Experimental Analysis and Heat Transfer Study of Damping Fluid in Shock Absorber Operation

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***Abstract* - The aim of this research work is to Study the Heat Transfer in Air-gap and in Shock Absorber body and from body to surround, to complete this objectives Shock Absorber test Rig was constructed. Most of shock absorber contains the air gap inside the shock absorber between internal cylinder and outer body, Air gap has lower heat transfer rate, and so Problem of overheating will be effect of damping fluid characteristics and decrease shock absorber performance, to improve heat transfer air gap is filled by fluid substance like ethylene glycol, propylene glycol and glycerol and collect Required data of improved Heat Transfer into Shock Absorber , Finally ethylene glycol as a substance can be increased heat transfer inside absorber up to 52%, And propylene glycol as a substance can be increase heat transfer inside shock absorber up to 39 but glycerol give maximum heat transfer rate up to 64 % . With increase heat transfer rate from inside absorber to surroundings problem of overheating of damper fluid should be decrease and maintain shock absorber performance for long time.**

Key Words - Heat Transfer, Shock Absorber Tester, Propylene glycol, Ethylene glycol, Glycerol

I. INTRODUCTION

The Automobile chassis is or body mounted on Axels but not directly but through some form of spring to provide Safety and Comfort. This spring system called suspension system. 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. 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 energy of road shock causes the spring to oscillate, this oscillation are Restricted to a reasonable level by Shock absorber. The purpose of Shock Absorber is to dissipate any energy into vertical motion of body or any motion arises from rough road. [6]

The removal of damper from suspension system can cause the vehicle Bounce up and down, and uncomfortable ride in order to reduce spring oscillation shock absorber absorbed energy. 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. [6]

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.[7]The shock absorber absorb different amount of energy depend on vehicle driving pattern and road condition. Shock absorber used fluid friction to absorb the spring energy. The shock absorber is 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 , If high Heat inside the absorber occurs, it will heat the damping fluid this can change the damping fluid property and also damping capacity decrease. 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. Heat transfer occurs when there has temperature difference when shock absorber absorbed shock on Road and change the kinetic energy into heat energy. The temperature of working fluid in the damper significantly alters the property of working fluid. It is widely known that shock absorber configuration change with change in temperature. [6]

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 date.[2] 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. [3]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.

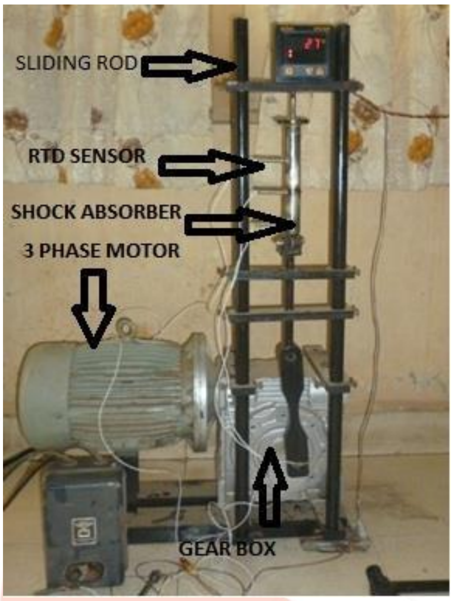


Fig. 1 Shock absorber test rig (www.ijsrd.org)

III. RTD SENSOR (RESISTANCE TEMPERATURE DETECTOR)

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.[3] 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. [4]

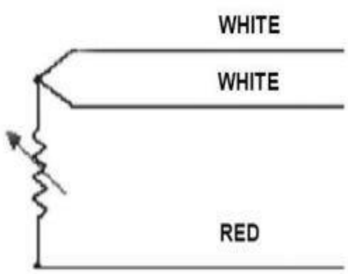


Fig. 2 Three wire RTD with line diagram (www.ijsrd.org)

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 (www.ijsrd.org)

V. RESULT AND DISCUSSION

A. Shock Absorber with Air Substance

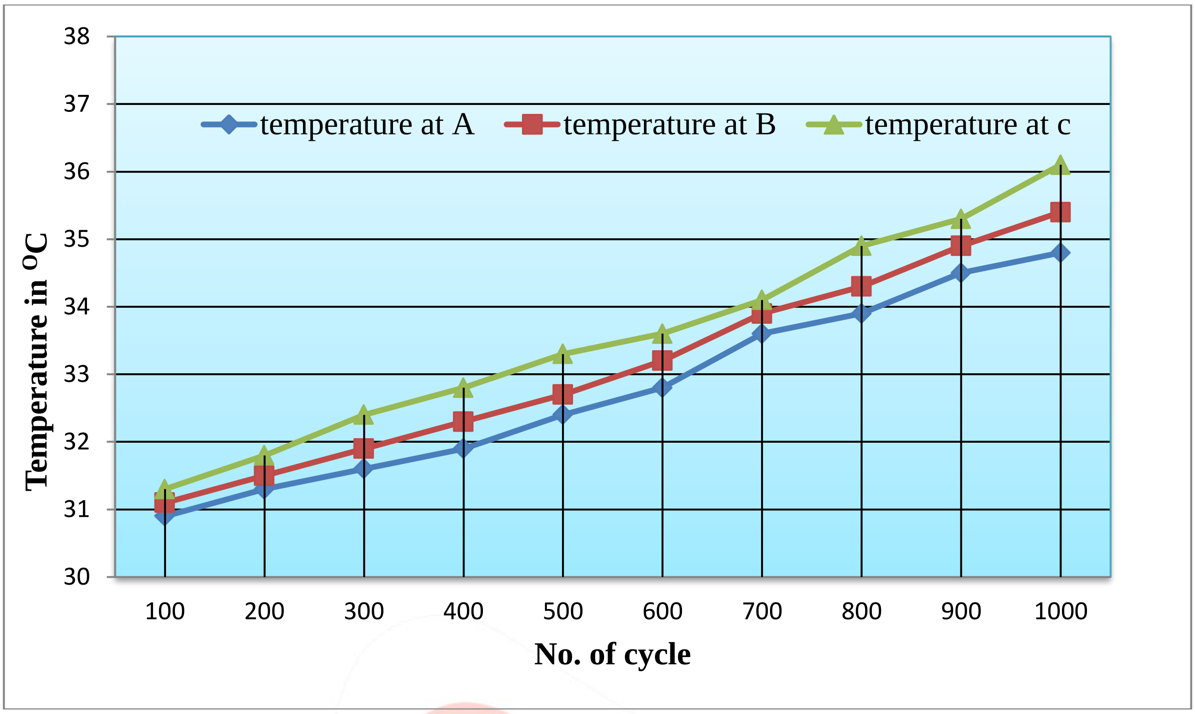
The testing of shock absorber is started with getting the early absorber performance. Before the experiment is started, the room temperature and surface temperature of the absorber was measured. The experiment is started to make 100 cycles of bounce and jounce for 10 times. Surface temperature will be 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 at A	Temperature at B	Temperature at 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	34.8	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:-

$$q = -K\frac{dT}{dX}$$

Where;

dT =Temperature difference in ^oC

dX=Distance/Thickness of Shock Absorber Body in metre

K= Thermal conductivity in W/mK

q= Heat flux in W/m^2

Calculation of Heat Flux for Air substance:-

Heat flux at Point A:-

$$q = -K\frac{dT}{dX} = [-0.026]\frac{(-3.9)}{0.019} = 5.34\ W/m^2$$

Heat flux at point B:-

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

Heat flux at point C:-

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

Maximum heat flux for experiment using air substance is 6.5 W/m^2

B. 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	$C_2H_6O_2$
Molecular mass	62.07 g/mol
Appearance	Colorless liquid
Boiling point	185^{o}C up to 197 ^{O}C
Melting point	-12.9 ^{O}C
Density	1097 Kg/m^3
Thermal conductivity	0.258 W/mK
Specific heat	2.36 KJ/KgK

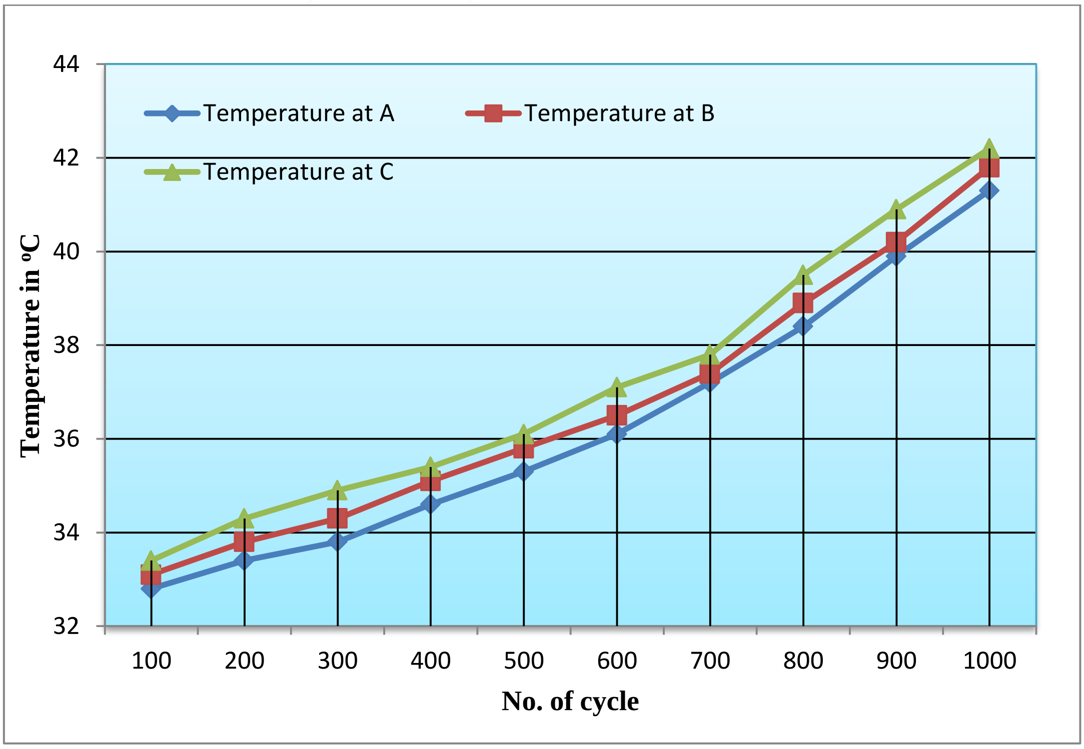
The room temperature and surface temperature of the absorber was measured in the beginning. The experiment is started to make 100 cycles of bounce and jounce for 10 times. Surface temperature will be measure after the end of each experiment. The results are shown as follow;

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 at A	Temperature at B	Temperature at 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:-

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

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/m^2.

C. 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

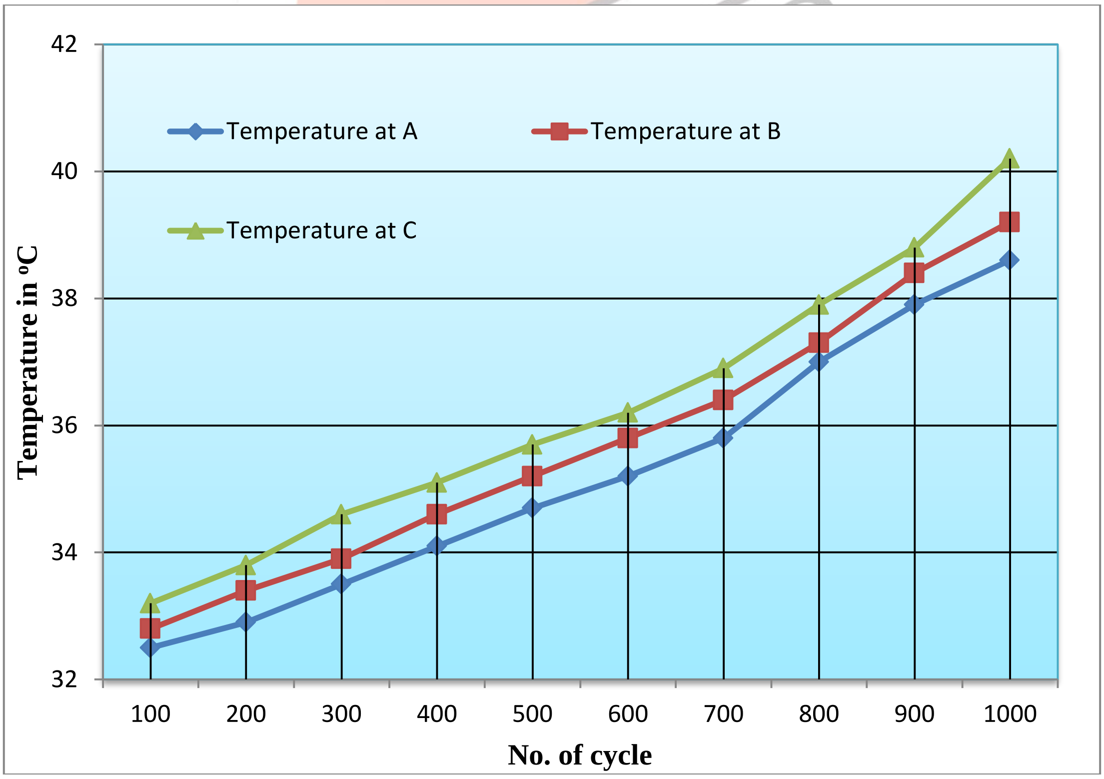
Name	**Propylene glycol**
Molecular formula	$C_3H_8O_2$
Molecular mass	76.09 g/mol
Appearance	Colorless liquid
Boiling point	187 ^{O}C
Melting point	-59 ^{O}C
Density	965.3 Kg/m^3
Thermal conductivity	0.147 W/mK

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 at A**	**Temperature at B**	**Temperature at 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

Calculation of Heat Flux for Propylene Glycol substance:-
Heat flux at Point A:-

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

Heat flux at point B:-

$$q = -[0.147]\frac{(-6.9)}{0.019} = 53.38 \text{ W/m}^2$$

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/m^2.

D. Shock absorber with glycerol

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. Glycerol characteristic is shown as below:

Table-6 Properties of Glycerol

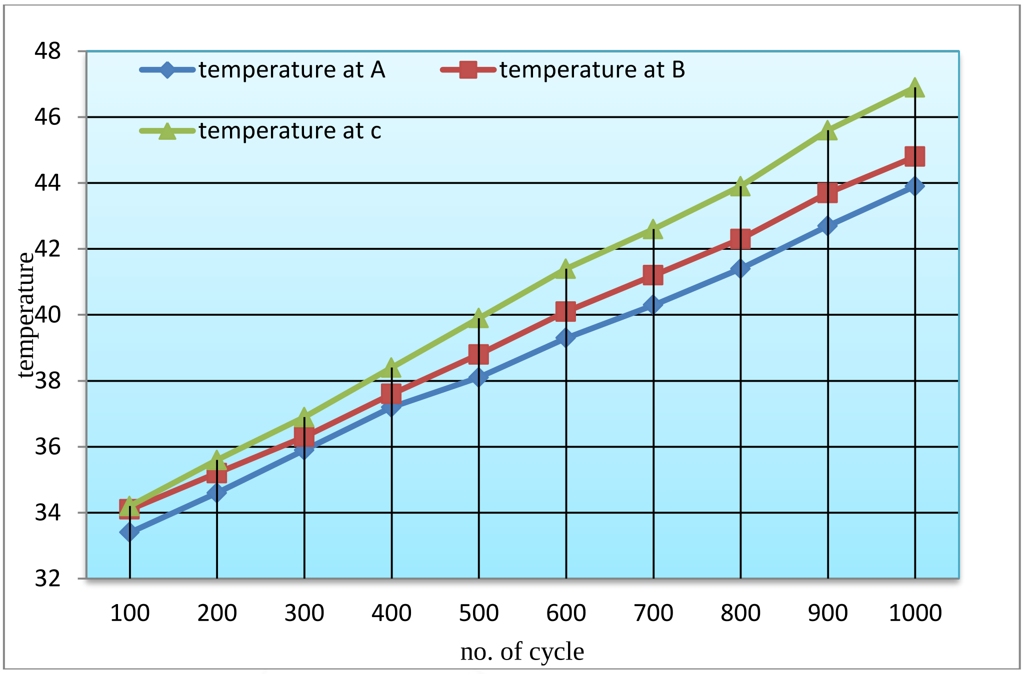
Name	Glycerol
Molecular formula	$C_3H_8O_3$
Molecular mass	92.09 g/mol
Appearance	Colorless liquid
Boiling point	$290^{O}C$
Melting point	$17.8^{O}C$
Density	1126 Kg/m^3
Thermal conductivity	0.28 W/mK

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: 33.1°C
Early temperature at the A: 33.3 °C
Early temperature at the B: 33.5 °C
Early temperature at the C: 33.6 °C

Table-7 Arising temperature of shock absorber with glycerol substance

Exp	cycle	Temperature at A	Temperature at B	Temperature at C
1	100	33.4	34.1	34.2
2	200	34.6	35.2	35.6
3	300	35.9	36.3	36.9
4	400	37.2	37.6	38.4
5	500	38.1	38.8	39.9
6	600	39.3	40.1	41.4
7	700	40.3	41.2	42.6
8	800	41.4	42.3	43.9
9	900	42.7	43.7	45.6
10	1000	43.9	44.8	46.9

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-4 Arising Temperature with Glycerol Substance in Shock Absorber

Calculation of Heat Flux for Glycerol substance:-

Heat flux at Point A:-

$$q = -K\frac{dT}{dX} = -[0.28]\frac{(-10.6)}{0.019} = 156.21 W/m^2$$

Heat flux at point B:-

$$q = -[0.285]\frac{(-11.3)}{0.019} = 166.52\ W/m^2$$

Heat flux at point C:-

$$q = -[0.28]\frac{(-13.3)}{0.019} = 196\ W/m^2$$

Maximum heat flux for experiment using air substance is 196 W/m^2.

This shows that the absorber is heated when it is operate. 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.

From the analysis of shock absorber result with different substance, the obvious difference of increasing temperature at surface body of the absorber become a major parameter in this analysis. Based on the result that the temperature rising for the modify design is 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 turpentine as the substance and aftermarket design that contain the air gap inside the shock absorber is 6.5 (W/m^2), 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/m^2). 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/m^2). Maximum Heat flux with modify design using glycerol as the substance and aftermarket design that contain the air gap inside the shock absorber is 196 (W/m^2). From the experimental and analysis, it is obviously shows that the arising temperature for modify design is much better than the aftermarket design.

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 and glycerol 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%.
- Using glycerol can give better result than the both the glycol, increasing the rate of heat transfer up to 64%.

This is because glycerol has a higher thermal conductivity than propylene glycol and ethylene glycol. This shows that glycerol 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.
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.
4. This experimental study can be investigated with convection correlations and measuring internal cylinder damping fluid temperature and to find the convective heat transfer coefficient.

VIII. REFERENCES

[1] Mohd Shahrir Mohd. Sani, Erlifi Husin & Muhamad Mat No " Experimental heat transfer study on the shock absorber operation" International Conference on Science & Technology: Applications in Industry& Education (2008)

[2] M.S.M.Sani, M.M. Rahman "Dynamic Characteristics of Automotive Shock Absorber System" Malaysian Science and Technology Congress, MSTC08, 16~17 Dec, KLCC, Malaysia, 2008.

[3] Hussein Mohammed, Hanim Salleh, Mohd Zamri Yusoff. "Design and fabrication of coaxial surface junction thermocouples for transient heat transfer measurements", International Communications in Heat and Mass Transfer 35 (2008) 853–859.

[4] Carl D Heritier1"Design of Shock Absorber Test Rig for UNSW@ADFA Formula SAE Car"

[5] K. Danisman a, I. Dalkiran a, F.V. Celebi "Design of a high precision temperature measurement system based on artificial neural network for different thermocouple types Measurement" 39 (2006) 695–700.

[6] Thomas W. Birch. Automotive Suspension & Steering System,3 rd Edition, 1999. (Book)

[7] Incropera, Dewitt,Bergman and Lavine. Introduction to Heat Transfer, Wiley 5th Edition, 2007 (Book)

[8] J.C.Ramos,A.Rivas,J.Biera,G.Sacramento and J.A.Sala."Development of a Thermal Model for Automotive Twin-Tube Shock Absorbers.Journal Applied Thermal Engineering 25(2005) 1836-1853

[9] W. Schiehlen and B.Hu. "Spectral Simulation andShock Absorber Identification",International Journal of Non-Linear Mechanics. Volume 38, Issue 2, March 2003, Pages 161-171.