causes an increase in the time taken by the mass to stop oscillating.

As every experiment has some errors, this experiments had some errors as well. Different temperatures of the fluid were attained using an ice bath and a water bath. The oil that was present at the bottom of the beaker was reaching the required temperature, whereas the temperature of the oil at the top was fluctuating a lot. The reason for this was that: only the bottom half of the beaker was immersed in the water bath. This error could've been avoided by placing the oil in a sealed chamber, where the temperature could be controlled. The mass was immersed in the vegetable oil after the desired temperature of the oil was reached; the temperature of the mass was the same as the room temperature. This would've changed the temperature of the vegetable oil and would've contributed in changing the temperatures.

These could've been one of the reasons why the calculated freezing point of vegetable oil wasn't the same as the freezing point of the vegetable oil that was hypothesized.

A better liquid (like a petroleum-based fluid) could have been used instead of vegetable oil that would have the properties that are closely related to the hydraulic fluid present in the shock absorbers. The shock absorbers work in an airtight chamber where the liquid doesn't interact with the air in the surroundings, but in this experiment, the oil was interacting with the air, and the surroundings and the set up that was used to simulate the working of a shock absorber wasn't airtight as well. This could have been on of the main reasons that would have caused the errors in the experiment. If the experiment was to place in an airtight container, the results could've been much more accurate and the time that would be taken by the load to stop oscillating would've been quite less as compared to the results now. The freezing point calculated using the equation could've been closer to the one hypothesized.

Over here to show the mechanism of how the piston rod and the hydraulic fluid work, spring was used. However, this was a basic version of the simulation of the working of the shock absorber.

The force of impact and the jerks that are controlled by the shock absorbers are way too high when compared to the force that was acting on the mass oscillating in the liquid.

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BIO DATA

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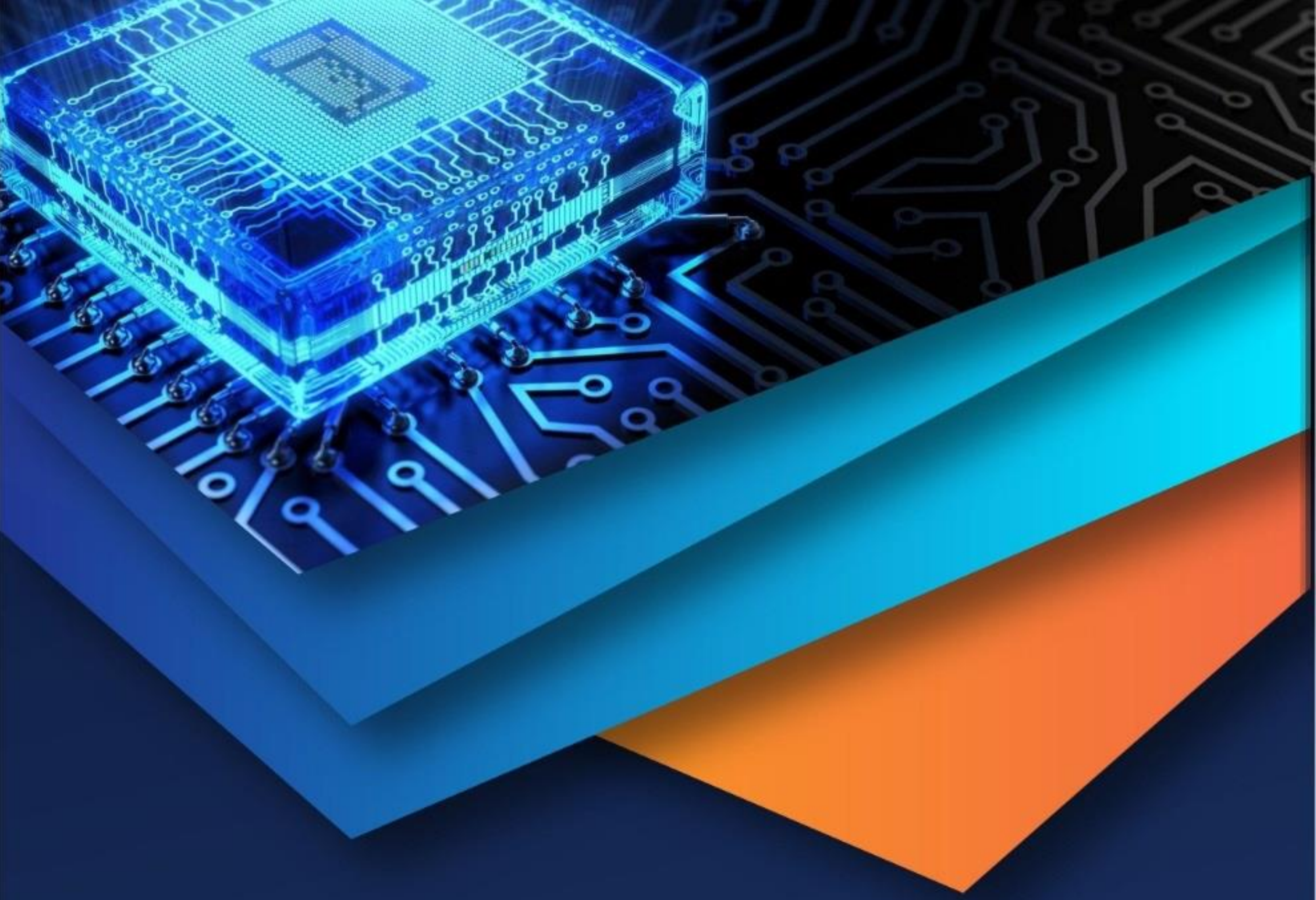

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