

Experimental Analysis and Heat Transfer Study of Damping Fluid in Hydraulic Twin Tube Shock Absorber

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Abstract--- The Aim Of The Research Focused On The Experimental Heat Transfer Study Of The Damping Fluid In 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 Will Be Used For This Experiment. Ethylene Glycol, Propylene Glycol 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 Ethylene Glycol, Propylene Glycol Will Be Good Substance To Improve Heat Transfer Inside The Shock Absorber. Propylene Glycol As A Substance Can Be Increased Heat Transfer Inside Absorber Up To 39%. Furthermore, Ethylene Glycol Has A Higher Thermal Conductivity And Increasing Heat Transfer Rate Better Than Propylene Glycol; The Result Shows That Using Ethylene Glycol The Can Increased The Rate Of Heat Transfer Up To 52%. Finally, Additive With Higher Thermal Conductivity As The Substance Should Give Better Heat Transfer Rate From Inside Absorber To Surroundings.

Key Words: — Heat Transfer, Shock Absorber Tester, Damping Fluid, Fluid Substance.

I. 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. Following Objectives Of Suspension System,

1. To Prevent Shocks From Rough Road.
2. To Preserve Stability While Rolling & Pitching During Vehicle In Motion.
3. To Give Comfort & Smooth Ride.

The Goal Of The Shock Absorber Is To Dampen Spring Oscillation By Converting The Kinetic Energy From Spring Movement Into Heat Energy. 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. 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. 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. 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. It Is Widely Know That Shock Absorber Characteristics Vary With Temperatures.

II. SHOCK ABSORBER TESTER

According To Experiment To Produce Actual Damping Condition Of Shock Absorber In Room It Is Necessary To Construct A Device Which Can Produce Up And Down Movement Of Shock Absorber. Shock Absorber Tester Was

developed for this purpose. The shock absorber test rig was developed to collect experimental data.

As shown in figure that the structure will consist of strong policed bar which supported on gearbox body. Strong bar which is tied together with a strong top plate. One plate is placed on guide shaft which can be adjustable according to height of shock absorber. For up and down of shock absorber crank mechanism used to sliding steel rod connected with connecting rod and revolve according to crank mechanism. One end of absorber body fitted on top plate in which internal grooves developed according to thread of rod of absorber, and another end fitted at the end of sliding rod. The 3-phase motor directly mounted on gearbox flies and gear box supported on base steel channels.

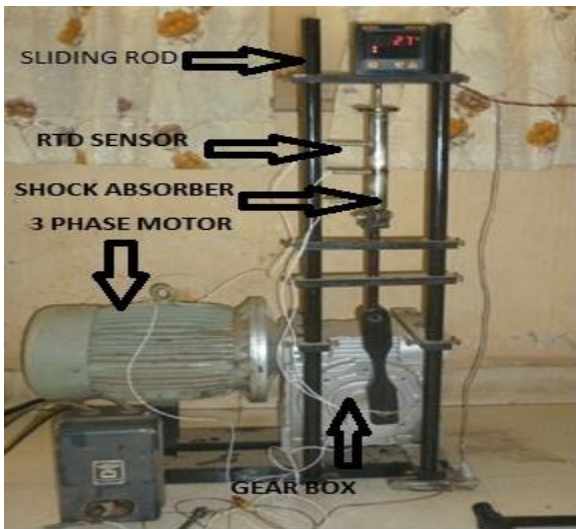


Fig. 1: Shock absorber test rig

III. RTD SENSOR

In order to estimate the absolute temperature of shock absorber RTD (resistant temperature detection) is used and brazed on the surface of shock absorber to measure surface temperature. RTDs are temperature sensors that contain a sensing element whose resistance change with temperature. According to our use in experiment 3 Wire configurations is comfortable with display unit. This is the standard wire configuration for most RTDs. It provides one connection to one end and two to the other end of the RTD sensor. Connected to an instrument designed to accept three-wire input, compensation is achieved for lead resistance and temperature change in lead resistance. This is the most commonly used configuration.

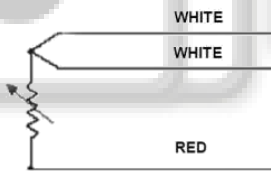


Fig. 2: Three wire RTD with line diagram

IV. MODIFIED SHOCK ABSORBER

Mostly common double tube shock absorber, the top and bottom cylinder ends are pressed from steel sheet, typically with amounting bush ring spot welded into the bottom one. The lower cup is welded to the cylinder and foot valve inserted. The piston, piston valve, rod, rod bush housing, top cup and the seal and bearing are assembled. The piston and oil is inserted and top cup welded or crimped into place. According to our requirement to change and fill damping oil and additives shock absorber top is not welded but one flange is developed and brazed with top side cylinder of the shock absorber body and cover plate is developed which fitted with flange by screw and sliding rod passed in the cover plate, so good sealing is conducted and problem of oil leakage is overcome which act as seal, so removal and filling of oil is easy.



Fig. 3: Shock absorber modifications

V. RESULT AND DISCUSSION

A. Shock Absorber with Air Substance

The testing of shock absorber is started with getting the early absorber performance. 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: 30.9 °C

Early temperature at the A: 30.9 °C

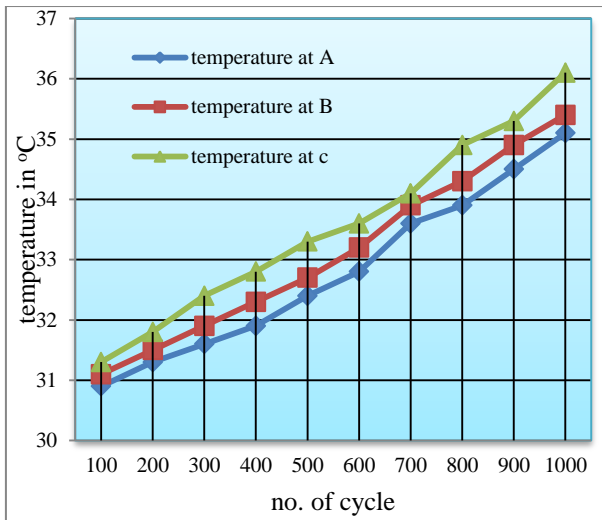
Early temperature at the B: 31.1 °C

Early temperature at the C: 31.3 °C

Table 1: Arising temperature of shock absorber with air substance

Exp.	cycle	Temperature in °C		
		A	B	C
1	100	30.9	31.1	31.3
2	200	31.3	31.5	31.8
3	300	31.6	31.9	32.4
4	400	31.9	32.3	32.8
5	500	32.4	32.7	33.3
6	600	32.8	33.2	33.6
7	700	33.6	33.9	34.1
8	800	33.9	34.3	34.9
9	900	34.5	34.9	35.3
10	1000	35.1	35.4	36.1

From the recorded data, the graph of temperature against number of cycle can be plotted to show how the temperature rising at the 3 different points.



Graph. 1: Arising Temperature with Air Substance in Shock Absorber

From the result and graph plotted above the temperature for the five places on the surface absorber are increases with number of cycle. This shows that the absorber is heated when it is operate.

Calculation of Heat Flux:-

$$q = -K \frac{\partial T}{\partial X}$$

Where;

∂T = Temperature difference in °C

∂X = Distance/Thickness of Shock Absorber Body in metre

K = Thermal conductivity in W/Mk

q = Heat flux in W/m²

B. Calculation of Heat Flux for Air substance:-

Heat flux at Point A:-

$$q = -K \frac{\partial T}{\partial X} = -[0.026] \frac{(-3.9)}{0.019} = 5.34 \text{ W/m}^2$$

Heat flux at point B:-

$$q = -[0.026] \frac{(-4.3)}{0.019} = 5.88 \text{ W/m}^2$$

Heat flux at point C:-

$$q = -[0.026] \frac{(-4.8)}{0.019} = 6.5 \text{ W/m}^2$$

Maximum heat flux for experiment using air substance is 6.5 W/m².

C. Shock Absorber With Ethylene Glycol

In order to improve the heat transfer inside the absorber, Ethylene glycol 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. Ethylene glycol characteristic is shown as below:

Table-2 Properties of Ethylene glycol

Name	Ethylene glycol
Molecular formula	C ₂ H ₆ O ₂
Molecular mass	62.07 g/mol
Appearance	Colorless liquid
Boiling point	185°C up to 197 °C
Melting point	-12.9 °C
Density	1097 Kg/m ³
Thermal conductivity	0.258 W/mK
Specific heat	2.36 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: 31.3 °C

Early temperature at the A: 31.3 °C

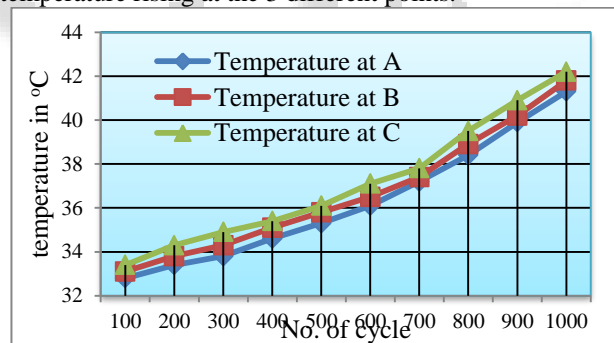
Early temperature at the B: 31.4 °C

Early temperature at the C: 31.5 °C

Table-3 Arising temperature of shock absorber with Ethylene glycol substance

Exp.	cycle	Temperature in °C		
		A	B	C
1	100	32.8	33.1	33.4
2	200	33.4	33.8	34.3
3	300	33.8	34.3	34.9
4	400	34.6	35.1	35.4
5	500	35.3	35.8	36.1
6	600	36.1	36.5	37.1
7	700	37.2	37.4	37.8
8	800	38.4	38.9	39.5
9	900	39.9	40.2	40.9
10	1000	41.3	41.8	42.2

From the recorded data, the graph of temperature against number of cycle can be plotted to show how the temperature rising at the 3 different points.



Graph-2 Arising Temperature with Ethylene Glycol Substance in Shock Absorber

Calculations of heat flux for Ethylene Glycol substance:-

Heat flux at Point A:-

$$q = -K \frac{\partial T}{\partial X} = -[0.258] \frac{(-8.7)}{0.019} = 118.13 \text{ W/m}^2$$

Heat flux at point B:-

$$q = -[0.258] \frac{(-9.0)}{0.019} = 122.21 \text{ W/m}^2$$

Heat flux at point C:-

$$q = -[0.258] \frac{(-9.3)}{0.019} = 126.28 \text{ W/m}^2$$

Maximum heat flux for experiment using air substance is 126.28 W/m².

D. Shock Absorber with Propylene Glycol

In order to improve the heat transfer inside the absorber, Propylene Glycol 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. Propylene Glycol characteristic is shown as below:

Table-4 Properties of Propylene glycol

Name	Propylene Glycol
Molecular formula	C ₃ H ₈ O ₂
Molecular mass	76.09 g/mol
Appearance	Colorless liquid
Boiling point	187 °C
Melting point	-59 °C
Density	965.3 Kg/m ³
Thermal conductivity	0.147 W/mK
Specific heat	2.5 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: 33.2 °C

Early temperature at the A: 33.3 °C

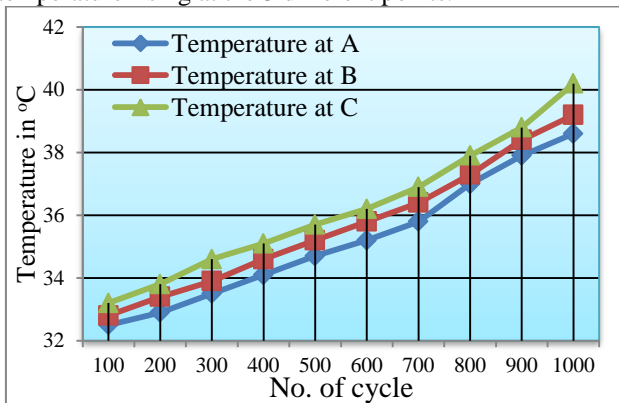
Early temperature at the B: 33.6 °C

Early temperature at the C: 33.7 °C

Table-5 Arising temperature of shock absorber with propylene glycol substance

Exp	cycle	Temperature in °C		
		A	B	C
1	100	32.5	32.8	33.2
2	200	32.9	33.4	33.8
3	300	33.5	33.9	34.6
4	400	34.1	34.6	35.1
5	500	34.7	35.2	35.7
6	600	35.2	35.8	36.2
7	700	35.8	36.4	36.9
8	800	37	37.3	37.9
9	900	37.9	38.4	38.8
10	1000	38.6	39.2	40.2

From the recorded data, the graph of temperature against number of cycle can be plotted to show how the temperature rising at the 3 different points.



Graph-3 Arising Temperature with Propylene Glycol Substance in Shock Absorber

From the result and graph plotted above, it shows that the early temperature at the three points is similar with the room temperature. The temperature for the three places on the surface absorber is increases with number of cycle.

Calculation of Heat Flux for Propylene Glycol substance:-

Heat flux at Point A:-

$$q = -K \frac{\partial T}{\partial X} = -[0.147] \frac{(-6.4)}{0.019} = 49.51 \text{ W/m}^2$$

Heat flux at point B:-

$$q = -[0.147] \frac{(-6.7)}{0.019} = 53.38 \text{ W/m}^2$$

Heat flux at point C:-

$$q = -[0.147] \frac{(-7.7)}{0.019} = 59.57 \text{ W/m}^2$$

Maximum heat flux for experiment using air substance is 59.57 W/m².

From the analysis of shock absorber with using substances like ethylene glycol and propylene glycol give the obvious difference of increasing temperature at surface body. It becomes a major parameter in this research work of air-gap investigation. 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 ethylene glycol as the substance and aftermarket design that contain the air gap inside the shock absorber without spring in term of arising temperature at point C is 48.39%. Meanwhile, for the arising temperature at point B, the percentage of difference is 49.51%. For the arising temperature at point A, the percentage of difference is 51.72%.The percentage of difference between the modify design using propylene glycol as the substance and aftermarket design shock absorber without spring in term of arising temperature at point C is 37.67%.Meanwhile, for the arising temperature at point B, the percentage of difference is 37.69%. For the arising temperature at point A, the percentage of difference is 39.07%.

From the experimental and analysis, it is obviously shows that the arising temperature for modify design is much better than the aftermarket design. It is obviously shows that the arising temperature for modify design is much better than the aftermarket design.

From the calculation based on the data that has been gathered from the experimental, maximum Heat flux with modify design using ethylene glycol as the substance and aftermarket design that contain the air gap inside the shock absorber is 126.28 (W/m²), maximum Heat flux with modify design using propylene glycol as the substance and aftermarket design that contain the air gap inside the shock absorber is 59.57 (W/m²).

From economical view we know that both the substance is easily available and cost of its distillation is not so high and health hazard from ethylene glycol is higher than propylene glycol because ethylene glycol is more toxic for human and animal life, but still we can use ethylene

glycol and propylene glycol because of its capability with ISO68 oil and heat transfer advantage as the substance for heat transfer. Both the substances are non-corrosive, so we can use both substances.

This experiment also proof that the higher value of thermal conductivity can give a better heat transfer through the substance. The propylene glycol has a higher thermal conductivity than the air but has a lower thermal conductivity comparing with ethylene glycol 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.

VI. CONCLUSION

The purpose of this experiment 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 propylene glycol has a substance can improve the heat transfer inside the absorber up to 39%.
- Using ethylene glycol can give better result than the propylene glycol, increasing the rate of heat transfer up to 52%.

This is because ethylene glycol has a higher thermal conductivity than propylene glycol. This shows that ethylene glycol is a good substance to improve the heat transfer inside the absorber and the absorber will have a long time usage.

VII. FUTURE SCOPE

1. The experimental study can be investigated with other available fluid substances like glycerol and toluene.
2. The top cylinder ends of shock absorber body are mostly pressed from steel sheet, which cannot be further use, so which replaced by flange and cover plate which give direction to reuse.
3. Improvement in shock absorber fluid, and additive or substance for increase heat transfer should be obtained.

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