Experimental Investigation on Thermophysical Properties of Nanofluids

[1] A. Saravanapandi Solairajan, [2] S. Alexraj, [3] P.Vijaya Rajan

[1, 2, 3]Assistant Professor,

[1, 2, 3] Department of Mechanical Engineering,

[1, 2, 3] Infant Jesus College of Engineering and Technology, Tuticorin, India

***Abstract*—Nanofluids are suspensions of nanoparticles in base fluids, a new challenge for thermal sciences provided by nanotechnology. The tested fluids are prepared by dispersing copper oxide and ethylene glycol at three different concentrations such as 1%, 2%, 3%. Thermo-physical properties of nanofluids are measured by Joule's Calorimeter and redwood viscometer. Experimental result show that heat transfer of nanofluids is higher than the base fluid and with increase in temperature. It is increased 25% (for 1% particle concentration), 49% (for 2% particle concentration), and 60% (for 3% particle concentration) from that of base fluid. The results indicate that particle volume fraction is also an important parameter for nanofluids. With increase in particle volume concentration, heat transfer of nanofluids also increased. The result indicates that the volumetric specific heat of CuO nanofluid decreases gradually with increasing volume concentration of nanoparticles with increase in temperature too. Viscosity of nanofluid is decreased in increase in temperature but with increase in particle concentration, viscosity is decreased.**

***Index Terms*—Nanomaterials, Nanoparticles-CuO, Ethylene Glycol, Volume concentration, Viscosity Measurement, Nanofluids.**

I. Introduction

In many industrial applications the primary requirement is transfer of heat from source to sink or one point to other point. Improving heat transfer efficiency is much important in telecommunication system. More than 50% of the total electrical energy is consumed for thermal management in case of electronic cooling system. Very high heat removal rate of the order of 2000W/cm^2 is required in electronic systems like optical devices, X-rays and laser applications. The performance of the system and devices can be altered or improved by rate of water, engine oil, ethylene glycol, formamide etc., which are being used. For more energy efficiency requires advanced heat transfer technologies. Now a day some latest inventions explain the utilisation of nano particles in heat transfer applications. Nano fluid is the dispersion of nano size metallic particles in the conventional heat transfer fluids. The drawback of using micro-sized particles (upto 10^{-6}m) is formation of sediment along the flow path which leads to erosion in path way. But nano fluid gives solution to the above said problem by complete mixing of base fluids with non-agglomerated particles. Enhancing of heat transfer more than 50% is achieved by using this colloidal mixture of nano-particles with base fluids. But past researchers tested with volume ratio of nano particles is less than 0.3% with base fluid. Micro sized particles helps to improve thermal conductivity and convective heat transfer of liquids when mixed with base fluids. Meanwhile the fluid path is disturbed and high pressure drop occurred due to sedimentation, excessive wear, and clogging due to micro-sized particles. These problems are overcoming and improvements in thermal properties are achieved by using nano fluids. In nano fluids the nano particles of (1100nm) and base fluid mixed thoroughly is identified by Choi in the year 1995 at the Argonne National Laboratory. This is the first mile stone in nano fluid heat transfer technology which provides better thermal properties than micro-sized particles. Nano fluids have been used as lubricant in engines, collant and cutting fluids in manufacturing sectors, and hydraulic fluids in industrial automation as the nano particles have the advantages such as larger relative surface area, high mobility less particle momentum, better stability under suspended condition and improved thermal conductivity of the mixer than micro sized particles. Nano fluids are available in various forms such as metals, metal oxides, ceramics, semiconductors and carbon nano tubes. Jacob Eapen et al stated that carbon nano tubes has better heat transfer characteristics but synthesis processing of carbon nano tubes is complicated and also manufacturing cost is high. Table 1 gives thermal conductivity values of some nano materials.

II. EXPERIMENTAL SETUP

Joules Calorimeter

The Joule's Calorimeter experiment, with the conversion of electrical energy into heat energy for determining of specific heat capacity of liquid by electrical method. The setup consisting of a copper vessel 75 x 50mm size with outer vessel of teakwood fitted with Bakelite top with hole for thermometer to record the temperature change. The terminals connected to a coil of wire (for current up to 3 amps) are fitted. Complete with stirrer and outer teakwood vessel but without thermometer.

Fig.1 Joule's Calorimeter

Specification

1. Teak wooden outer vessel
2. Copper inner vessel
3. Outer vessel is 100mm tall and 75mm in diameter
4. Inner vessel is 75mm tall and 50mm in diameter
5. 3 to 6V heating coil, Max. current 1A
6. Built-in stirrer
7. Hole for a thermometer
8. Voltmeter, Ammeter and Rheostat

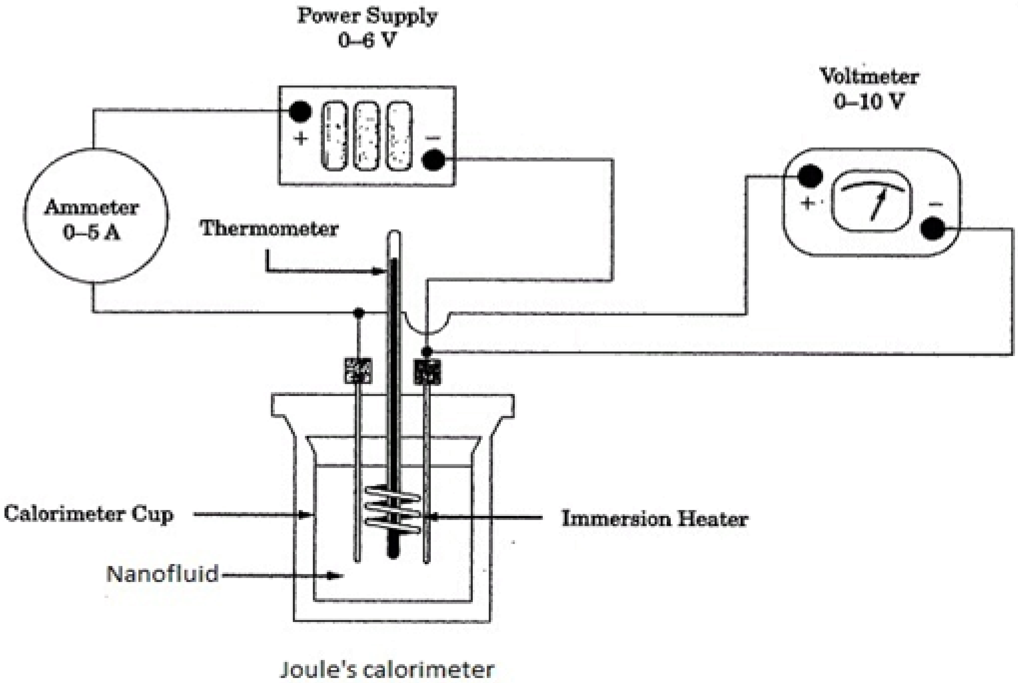

Fig.2 Circuit diagram of Joule's Calorimeter

Redwood Viscometer

This is used to measure the viscosity of fluids. The redwood viscometer consists of vertical cylindrical oil cup with an orifice in the centre of its base. The orifice can be closed by a ball. A hook pointing upward serves as a guide mark for filling the oil. The cylindrical cup is surrounded by the water bath. The water bath maintains the temperature of the oil to be tested at constant temperature. The oil is heated by heating the water bath by means of an immersed electric heater in the water bath, The provision is made for stirring the water, to maintain the uniform temperature in the water bath and to place the thermometer to record the temperature of oil and water bath. The orifice is 1.70mm in diameter and 12mm in length. This viscometer is used to determine the kinematic viscosity of the oil. From the kinematic viscosity the dynamic viscosity is determined.

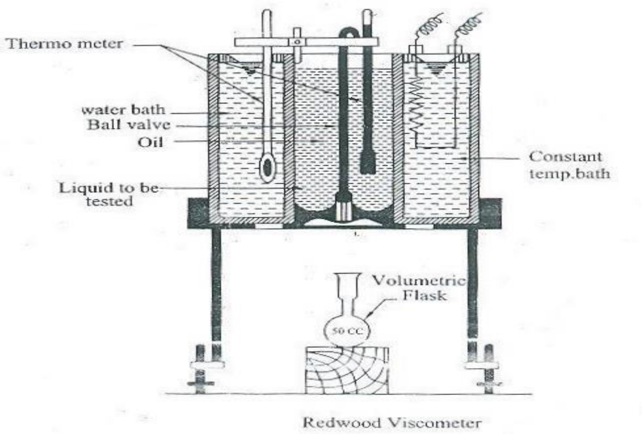

Fig.3 Redwood Viscometer

III. MATERIAL PROPERTIES

Copper Oxide (CuO)

Copper oxide nanoparticles appear as a brownish-black powder. They can be reduced to metallic copper when exposed to hydrogen or carbon monoxide under high temperature. They are graded harmful to humans and as dangerous for the environment with adverse effect on aquatic life.

Table 1 Material Properties for CuO

Chemical Composition		**Physical Properties**		**Thermal Properties**	
Copper	Oxygen	Density	Molar mass	Melting point	Boiling point
79.87 %	20.10 %	6.31 g/cm^3	79.55 g/mol	1201°C	2000°C

Ethylene Glycol

Ethylene Glycol based water solutions are common in heat-transfer applications where the temperature in the heat transfer fluid can be below *32^{o}F (0^{o}C)*. Ethylene glycol is also commonly used in heating applications that temporarily may not be operated (cold) in surroundings with freezing conditions - such as cars and machines with water cooled engines.

Ethylene Glycol is the most common antifreeze fluid for standard heating and cooling applications. Ethylene glycol should be avoided if there is a slightest chance of leakage to potable water or food processing systems. Instead solutions based on propylene glycol are commonly used.

Specific heat capacity, viscosity and specific weight of a water and ethylene glycol solution vary significantly with the percent of ethylene glycol and the temperature of the fluid. Properties differs so much from clean water that heat transfer systems with ethylene glycol should be calculated thoroughly for actual temperature and solution.

IV. METHODOLOGY

Preparation of nanofluids

Nanofluids are prepared by two step process. The resulting nanoparticles are then dispersed into the base fluid i.e. Ethylene glycol. Make the volume concentration of 1 %, 2 %, and 3% by mixing 0.6gm, 1.2gm, and 1.8gm of nanoparticles in 60 ml of Ethylene glycol. To make the nanoparticles more stable and remain more dispersed in water, agitation is used. Agitation had done for about 15-20 minutes before testing any thermo physical property of the nanofluids. By this nanoparticles become more evenly dispersed in distilled water.

Thermo physical Properties Measurement

For the measurement of specific heat, Joule's Calorimeter is used. Initially weight the empty copper vessel. Then the prepared nanofluid is poured into the copper vessel and weighed again. The difference in the weight gives the mass of the nanofluid taken. The heating coil is just dipped in the nanofluid such that the coil is fully immersed in fluid.

The temperature probe was suspended to ensure that it does not touch the coil or interfere with the stirrer. The battery was connected in series with joules calorimeter, a rheostat, ammeter and plug key. The switch was turned on for the power supply, voltage, current and the temperature raised for equal intervals of time period were measured and the specific heat was calculated by using equation (1)

$$C_p = \frac{1}{M}\left(\left(\frac{E \times I \times t}{T_f - T_i}\right) - (W \times C_{pm})\right) \cdots\cdots\cdots\cdots\cdots\cdots\cdots (1)$$

where C_p, M, w, E, I, t, T_f, T_i and C_{pm} are Specific heat of the fluid, Mass of the fluid, weight of the copper vessel, Voltage, Current, time, Final temperature and Initial temperature and specific heat of the copper vessel (385 J/(kg-k)). Same experiment is repeated for different volume concentration of Nanofluids (i.e., 1%, 2%, and 3%).

For the Measurement of Viscosity, Redwood viscometer is used. Initially the orifice is closed by a ball .The Nanofluid is filled into the cylindrical cup up to the guide mark of a hook. The cylindrical cup is surrounded by the water bath. The water bath maintains the temperature of the Nanofluid to be tested at constant temperature. The nanofluid is heated by heating the water bath by means of an immersed electric heater in the water bath, The provision is made for stirring the water, to maintain the uniform temperature in the water bath and to place the thermometer to record the temperature of oil and water bath .This viscometer is used to determine the kinematic viscosity of the nanofluid. From the kinematic viscosity the dynamic viscosity is determined.

Kinematic Viscosity, $\gamma = At - \frac{B}{t}$ .... (2) in stokes or centistokes

A = 0.0026
B = 1.72
A = 0.26
B = 172
t = Seconds

Density of Nanofluid at particular temperature $\rho_t = \rho_r - 0.00065\ (T - T_R)$

T = Temperature at which the density is required
T_R = Room Temperature
ρ_r = Density of nanofluids at room temperature in kg/m^3

The kinematic viscosity of the fluid is defined as the ratio of the dynamic viscosity and density of the fluid. Its symbol is 'γ'.

$\gamma = \frac{\mu}{\rho}$ .... (3)Where, $\rho = mass\ density\ of\ oil$

Dynamic viscosity is calculated from the above equation. Also the time taken for the 20ml of nanofluid through the viscometer is noted down. This is done for various temperature range i.e. 32° C to 60° C. Firstly, it was done for Ethylene Glycol as it is used as a base fluid for preparing nanofluids. Then, same method is done for the other sample i.e. 1%, 2%, 3% volume concentrations of nanofluidds and noted down the time at different temperatures. Then, calculate the dynamic viscosity by dividing it by density.

V. RESULTS AND DISSCUSSIONS

Volumetric specific heat measurement

Volumetric specific heat can be measured by Joule's Calorimeter. It is measured for the different volumetric concentration of nanoparticles such as 1%, 2% and 3% of ethylene glycol and its mixture of distilled water in the ratio 65:35.The Data calculated by experiment is mentioned in Table 2.

Table 2 Values of volumetric specific heat at different volume concentration

S.No	Fluid	Volumetric Specific Heat (J/kg-k)
1	Ethylene Glycol (EG)	7356.30
2	EG + 1% CuO	7301.5
3	EG + 2% CuO	6190.8
4	EG + 3% CuO	5135.9
5	65:35 EG/WATER	12286.8
6	EG/WATER + 1% CuO	8438.5
7	EG/WATER + 2% CuO	8239.9
8	EG/WATER + 3% CuO	7862.5

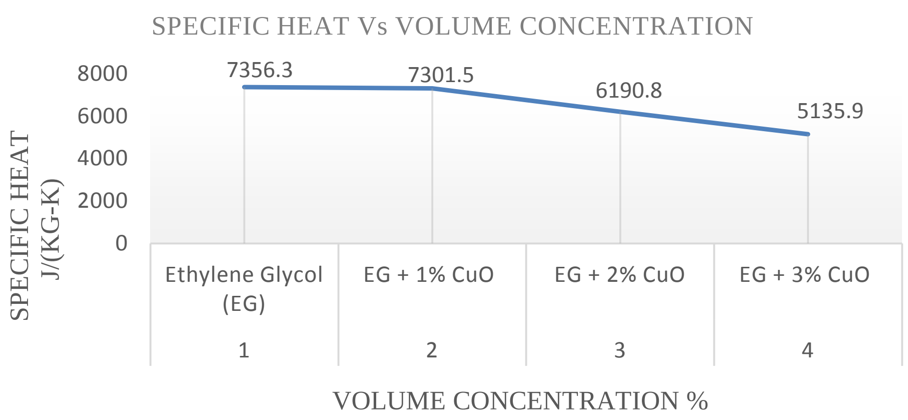

Fig.4 Specific Heat as the function of volume concentration of Ethylene Glycol based CuO Nanofluids

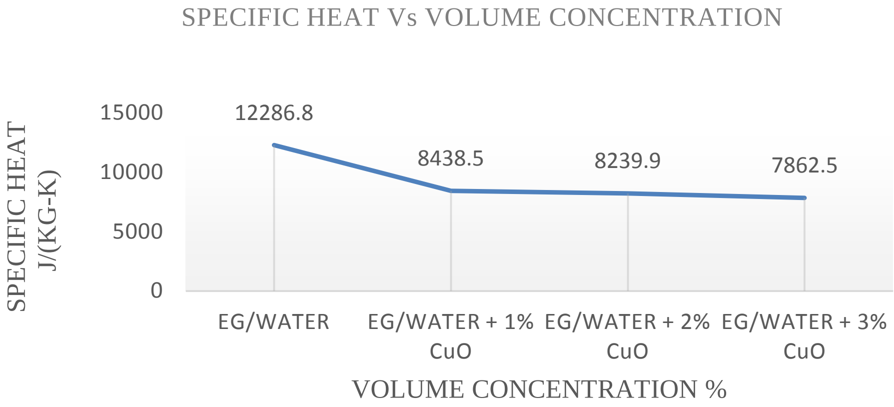

Fig.5 Specific Heat as the function of volume concentration of Ethylene Glycol and Distilled Water based CuO Nanofluids

From the specific heat values, heat transfer rate can be calculated by the following formulae and mentioned in Table 3
Q = (specific heat)* (mass)* (Temperature Difference)
$= C_p\ (m)\ (\Delta t)$

Table 3 Values of heat transfer at different volumetric concentrations

S.No	Fluid	Heat Transfer
1	Ethylene Glycol (EG)	1865.6
2	EG + 1% CuO	2332.1
3	EG + 2% CuO	2784.9
4	EG + 3% CuO	2997.7
5	65:35 EG/WATER	2117.4
6	EG/WATER + 1% CuO	2449.0
7	EG/WATER + 2% CuO	2899.3
8	EG/WATER + 3% CuO	3260.6

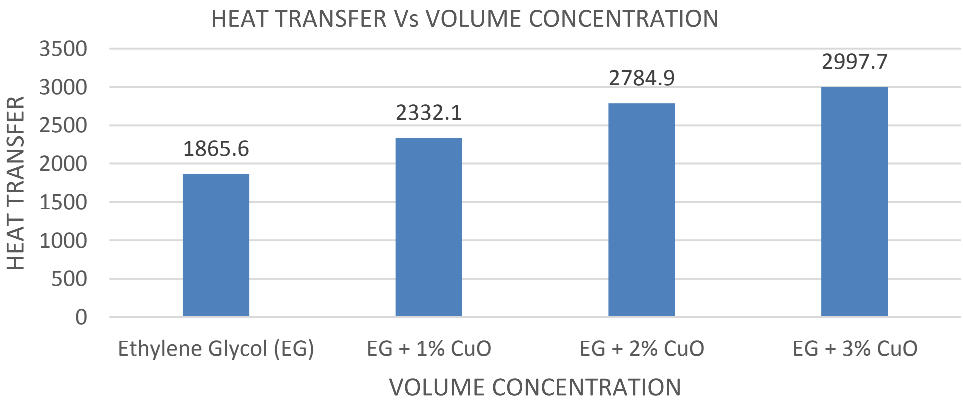

Fig.6 Heat Transfer as the function of volume concentration of Ethylene Glycol based CuO Nanofluids

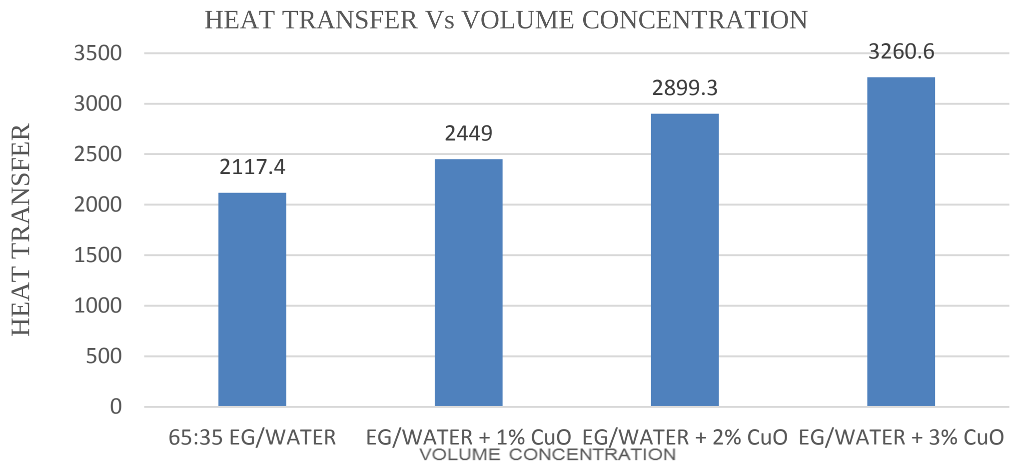

Fig.7 Heat Transfer as the function of volume concentration of Ethylene Glycol and Distilled Water based CuO Nanofluids

Viscosity Measurement

Viscosity can be measured by Redwood viscometer at various ranges of temperatures such as 32°C, 40°C, 50°C, and 60°C. It can be measured for Ethylene glycol and mixture of Ethylene glycol with Distilled Water (65:35), 1%, 2%, 3% volume concentration of CuO. The time taken for the flow of 20ml of nanofluid of different concentration is also is measured for the temperature range.

The experimental values which are drawn by the experiment are mentioned in the following Table 4

Table 4 Viscosity at different temperatures for 1 %, 2 %, and 3 % Volume Concentrations

S.No	Fluid	32 °C	40 °C	50 °C	60 °C
1	Ethylene Glycol (EG)	9.6779	9.0816	7.0927	4.4701
2	EG + 1% CuO	8.54631	6.3465	5.7111	4.3141
3	EG + 2% CuO	6.6116	5.8376	4.4352	3.9488
4	EG + 3% CuO	4.5725	3.6868	2.8525	1.8385
5	65:35 EG/WATER	3.4504	2.6233	1.4491	1.07429
6	EG/WATER + 1% CuO	3.2087	2.3609	1.7517	0.9672
7	EG/WATER + 2% CuO	2.8667	2.0833	1.4423	0.7288
8	EG/WATER + 3% CuO	2.7055	1.7880	1.2269	0.4716

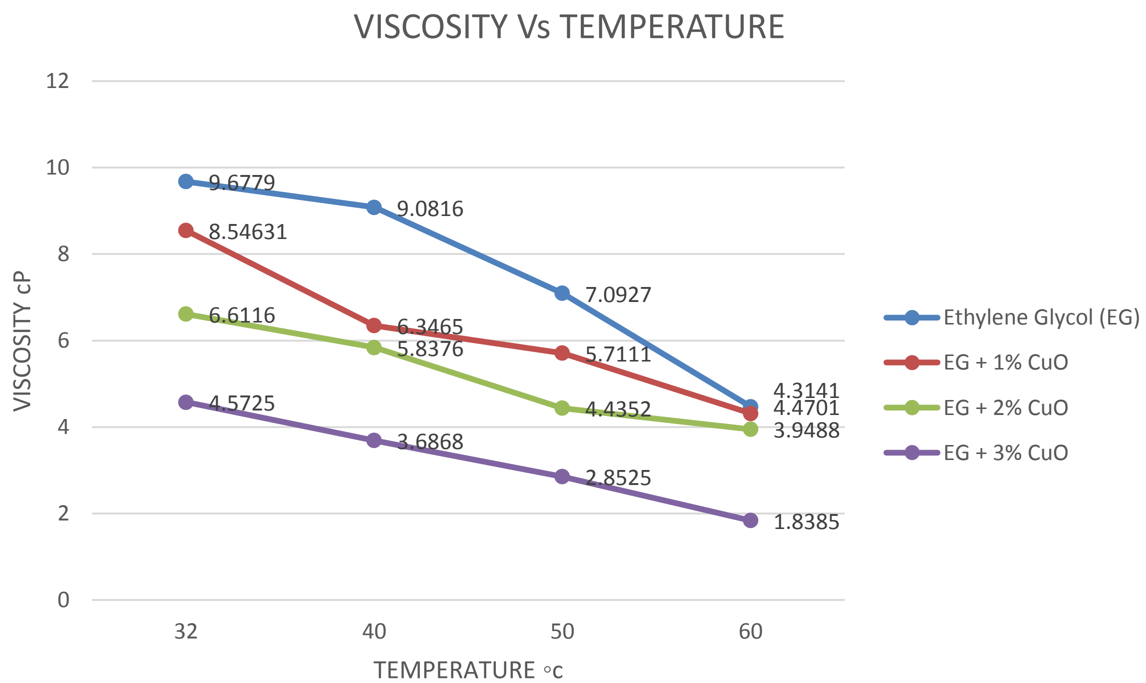

Fig.8 Viscosity as the function of Temperature for different volume concentration of Ethylene Glycol based CuO Nanofluids

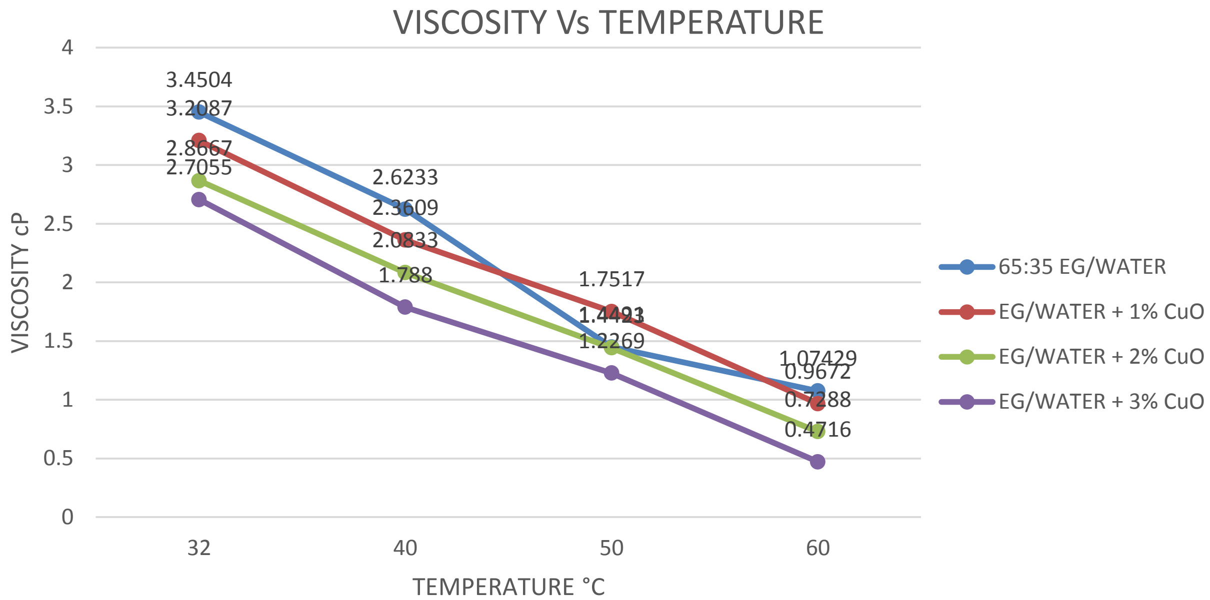

Fig.9 Viscosity as the function of Temperature for different volume concentration of Ethylene Glycol and Distilled Water based CuO Nanofluids

From the above data, it seems that viscosity is gradually decreased with increase in temperature as well as with nanoparticle volume fraction. And as further nanoparticle concentration increases, viscosity is decreased. Behaviour of viscosity of nanofluids with temperature is same as for ethylene glycol this is quite uncertain that as the nanoparticles are added in ethylene glycol and further increases the concentrations, viscosity get decreased.

Table 5 Time Taken for different temperatures on Redwood viscometer

S.No	Fluid	32°C	40°C	50°C	60°C
1	Ethylene Glycol (EG)	2min	1min 57sec	1min 34sec	1min
2	EG + 1% CuO	1min 50sec	1min 25sec	1min 18sec	1min
3	EG + 2% CuO	1min 28sec	1min 19sec	1min	59sec
4	EG + 3% CuO	1min	56sec	48sec	39sec
5	(65:35) EG/WATER	58sec	49sec	42sec	34sec
6	EG/WATER + 1% CuO	55sec	46sec	40sec	30sec
7	EG/WATER + 2% CuO	51sec	43sec	37sec	31sec
8	EG/WATER + 3% CuO	49sec	40sec	35sec	29sec

VI. CONCLUSION

Nanofluids are dilute colloidal suspensions with nano-sized particles. It can be prepared by dispersing the nanoparticles in basefluid and then put the samples for agitation to make the nanoparticles more suspended in the fluid and it also increases the stability of nanofluid. The volumetric specific heat of nanofluids can be measured by Joule's calorimeter. Effect of Heat transfer enhancement is even more than Base fluid (Ethylene Glycol) and it rises from 25% (for 1% particle concentration), 49% (for 2% particle concentration), 60% (for 3% particle concentration). The results indicate that particle volume fraction is also an important parameter for nanofluids.With increase in particle volume concentration, Heat transfer of nanofluids also increased. It has also been found that volumetric specific heat of nanofluid decrease with increasing nano particle volume fraction. But the effect of nanoparticle volume fraction is very small. Viscosity of nanofluids can be measure by Redwood viscometer. From the experimental results, it is observed that nanofluids have lower viscosity. Viscosity decreases with increases in temperature. These properties are also depending upon the nanoparticle volume concentration present in the base fluid. Viscosity decreases by increasing the particle volume concentration of nanofluids.

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