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EXPERIMENTAL HEAT TRANSFER STUDY ON THE SHOCK ABSORBER OPERATION

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Abstract. *This paper focused on the experimental heat transfer study on the shock absorber operation. The objective of this study is to analysis the heat transfer rate at surface absorber body. The shock absorber test rig was developed to collect experimental data. This test rig also useful to test and indicates the condition of shock absorber. A new and modify shock absorber twin tube type 1600cc will be used for this experiment. Ethanol and water are using as alternative substance for damping fluid to improve the air gap between the internal and outside body. Ten cycles of bounce and jounce shock absorber operation before heat transfer were measured. The problem of overheating will be effect of damping fluid characteristics and decrease shock absorber performance. However, using additive on damping fluid with water or ethanol will be good substance to improve heat transfer inside the absorber. Ethanol as a substance can be increased heat transfer inside absorber up to 38%. Furthermore, water has a higher thermal conductivity and increasing heat transfer rate better than ethanol; the result shows that using the water can increased the rate of heat transfer up to 45%. Finally, additive with higher thermal conductivity as the substance should give better heat transfer rate from inside absorber to surroundings.*

Keywords: Heat Transfer, Shock Absorber, Damping Fluid, Water and Ethanol.

Introduction

An automotive suspension system is meant to provide safety and comfort for the occupants. Shock absorber is an important part of automotive suspension system which has an effect on ride characteristics such as ride comfort and driving safety. In every moving vehicle there must have a good suspension to absorb the shock of the tires and wheels meeting bumps and holes in the road. The suspension system looks unnecessary to us but it gives a great responsibility or doing an important job to give a safety ride. If there is no suspension install to the vehicle, it will cause a great shock when the tire meets bad condition of the road and give some damage to the component inside the vehicle. It also gives uncomfortable to the driver and passenger when the car is taking corner or breaking.

One part of the suspension is the absorber. It is connected between the frame and suspension. Shock absorbers may increase the ride-height which could affect the stability of the car and thus the safety. However, the handling of some cars may even improve by using these shock absorbers. Thus the shock absorber can give results in the best road holding, safety and comfort. Shock absorbers are also critical for tire to road contact which to reduce the tendency of a tire to lift off the road [1]. This affects braking, steering, cornering and overall stability [2]. The removal of the shock absorber from suspension can cause the vehicle bounce up and down. It is possible for the vehicle to be driven, but if the suspension drops from the driving over a severe bump, the rear spring can fall out [3].

The goal of the shock absorber is to dampen spring oscillation by converting the kinetic energy from spring movement into heat energy [2]. In order to reduce spring oscillation, shock absorber absorbs energy. The shock absorber absorbs different amounts of energy depending on how fast the suspension is moving. If high heat inside the absorber occurs, it will heat the damping fluid. This will change the molecular structure and density of fluid inside the absorber that cause it's damping capability to be decrease. In other words, shock absorber also could be call as the energy converter.

Heat transfer occurs when there has a temperature different in a medium or between media. When a temperature gradient exists in a stationary medium, which may be a solid or a fluid, the term conduction is use to refer to the heat transfer that will occur across the medium [4]. Shock absorbers absorb shock on the road and

change the kinetic energy into heat energy. The internal energy variation consists of one term of elastic energy variation related to oil temperature [5]. Today's shock absorber is either mono tube or double tube design. The early style of shock absorber used friction to absorb the spring energy. Nowadays, modern shock absorber operate hydraulically with one end is attached to the suspension and the other is attached to the frame. The hydraulically shock absorber are basically oil pump that force the oil through the opening called orifice. This action generates hydraulic friction, which convert kinetic energy to heat energy as it reduces unwanted motion [6]. The hydraulic shock absorber can operate through many cycles without wearing because the internal friction is fluid friction. The temperature of the working fluid in the liquid spring significantly alters the properties for working fluids, e.g. bulk modulus and viscosity [7]. It is widely know that shock absorber characteristics vary with temperatures.[4]

Shock Absorber Test Rig

The design of shock absorber test rig has been developed for vibration measurement system. This product actually developed to test and indicates the condition of shock absorber in automotive vehicle. As it functioning, this product can be used as a tool to verify the capability of shock absorber. The Figure 1 shows the complete of the design of shock absorber test rig.

This shock absorber test rig is a rigid structure with two main components connected vertical. The upper vertical is the shock absorber while the lower connection to the base structure is the pneumatic cylinder. The upper and lower component is divided by the middle plate. This middle plate is supported with two units of guide shaft for smooth movement. The shaft holder is placed at each end of the guide shaft for protecting and secures the guide shaft joints. The complete shock absorber test rig is system consist of a few important parts which are:

- Shock absorber
- Guide shaft
- Linear guide bushes
- Air cylinder
- Air Regulator
- Air pilot valve

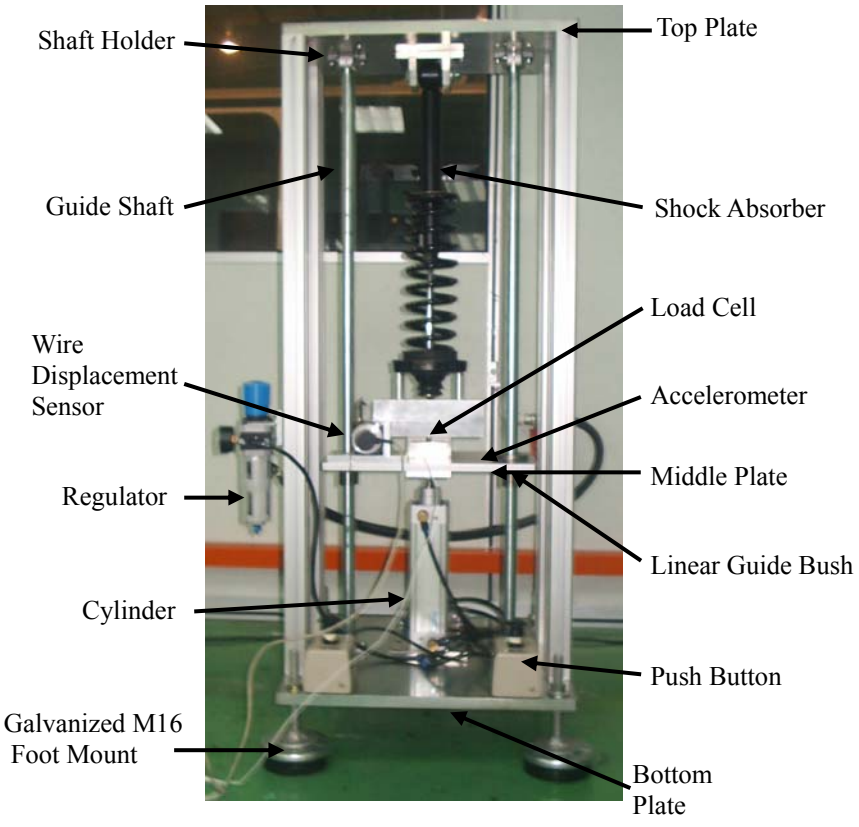

Figure 1: The design of shock absorber test rig

Result and Discussion

Result of Testing Aftermarket Shock Absorber (1st Design-Air Substance)

The testing of aftermarket shock absorber is started with getting the early absorber performance and characteristic. Before the experiment is started, the room temperature and surface temperature of the absorber was measured. The experiment is started to make 100 cycles of bounce and jounce for 10 times. Surface temperature will be measure after the end of each experiment. The results are shown as follow:

Room temperature : 26.9 °C
Early temperature at the x (upper part) : 26.9 °C
Early temperature at the y (middle part) : 27.0 °C
Early temperature at the z (lower part) : 27.0 °C

Table 1**:** Arising temperature result for 1st design of absorber (air substance)

Exp.	Cycle	Temperature at x (◦C)	Temperature at y (◦C)	Temperature at z (◦C)
1	+100	26.9	27.0	27.0
2	+100	27.0	27.2	27.3
3	+100	27.1	27.3	27.5
4	+100	27.3	27.5	27.7
5	+100	27.6	27.8	28.0
6	+100	27.7	27.9	28.2
7	+100	27.8	28.3	28.6
8	+100	28.0	28.6	28.9
9	+100	28.4	28.9	29.2
10	+100	28.7	29.3	29.7

From the result above, the graph temperature against number of cycle can be plotted to show how the temperature rising at the 3 part of the absorber.

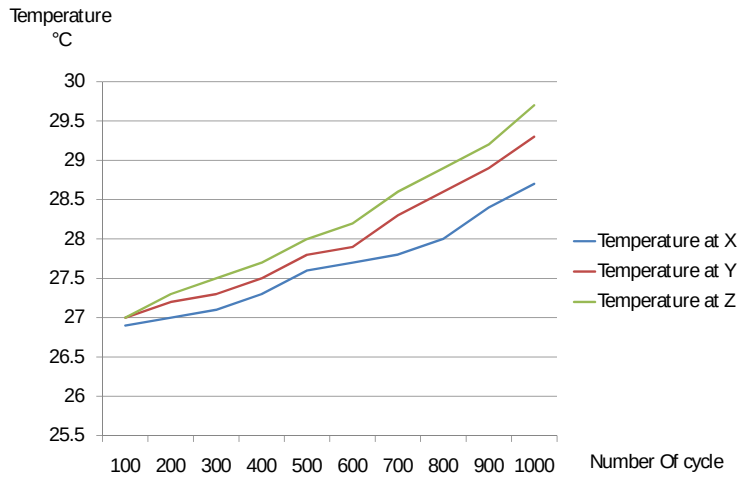

Figure 2**:** Graph temperature versus number of cycle for air substance

From the result and graph plotted above, it shows that the early temperature at the three places; upper, middle and lower part is similar with the room temperature. The temperature for the three places on the surface absorber is increases with number of cycle. This shows that the absorber is heated when it is operate. The lower part at mark Z has a higher temperature rising between both the middle and upper part of the absorber that is 2.7 °C. This is because the distance for the piston inside the absorber crossing at point Z is higher than at point X and Y.

As the piston compress and expand to absorb the shock, it will give a force to the oil inside the absorber. The friction force will occur at the piston surface and this friction force will transfer to heat energy around the surface cylinder. The arising temperature at point X and Y is 1.8 °C and 2.3 °C for the total 1000 cycle of bounce and jounce.

Calculation of Heat Flux :-

Heat Flux $q_{x"} = -K\ \partial T/\partial X$ ……(1)

Where:

∂T = Temperature difference

∂X= Distance/ Thick of absorber body

K= Thermal Conductivity

At point X:

$q_{x"} = (-0.026\ WM^{-1}K^{-1})\ (-1.8K)/(0.02M) = \underline{2.34\ WM^{-2}}$

At point Y:

$q_{x"} = (-0.026\ WM^{-1}K^{-1})\ (-2.3K)/(0.02M) = \underline{2.99\ WM^{-2}}$

At point Z:

$q_{x"} = (-0.026\ WM^{-1}K^{-1})\ (-2.7K)/(0.02M) = \underline{3.51\ WM^{-2}}$

Maximum heat flux for experiment using air substance is $3.51\ WM^{-2}$

Result of 2nd Design of Shock Absorber: Using Ethanol As Substance

In order to modify and improve the heat transfer inside the absorber, an ethanol is use as a first substance insert inside the absorber to fill the air gap between the internal cylinder (which contains piston and damping fluid) and outside cylinder. The ethanol characteristic is shown as below:

Table 2: Properties of Ethanol

Molecular formula	C_2H_5OH
Molar mass	46.06844(232) g/mol
Appearance	Colorless clear liquid
Density	0.789 g/cm³, liquid
Melting point	−114.3 °C (158.8 K)
Boiling point	78.4 °C (351.6 K)
Thermal Conductivity	0.14 W/m K
Specific Heat Capacity	2.48 KJ/kgK

The room temperature and surface temperature of the absorber was measured in the beginning. The experiment is started to make 100 cycles of bounce and jounce for 10 times. Surface temperature will be measure after the end of each experiment. The results are shown as follow

Room temperature : 27.7 °C

Early temperature at the x (upper part) : 27.8 °C

Early temperature at the y (middle part) : 27.8 °C

Early temperature at the z (lower part) : 27.9 °C

Table 3: Arising temperature result for 2nd design of absorber (ethanol substance)

Exp.	Cycle	Temperature at x (◦C)	Temperature at y (◦C)	Temperature at z (◦C)
1	+100	28.0	28.0	28.3
2	+100	28.2	28.4	28.7
3	+100	28.5	28.7	29.0
4	+100	28.9	29.0	29.4
5	+100	29.3	29.5	29.8
6	+100	29.6	29.8	30.1
7	+100	29.9	30.2	30.5
8	+100	30.3	30.6	30.7
9	+100	30.5	30.8	31.0
10	+100	30.7	31.0	31.4

From the result above, the graph temperature against number of cycle can be plotted to show how the temperature rising at the 3 part of the absorber.

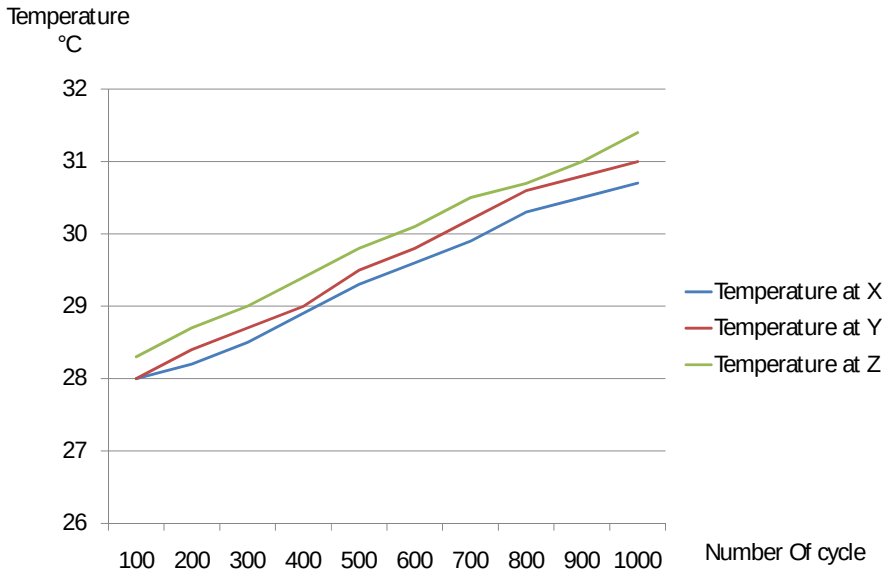

Figure 3: Graph temperature versus number of cycle for ethanol substance

The temperature for the three places on the surface absorber is increases rapidly with number of cycle. This shows that the heat inside the absorber is transfer out of the absorber very well. The lower part at mark Z has a higher temperature rising between both the middle and upper part of the absorber that is 3.5 °C due to high friction force occur at this area. The arising temperature at point X and Y is 2.9 °C and 3.2 °C for the total 1000 cycle of bounce and jounce. This shows that using ethanol as substance at the middle between internal and outside cylinder has increase the rate of heat transfer from inside absorber through surrounding.

Calculation of Heat Flux:-

At point X: $q_{x"} = (-0.14\ WM^{-1}K^{-1})\ \underline{(-2.9K)}\ (0.02M) = \underline{20.3\ WM^{-2}}$

At point Y: $q_{x"} = (-0.14\ WM^{-1}K^{-1})\ \underline{(-3.2K)}\ (0.02M) = \underline{22.4\ WM^{-2}}$

At point Z: $q_{x"} = (-0.14\ WM^{-1}K^{-1})\ \underline{(-3.5K)}\ (0.02M) = \underline{24.5\ WM^{-2}}$

Maximum heat flux for experiment using ethanol is 24.5 WM^{-2}

Result of 3rd Design of Shock Absorber: Using Water As Substance

After testing the absorber using ethanol, modification is continue by using water as substance. Water is filling between the inside and outside cylinder. The characteristic of water is shown as below:

Table 4: Properties of Water

Molecular formula	H_2O
Molar mass	18.0153 g/mol
Density and Phase	0.998g/cm³ (liquid at 20 °C) 0.92 g/cm³ (solid)
Melting point	0 °C (273.15 K) (32 °F)
Boiling point	100 °C (373.15 K) (212 °F)
Thermal Conductivity	0.67 W/m K
Specific Heat Capacity	4.184 KJ/kgK

The room temperature and surface temperature of the absorber was measured before starting 100 cycles of bounce and jounce for 10 times. Surface temperature will be measure after the end of each experiment. The

results are shown as follow:

Room temperature : 26.2 °C
Early temperature at the x (upper part) : 26.2 °C
Early temperature at the y (middle part) : 26.3 °C
Early temperature at the z (lower part) : 26.3 °C

Table 5: Arising temperature result for 3rd design of absorber (water substance)

Exp.	Cycle	Temperature at x (◦C)	Temperature at y (◦C)	Temperature at z (◦C)
1	+100	26.4	26.5	26.5
2	+100	26.8	26.9	27.0
3	+100	27.2	27.4	27.6
4	+100	27.6	28.0	28.2
5	+100	27.9	28.3	28.6
6	+100	28.3	28.5	28.9
7	+100	28.8	28.9	29.2
8	+100	29.0	29.3	29.4
9	+100	29.4	29.6	29.9
10	+100	29.5	29.8	30.4

From the result above, the graph temperature against number of cycle can be plotted to show how the temperature rising at the 3 part of the absorber.

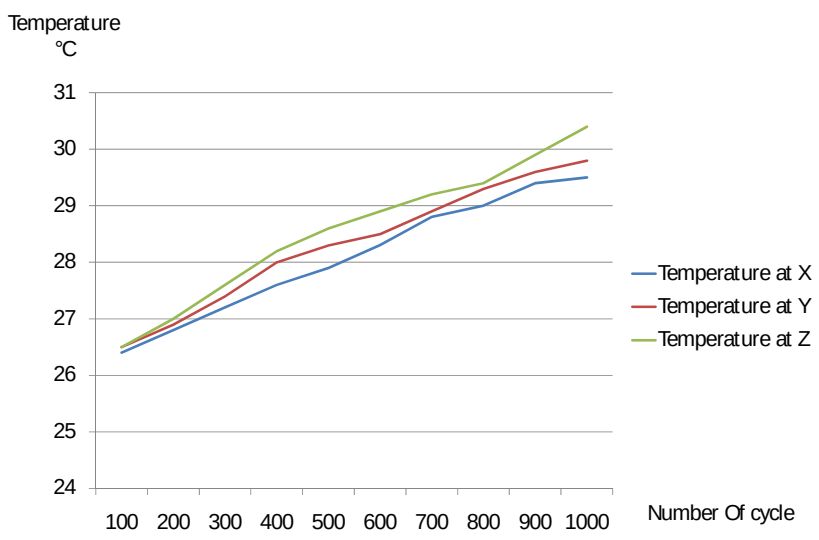

Figure 4 : Graph temperature versus number of cycle for water substance

The temperature for the three places on the surface absorber is increases rapidly with number of cycle. This shows that the heat inside the absorber is transfer out of the absorber very well similar with the result for air and ethanol substance. The lower part at mark Z has a higher temperature rising between both the middle and upper part of the absorber that is 4.1 °C due to high friction force occur at this area. The arising temperature at point X and Y is 3.3 °C and 3.5 °C for the total 1000 cycle of bounce and jounce. This shows that using water give a better result than using ethanol. From the graph, it is shows that the rate of heat transfer using water is higher than ethanol and air substance.

Calculation of Heat Flux :-

At point X: $q_{x"} = (-0.67\ WM^{-1}K^{-1})\ \underline{(-3.3K)}\ (0.02M) = \underline{110.55\ WM^{-2}}$
At point Y: $q_{x"} = (-0.67\ WM^{-1}K^{-1})\ \underline{(-3.5K)}\ (0.02M) = \underline{117.25\ WM^{-2}}$
At point Z: $q_{x"} = (-0.67\ WM^{-1}K^{-1})\ \underline{(-4.1K)}\ (0.02M) = \underline{137.35\ WM^{-2}}$
Maximum heat flux for experiment using water is 137.35 WM^{-2}

From the analysis of shock absorber result for 1st, 2nd and 3rd design, the obvious difference of increasing temperature at surface body of the absorber become a major parameter in this analysis. Based on the result that is obtained from the experimental, the temperature rising for the modify design is better than the aftermarket design. These values can be explained in percentage of difference. From the calculation based on the data that has been gathered from the experimental, the percentages of difference between modify design using ethanol as the substance and aftermarket design that contain the air gap inside the shock absorber 1600cc without spring in term of arising temperature at point Z is 22.86%. Meanwhile, for the arising temperature at point Y, the percentage of difference is 28.13%. For the arising temperature at point X, the percentage of difference is 37.93%. The percentage of difference between the modify design using water as the substance and aftermarket design shock absorber 1600cc without spring in term of arising temperature at point Z is 34.15%. Meanwhile, for the arising temperature at point Y, the percentage of difference is 34.29%. For the arising temperature at point X, the percentage of difference is 45.45%. From the experimental and analysis, it is obviously shows that the arising temperature for modify design is much better than the aftermarket design. This is because the ethanol and water has a high thermal conductivity than the air. The ethanol and water help transfer the heat inside the absorber through the outside body proportionate with air. This experiment also proof that the higher value of thermal conductivity can give a better heat transfer through the substance. The ethanol has a higher thermal conductivity than the air but has a lower thermal conductivity comparing with water. Using water as the substance to fill the air gap inside the absorber can give a more improvement to the absorber. The higher temperature rising at the surface body of the absorber gives higher advantage to the absorber. This is because the temperature is transfer out of the absorber and prevents the damping fluid inside the absorber from being heated. This can save the damping fluid from changing its properties and the performance of the absorber can still maintain although being use for a long time

Conclusion

The purpose of this project is to test and modify the absorber using the different working fluids. As the absorber operates, it will become heated. If the heat cannot be transfer very well through the surrounding, it will heated the damping fluid inside the absorber thus changes the damping fluid characteristic and decreasing the absorber performance. In order to overcome this problem, a substance that has a high thermal conductivity must be added inside the absorber. Many existence absorbers have an air gap between the internal cylinder and outside body of the absorber. The air has a lower thermal conductivity which is a poor substance to transfer an amount of heat. Using ethanol as a substance can improve the heat transfer inside the absorber up to 38%. However, using water can give better result than the ethanol, increasing the rate of heat transfer up to 45%. This is because water has a higher thermal conductivity than ethanol. This shows that water is a good substance to improve the heat transfer inside the absorber and the absorber will have a long time usage.

Acknowledgement

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References

[1] Don Knowles. Today's Technician: *Automotive Suspension & Steering System, Shop manual,* 3rd Edition. Cliftorn Park, NY: Delmar Learning, 2003.
[2] Tim Gilles. *Automotive Chassis: Brake, Steering & Suspension*, 2005
[3] Thomas W. Birch. *Automotive Suspension & Steering System*, 3rd Edition, 1999.
[4] Incropera,Dewitt,Bergman and Lavine. *Introduction to Heat Transfer,* Wiley 5th Edition, 2007
[5] J.C.Ramos, A.Rivas, J. Biera, G. Sacramento and J.A.Sala. *Development of a Thermal Model for Automotive Twin-Tube Schock Absorbers.* Journal Applied Thermal Engineering 25(2005) 1836-1853
[6] W. Schiehlen and B. Hu. *Spectral Simulation and Shock Absorber Identification*, International Journal of Non-Linear Mechanics. Volume 38, Issue 2, March 2003, Pages 161-171
[7] A.K. Smantaray. *Modeling and Analysis of Preloaded Liquid Spring/Damper Shock Absorbers*