ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Experimental Heat Transfer Analysis of Air Gap in Twin Tube Shock Absorber

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Abstract:
This research work is focused on the experimental heat transfer study on the shock absorber operation. The aim of this study is to analyze the heat transfer rate at surface absorber body. For this shock absorber test equipment was fabricated to collect experimental data. A new and modified twin tube shock absorber type was used for this experiment. Water, glycerol and Ethylene glycol are using as alternative substance for damping fluid to improve the air gap between the internal and outside body. Before the cyclic operation of Shock absorber heat transfer was measured. The complication of excessive heating will effect the shock absorber fluid characteristics which reduce shock absorber performance. However, using additive with damping fluid either Ethylene glycol or glycerol or water will be good substance to improve heat transfer inside the absorber. Ethylene glycol as a substance can be increased heat transfer inside absorber up to 41.9%. And glycerol as a substance can be increased heat transfer inside absorber up to 45.38%. Furthermore, water has a higher thermal conductivity and increasing heat transfer rate better than ethylene and glycerol; the result shows that using the water can increase the rate of heat transfer up to 54.8%. In the end, shock absorber will transfer more heat to the surroundings if we use higher thermal conductivity additive substance.

Keywords: ***Shock Absorber, Ethylene Glycol, Glycerol, Water, Shock absorber Test Rig.***

I. Introduction

The Automobile chassis is or a body mounted on Axels which is not directly but through some form of spring to provide Safety and Comfort. This is generally referred as suspension system of a vehicle. Following are the objectives of a 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.

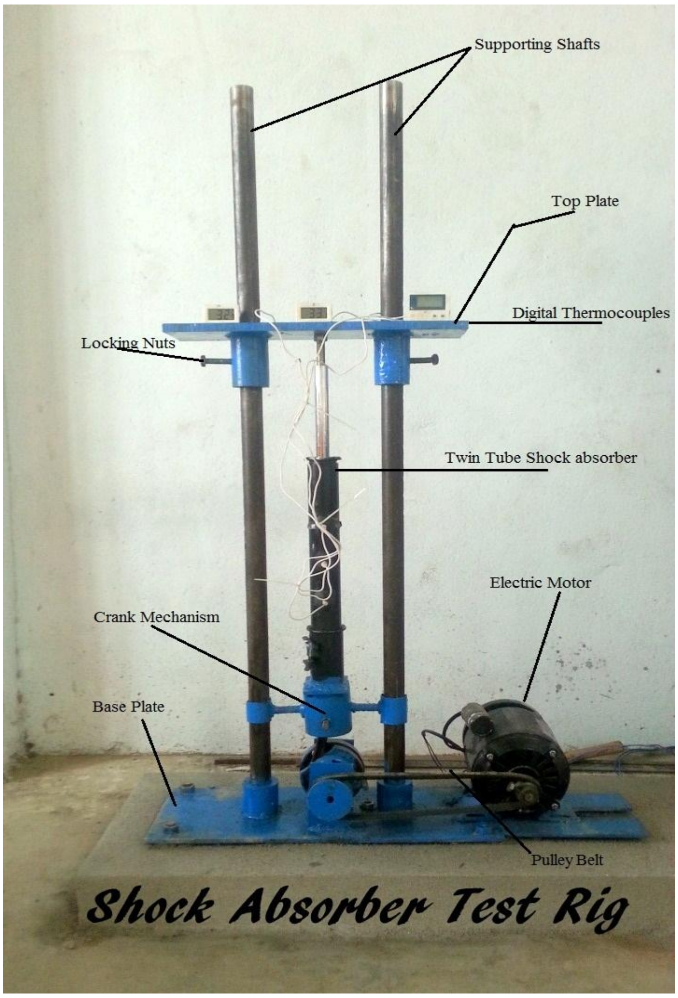
The energy affected from road shock causes the spring to oscillate, these oscillations are restricted to a reasonable level by Shock absorber. The objective of Shock Absorber is to disperse any energy from vertical motion of body or any motion arises from uneven road. The absence of damper from suspension system can cause the vehicle Bounce up and down, and to avoid this uncomfortable ride generated from spring oscillation, shock absorber absorbs produced energy. The amount of energy obsorbed depends on vehicle driving pattern and road condition. Shock absorber uses fluid friction to absorb the spring energy [1]. The shock absorber is basically an oil pump that forces the oil through an opening called orifice. This action generates hydraulic friction, which translates kinetic energy to heat energy as it reduces unwanted motion. If high Heat inside the absorber occurs, it will heat the damping fluid which results in change of damping fluidic property along with decrease in damping capacity.

The temperature of working fluid in the damper significantly alters the fluidic properties of it. It is evidently known that shock absorber configuration change with change in temperature [2].

Cite this article as: Prema Jyothi P. & Jagadish Sai T., "Experimental Heat Transfer Analysis of Air Gap in Twin Tube Shock Absorber", International Journal & Magazine of Engineering, Technology, Management and Research, Volume 5 Issue 1, 2018, Page 1-6.

II. Shock Absorber Test Rig

To get the real-time working damping condition of shock absorber, it is necessary to fabricate 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 you can see in the above figure the structure will consist of strong policed bar inserted in to bushes provided on base plate [3].



These bars were provided with number of holes to vary the volume of shock absorber cylinder. Strong bars which are tied together with a strong top plate. This top plate was adjustable according to the necessity. For up and down of shock absorber crank mechanism was used. This crank and piston mechanism was taken from a scooter engine. Piston head is modified to assemble and disassemble the shock absorber. And piston is guided with two supporting bushes to get linear movement. Shock absorber cylinder is fitted with three thermocouples at three different points to measure the temperature. Finally the shock absorber cylinder is welded on top of the modified piston head. The crank is rotated with the help of an electric motor connected by a belt [4-7].

III. Thermocouples

In order to identify the absolute temperature of shock absorber, thermocouple is brazed on the surface of shock absorber to measure surface temperature. According to our use in experiment three thermocouples are placed uniformly on shock absorber body.

IV. Result and Discussion

Result of 1st Design of Shock Absorber: (Air as a Substance)

The experimenting of aftermarket shock absorber is started with getting the earlier absorber performance and characteristics. 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 [8].

Surface temperature will be measure after the end of each experiment. The results are shown as follow:

Room temperature: 31.9 °C

Early temperature at the A (upper part): 31.9 °C

Early temperature at the B (middle part): 32.1 °C

Early temperature at the C (lower part): 32.3°C

Exp.	Cycle	Temperature		
		A	B	C
1	100	31.9	32.1	32.1
2	100	32.3	32.5	32.8
3	100	32.6	32.9	33.4
4	100	32.9	33.3	33.8
5	100	33.4	33.7	34.3
6	100	33.8	34.2	34.6
7	100	34.6	34.9	35.1
8	100	34.9	35.3	35.9
9	100	35.5	35.9	36.3
10	100	35.8	36.4	37.1

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

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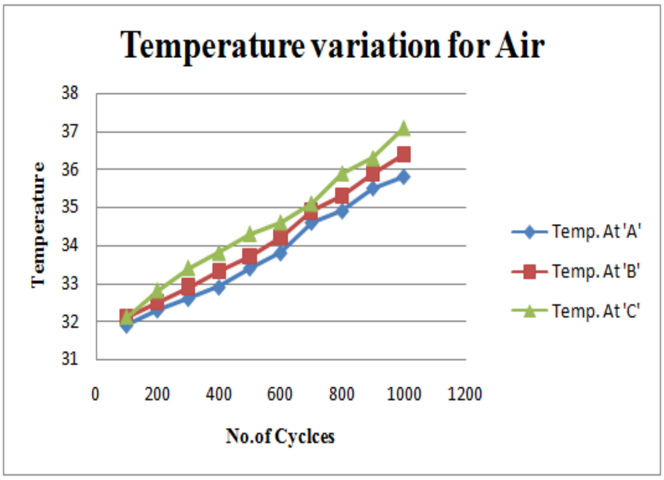
From the result above, the graph temperature against number of cycle can be plotted to show how the temperature rising at the 3 part of the absorber.



Graph 1: Temperature versus number of cycle for air substance

Calculation of Heat Flux:-
Heat Flux q = -K ∂T/∂X
Where:
∂T = Temperature difference
∂X= Distance/ Thick of absorber body
K= Thermal Conductivity
At point A:
q=(-0.026wm-1K-1)(-3.9K)/(0.02m)= 5.07 wm-2

At point B:
q=(-0.026wm-1K-1)(-4.3K)/(0.02m)= 5.59 wm-2

At point C:
q =(-0.026 wm-1K-1) (-5K)/(0.02m)=6.5 wm-2
Maximum heat flux for air substance 6.5 wm-2
Result of 2nd Design of Shock Absorber: (Using Water as Substance)

In order to modify and improve the heat transfer inside the absorber, water was used as a first substance inside the absorber to fill the air gap between the internal (which contains piston and damping fluid) and external cylinder. The characteristics of water were shown as below:

Table 2: Properties of Water

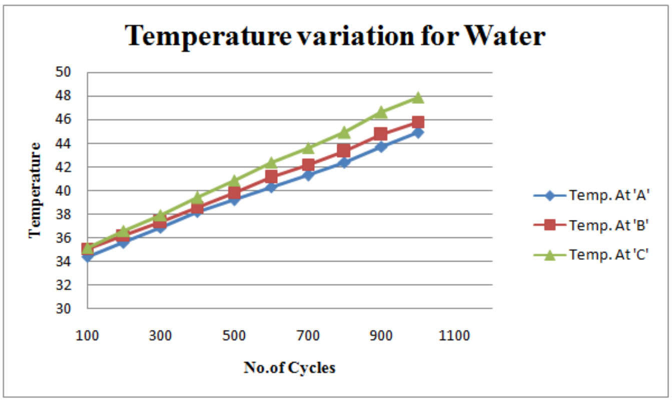
Molecular formula	H_2O
Molar Mass	18.0153 g/mol
Density and Phase	0.998g/cm³(liquid at 20° C) 0.92 g/cm³ (Solid)
Melting Point	0 °C (32 °F; 273 K), 1 atm
Boiling Point	100°C (373.12K) (212°F)
Thermal Conductivity	0.67 W/m.K
Specific Heat Capacity	4.184 KJ/kgK

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

Room temperature: 35.5 °C
Early temperature at the A (upper part): 35.3 °C
Early temperature at the B (middle part): 35.4 °C
Early temperature at the C (lower part): 35.4°C

Exp.	Cycle	Temperature		
		A	B	C
1	100	35.5	35.6	35.6
2	100	36.1	36.3	36.5
3	100	36.7	36.8	36.9
4	100	37.3	37.5	37.8
5	100	38.1	38.3	38.5
6	100	38.9	39.1	39.5
7	100	39.9	40.3	40.8
8	100	40.8	41.1	41.5
9	100	42.1	42.5	42.8
10	100	43.2	43.4	43.2

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



Graph 2: Temperature versus number of cycle for Water substance

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International Journal & Magazine of Engineering, Technology, Management and Research
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From the result above, the graph temperature against the number of cycles can be plotted to show how the temperature rising at the 3 part of the absorber.

Calculation of Heat Flux:-

At point A:

q=(-0.67wm-1K-1)(-7.7K)/(0.02m)=257.95wm-2

At point B:

q=(-0.67wm-1K-1)(-7.9K)/(0.02m)=264.65wm-2

At point C:

q=(-0.67wm-1K-1)(-7.6K)/(0.02m)=254.65wm-2

Maximum heat flux for experiment using water substance is 264.65 wm-2

Result of 3rd Design of Shock Absorber: Using Ethylene Glycol as Substance

After testing the absorber using water, the modification is continued by using ethylene glycol as substance. Ethylene glycol is filling between the inside and outside cylinder. The characteristic of Ethylene Glycol is shown as below:

Table 4: Properties of Ethylene glycol

Molecular formula	$C_2H_6O_2$
Molar Mass	62.07 g/mol
Density	1097 kg/m³
Melting Point	-12.9 °C
Boiling Point	197.3°C
Thermal Conductivity	0.258 W/m.K
Specific Heat Capacity	2.36 KJ/kgK

Room temperature: 32.3 °C

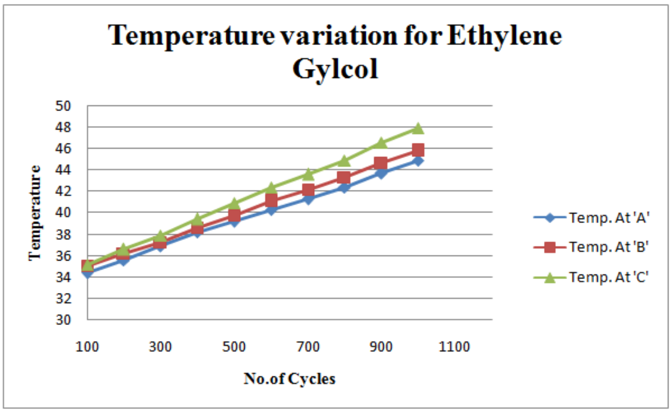
Early temperature at the A (upper part): 32.3 °C

Early temperature at the B (middle part): 32.4 °C

Early temperature at the C (lower part): 32.5°C

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

Exp.	Cycle	Temperature		
		A	B	C
1	100	33.8	34.1	34.4
2	100	34.4	34.8	35.3
3	100	34.8	35.3	35.9
4	100	35.6	36.1	36.4
5	100	36.3	36.8	37.1
6	100	37.1	37.5	38.1
7	100	38.2	38.4	38.8
8	100	39.4	39.9	40.5
9	100	40.9	41.2	41.9
10	100	42.3	42.8	43.2



Graph 3: Temperature versus number of cycle for Ethylene Glycol substance

Calculation of Heat Flux:-

At point A:

q=(-0.258wm-1K-1)(-8.7K)/(0.02m)= 112.23wm-2

At point B:

q=(-0.258wm-1K-1)(-9K)/(0.02m) = 116.1wm-2

At point C:

q=(-0.258wm-1K-1)(-9.3K)/(0.02m)=119.7wm-2

Maximum heat flux for experiment using ethylene glycol substance is 119.7 wm-2

Result of 4th Design of Shock Absorber: Using Glycerol as Substance

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

Table 6: Properties of Glycerol

Molecular formula	$C_3H_8O_3$
Molar Mass	92.09382 g/mol
Density	1126 kg/m³
Melting Point	17.8 °C
Boiling Point	290.3°C
Thermal Conductivity	0.28 W/m.K
Appearance	Colorless Liquid

Room temperature: 34.3 °C

Early temperature at the A (upper part): 34.3 °C

Early temperature at the B (middle part): 34.5 °C

Early temperature at the C (lower part): 34.6 °C

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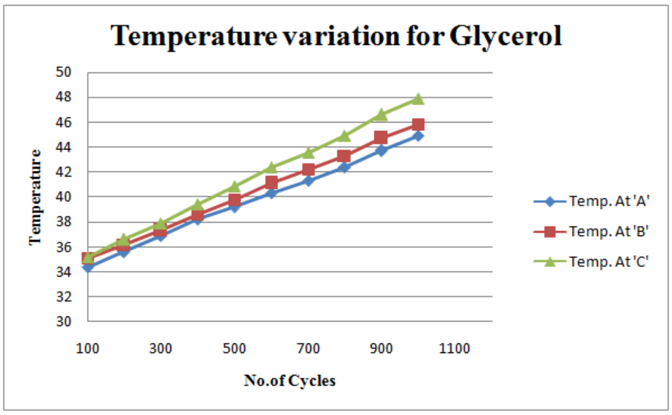
Exp.	Cycle	Temperature		
		A	B	C
1	100	34.4	35.1	35.2
2	100	35.6	36.2	36.6
3	100	36.9	37.3	37.9
4	100	38.2	38.6	39.4
5	100	39.2	39.8	40.9
6	100	40.3	41.1	42.4
7	100	41.3	42.2	43.6
8	100	42.4	43.3	43.9
9	100	43.2	43.7	44.6
10	100	44.5	44.8	44.9

Table 7: Arising temperature result for 4th design of absorber (Glycerol substance)



Graph 4: Temperature versus number of cycle for glycerol substance

Calculation of Heat Flux:-
At point A:
q=(-0.28wm-1K-1)(-10.6K)/(0.02m)=148.4wm-2
At point B:
q=(-0.28wm-1K-1)(-11.3K)/(0.02m)=158.2wm-2
At point C:
q=(-0.28wm-1K-1)(-13.3K)/(0.02m)=186.2wm-2
Maximum heat flux for experiment using glycerol substance is 186.2 wm-2

From the analysis of shock absorber result for 1st, 2nd, 3rd and 4th design, the obvious difference of increasing temperature at the 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 modified design is better than the aftermarket design. These values can be explained in the percentage of difference [9]. From the calculation based on the data that has been gathered from the experimental, Heat Flux aftermarket design that contain the air gap inside the shock absorber is 6.5 (W/m2), 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 119.7 (W/m2). Maximum Heat flux with modified design using glycerol as the substance and aftermarket design that contains the air gap inside the shock absorber is 186.2 (W/m2). Maximum Heat flux with modified design using water as the substance and aftermarket design that contain the air gap inside the shock absorber is 264.65 (W/m2). From the experimental and analysis, it is obviously shown that the arising temperature for modified design is much better than the aftermarket design [10].

This experiment proves that the higher value of thermal conductivity can give a better heat transfer through the substance. The Glycerol and Ethylene glycol has a higher thermal conductivity than the air but has a lower thermal conductivity compared with water. Opting water as the substance to fill the air gap inside the absorber can improve the performance of the absorber. The higher temperature rising at the surface body of the absorber gives a higher advantage to the absorber [11]. This happens because of the temperature is transferred out of the absorber and restricts 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 used for a long time.

V. Conclusion

The motive of this experiment is to test and modify the absorber using the different working fluids. As the absorber operates, it will get heated up. 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 existing shock 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 Water as a substance can improve the heat transfer inside the absorber up to 54.8%.
- Using ethylene glycol can give a better result than the air, increasing the rate of heat transfer up to 41.9%.
- Using glycerol can give a better result than both air and ethylene glycol, increasing the rate of heat transfer up to 45.38%.

This is because water has a higher thermal conductivity than glycerol and ethylene glycol. This shows that water is a good substance to improve the heat transfer inside the absorber which results in long time usage.

VI. Future Scope

- This experimental study can be carried out with other available fluid substances.
- Improvement in shock absorber fluid, and additive or substance for increase heat transfer should be obtained.
- Furthermore this study can be explored with convection correlations by measuring internal cylinder damping fluid temperature and to find the convective heat transfer coefficient.
- By varying the volume proportions of damping fluid and coolant we can find out the best heat transfer agents.

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