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Heat Transfer in Nano Fluid

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***Abstract*: This project work deals with the fabrication of steady-state parallel-plate thermal conductivity (PPTC) apparatus to determine the effective thermal conductivity of base fluid and nanofluids and to show the enhancement in the effective thermal conductivity of nanofluids. A nanofluid is a fluid containing nanometer-sized particles called nanoparticles. These fluids are engineered colloidal suspensions of nanoparticles in a base fluid. In this project water is taken as base fluid and nanoparticles of silver and graphene quantum dots are used to prepare nanofluids. The steady state PPTC apparatus consists of two square copper plate kept at a distance of 8mm in which the test fluid specimen is filled and the top plate is imbedded with a heater assembly. This creates a temperature difference which is measured by calibrated LM 35 temperature sensor imbedded in the parallel plates. This temperature difference is then used, along with the heating power, to calculate the thermal conductivity of the test fluid specimen using fourier's law of heat conduction.**

***Keywords*: Steady state parallel plate thermal conductivity (PPTC) apparatus, Nanofluid, Silver nanoparticle, Graphene quantum dots (GQD), Thermal conductivity.**

I. INTRODUCTION

A nanofluid is a mixture of water and suspended metallic nanoparticles. Since the thermal conductivity of metallic solids are typically orders of magnitude higher than that of fluids, it is expected that a solid/fluid mixture will have higher effective thermal conductivity compared to the base fluid. Thus, the presence of the nanoparticles changes the transport properties of the base fluid thereby increasing the effective thermal conductivity and heat capacity, which ultimately enhance the heat transfer rate of nanofluids. Because of the small size of the nanoparticles (10^{-9} m), nanofluids incur little or no penalty in pressure drop and other flow characteristics when used in low concentrations. Nanofluids are extremely stable and exhibit no significant settling under static conditions, even after weeks or months.

II. STEADY STATE PPTC APPARATUS

This apparatus is based on steady-state heat conduction, various design of test cells can be constructed for the measurement of thermal conductivity of liquids. To facilitate the heat transfer predominantly in one direction either parallel-plate type or concentric cylindrical cell type test facilities are preferred. The apparatus for the steady-state parallel-plate method can be constructed on the basis of the design by Challoner and Powell. A schematic diagram of the experimental set up is shown in fig.1 where a small volume of the fluid sample is placed between two parallel pure copper plates. The upper copper plate is being heated by main heater. In this method, two important parameters are to be carefully controlled. One needs to accurately measure the temperature increase in each temperature sensor. The difference in temperature readings need to be minimized when the temperature sensors are at the same temperature.

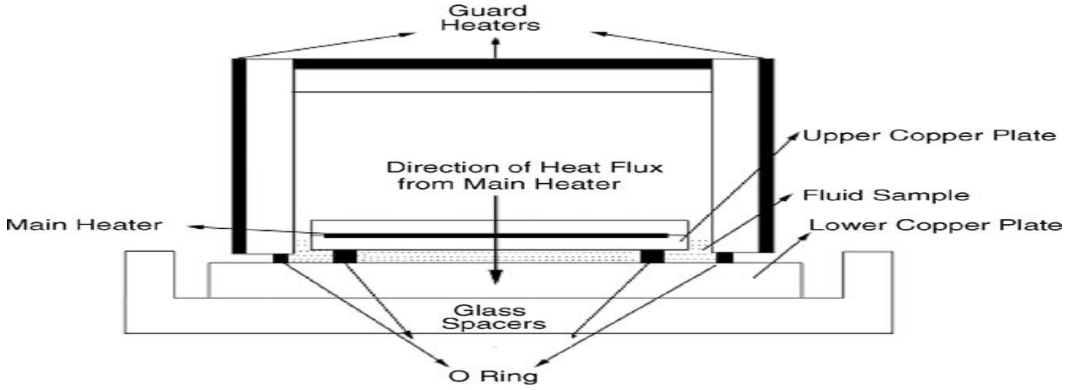

Fig.1: Apparatus design

As the total heat supplied by the main heater flows through the liquid between the upper and lower copper plates, the overall thermal conductivity across the two copper plates, including the effect of the copper plate and glass spacers, can be calculated from the one-dimensional heat conduction equation relating the power q of the main heater, the temperature difference ΔT between the two copper plates, and the geometry of the liquid cell as

$k_o = (q\, L_g) / (S \Delta T)$

Where,

Lg is the thickness of the glass spacer between the two copper plates

S is the cross-sectional area of the top copper plate.

The effective thermal conductivity of the liquid can be calculated as

$k_e = (k_o\, S - k_g\, S_g) / 100(S - S_g)$

where,

k_g is the thermal conductivity of glass spacers

S is cross-sectional area of the top copper plate

S_g the total cross-sectional area of the glass spacers

In this method, it has to be ensured that there is no heat loss from the fluid to the surrounding. To take care of this, guard heaters are used to maintain a constant temperature of the fluid. The guard heaters are heated to a temperature same as that of the fluid. If the fluid and the guard heater temperature are equal, then there will be no heat radiated to the surroundings from the fluid.

III. FABRICATED STEADY STATE PPTC APPARATUS

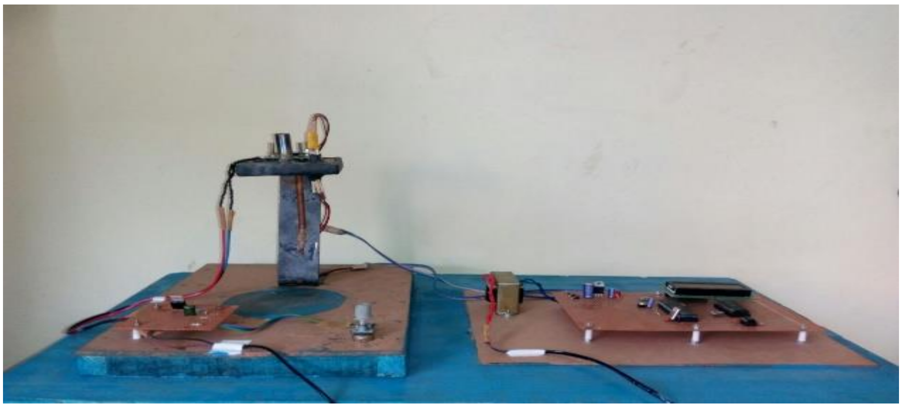

Fig.2: Fabricated apparatus

In this set-up, a unidirectional heat flow takes place across the liquid whose two faces are maintained at different temperatures by hot plate on one end and by cold plate at the other end. At the steady state the face temperatures are recorded along with the rate of heat transfer (q). Knowing, the heat transfer area and thickness (L_g) across which the heat transfer takes place the overall thermal conductivity of the sample can be calculated using Fourier law of heat conduction.

A. TECHNICAL SPECIFICATION OF APPARATUS

- Dimension of copper plate is 8 cm X 8cm
- Thickness of glass spacer is 8 mm
- Diameter of inlet is 1 cm
- Diameter of outlet is 4 mm
- Heater rating is 400 watt ,220 V , 6 A
- Volume of gap between copper plates is 35ml

B. PROCEDURE OF EXPERIMENTATION

- Fill the liquid cell with the 35 ml of liquid sample through the inlet port.
- Note down the initial temperature of both the copper plate from the LCD display.
- Take a stop watch and set it to zero.
- Start the electric heater of upper plate and adjust the voltage regulator for desired power output say 50V and 100V.
- Go on recording the temperature sensor reading of both the plates at regular interval of 5 minutes.
- At the end of 30 minutes take the final reading of temperature of both the plates as it is assumed that after 30 minute the steady state condition is achieved.
- Stop the electricity supply to the heater.
- Open the liquid outlet port and drain the sample liquid.

IV. NANOPARTICLES

A. SILVER NANOPARTICLE:

Silver nanoparticles are nanoparticles of silver. It is prepared by reduction of a silver salt such as silver nitrate with a reducing agent like sodium borohydride in the presence of colloidal stabilizer.PVP (Poly Vinyl Pyrrolidone) is used to prevent aggregation of silver nanoparticles. Concentration of sample used is 1mM and size of silver nanoparticles are in range of 15-25nm.

Fig.3: Silver nanoparticle

B. GRAPHENE QUANTUM DOTS:

Graphene quantum dots (GQDs) are a kind of 0 dimension material of 20nm diameter with characteristics derived from both graphene and carbon dots (CDs).It is prepared by graphite powder in which H_2SO_4 and HNO_3 is added in 3:1 ratio. The mixture is sonicated and then stirred until light yellow colour is appeared. Concentration of sample is used 1mg/ml

Fig.4: GQD nanoparticle

V. EXPERIMENTATION

A. TECHNICAL DATA:

- V stands for voltage
- I stands for current
- q stands for heat input.
- S= cross sectional area of upper copper plate = 0.08*0.08 = 0.0064 m^2
- Lg = thickness of the glass spacer between the two copper plates = 0.008 m
- T1= temperature of upper copper plate
- T2= temperature of bottom copper plate
- ΔT= T1 - T2 (After 30 minutes)
- k_o = overall thermal conductivity
- k_e = effective thermal conductivity of liquid sample
- k_g = thermal conductivity of glass spacers

  = 1.4 W/m°C
- S_g = total cross-sectional area of the glass spacers

  =2*(0.08*0.008) +2*(0.064*0.008)

  =0.0023 m^2

B: EXPERIMENT NO.1:

Liquid sample = water

Amount = 35ml

Current I = 6 Amp

Initial temperature - T1 = 36°C and T2 = 36°C

TABLE I: Temperature reading for water

S.N.	Time (min)	50 Volt		100 volt	
		T1	T2	T1	T2
1.	5	45	38	56	42
2.	10	50	42	67	53
3.	15	53	46	73	60
4.	20	58	50	80	68
5.	25	63	54	83	71
6.	30	66	58	86	74

Calculations:

- At 50 Volt

T1 after 30 min = 66°C

T2 after 30 min = 58°C

q = I * V

q = 50 * 6 = 300 W

ΔT= T1-T2

= 66-58

= 8 °C

L_g = 0.008 m

$k_0 = q\ L_g/S\Delta T$

= (300*0.008)/(0.0064*8) = 46.87 W/m°C

$k_e = (k_oS - k_gS_g)/100*(S - S_g)$

= (46.87*0.0064 – 1.4*0.0023)/100*(0.0064 - 0.0023)

= 0.72 W/m°C

The effective thermal conductivity of water sample at 50 V = 0.72 W/m°C

- At 100 Volt

T1 after 30 min = 86°C

T2 after 30 min = 74°C

q = I * V

q = 100 * 6 = 600 W

ΔT= T1-T2

= 86 - 74

= 12 °C

L_g = 0.008 m

$k_0 = q\ L_g/S\Delta T$

= (600*0.008)/(0.0064*12) = 62.5 W/m°C

$k_e = (k_oS - k_gS_g)/100*(S - S_g)$

= (62.5*0.0064 – 1.4*0.0023)/100*(0.0064 - 0.0023)

= 0.96 W/m°C

The effective thermal conductivity of water sample at 100 V = 0.96 W/m°C

Graph:

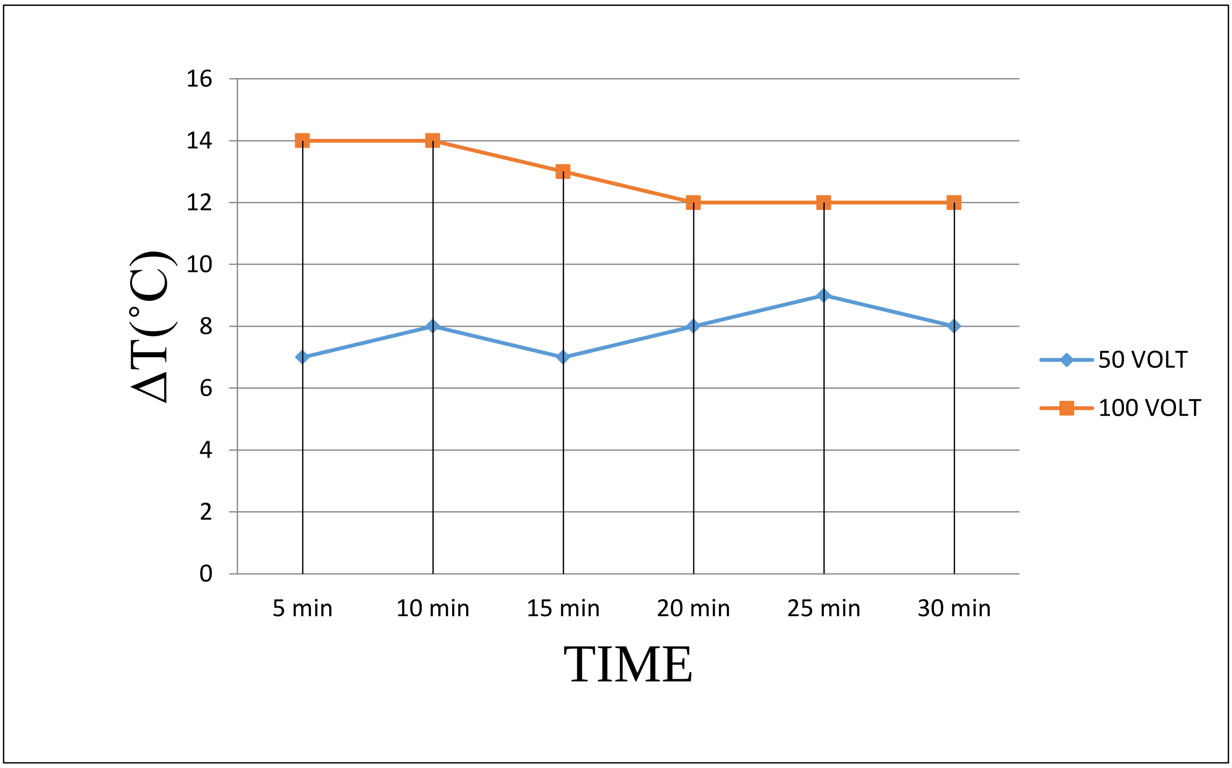

Fig.5: ΔT vs Time graph for water

C: EXPERIMENT NO.2

Liquid sample = silver nanofluid

Amount = 30ml water(base fluid) + 5ml(silver nanoparticles)

Current I = 6 Amp

Initial temperature - T1 = 36°C and T2 = 36°C

TABLE II: Temperature reading for silver nanofluid

S.N.	Time (min)	50Volt		100 Volt	
		T1	T2	T1	T2
1.	5	41	37	57	43
2.	10	47	41	68	55
3.	15	52	46	77	65
4.	20	54	50	81	70
5.	25	57	51	83	74
6.	30	59	54	85	78

Calculations:

- At 50 Volt

T1 after 30 min = 59°C

T2 after 30 min = 54°C

q = I * V

q = 50 * 6 = 300 W

ΔT= T1-T2

= 59 - 54 = 5 °C

L_g = 0.008 m

$k_0 = q\, L_g / S\Delta T$ = (300*0.008)/(0.0064*5) = 75 W/m°C

$k_e = (k_o S - k_g S_g)/100*(S – S_g)$

= (75*0.0064 – 1.4*0.0023)/100*(0.0064 - 0.0023)

= 1.16 W/m°C

The effective thermal conductivity of silver nanofluid sample at 50 V = 1.16 W/m°C

- At 100 Volt

T1 after 30 min = 85°C

T2 after 30 min = 78°C

q = I * V

q = 100 * 6 = 600 W

ΔT= T1-T2

= 85 - 78

= 7 °C

L_g = 0.008 m

$k_0 = q\, L_g / S\Delta T$

= (600*0.008)/(0.0064*7) = 107.14 W/m°C

$k_e = (k_o S - k_g S_g)/100*(S – S_g)$

= (107.14*0.0064 – 1.4*0.0023)/100*(0.0064 - 0.0023)

= 1.66 W/m°C

The effective thermal conductivity of silver nanofluid sample at 100 V = 1.66 W/m°C

Graph:

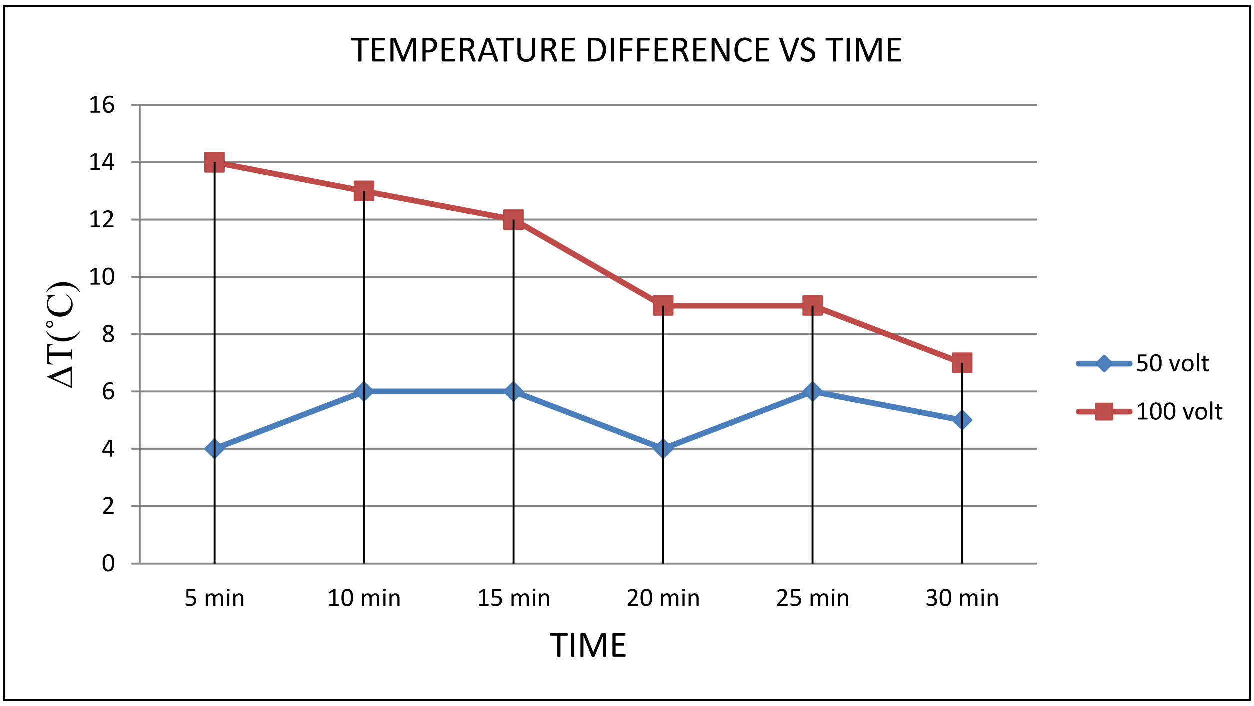

Fig.6: ΔT vs Time graph for silver nanofluid

D: EXPERIMENT NO.3

Liquid sample = Graphene Quantum Dot (GQD) nanofluid

Amount = 30ml water(base fluid) + 5ml(GQD nanoparticles)

Current I = 6 Amp

Initial temperature - T1 = 38°C and T2 = 38°C

TABLE III: Temperature reading for GQD nanofluid

S.N.	Time (min)	50 Volt		100 Volt	
		T1	T2	T1	T2
1.	5	49	42	55	43
2.	10	55	47	64	52
3.	15	60	51	69	59
4.	20	62	54	74	66
5.	25	63	56	76	67
6.	30	65	58	78	70

Calculations:

- At 50 Volt

T1 after 30 min = 65°C

T2 after 30 min = 58°C

q = I * V

q = 50 * 6 = 300 W

$\Delta T = T1 - T2$

$= 65 - 58 = 7$ °C

$L_g = 0.008$ m

$k_0 = q\, L_g / S\Delta T = (300*0.008)/(0.0064*7) = 53.57$ W/m°C

$k_e = (k_o S - k_g S_g)/100*(S - S_g)$

$= (53.57*0.0064 - 1.4*0.0023)/100*(0.0064 - 0.0023)$

$= 0.82$ W/m°C

The effective thermal conductivity of GQD nanofluid sample at 50 V = 0.82 W/m°C

- At 100 Volt

T1 after 30 min = 78°C

T2 after 30 min = 70°C

$q = I * V$

$q = 100 * 6 = 600$ W

$\Delta T = T1 - T2$

$= 78 - 70$

$= 8$ °C

$L_g = 0.008$ m

$k_0 = q\, L_g / S\Delta T$

$= (600*0.008)/(0.0064*8) = 93.75$ W/m°C

$k_e = (k_o S - k_g S_g)/100*(S - S_g)$

$= (93.75*0.0064 - 1.4*0.0023)/100*(0.0064 - 0.0023)$

$= 1.45$W/m°C

The effective thermal conductivity of GQD nanofluid sample at 100 V = 1.45 W/m°C

Graph:

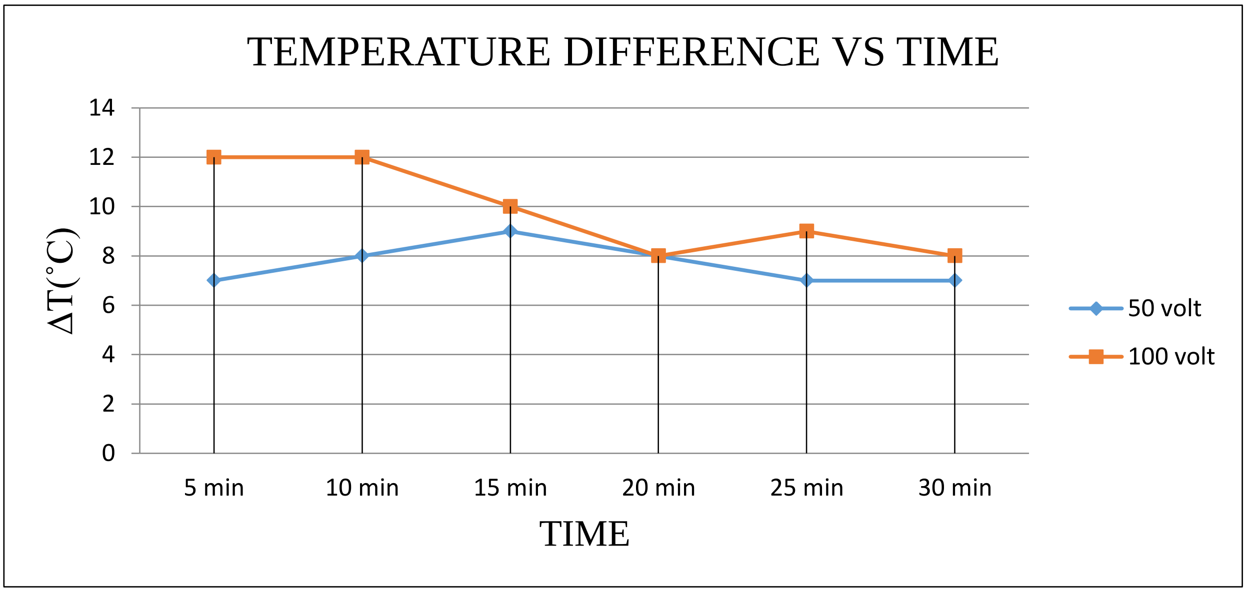

Fig.7: ΔT vs Time graph for GQD nanofluid

VI. RESULT AND ANALYSIS

A: EFFECTIVE THERMAL CONDUCTIVITY:

The value of effective thermal conductivity of various fluids sample is tabulated below under different heat input.

TABLE: IV Result table

Fluid sample	**Effective thermal conductivity(W/m°C)**	
	At q= 300 W	**At q= 600W**
Water	0.72	0.96
Silver nanofluid	1.16	1.66
GQD nanofluid	0.82	1.45

B: ENHANCEMENT IN EFFECTIVE THERMAL CONDUCTIVITY:

The percentage enhancement in the value of thermal conductivities of nanofluids has been calculated with respect to the water.

- Silver nanofluid

Percentage enhancement in the value of effective thermal conductivity at q= 300W is:

= ((1.16 – 0.72)*100) / 0.72

= 61.11%

Percentage enhancement in the value of effective thermal conductivity at q= 600W is:

= ((1.66 – 0.96)*100) / 0.96

= 72.91%

- GQD nanofluid

Percentage enhancement in the value of effective thermal conductivity at q= 300W is:

= ((0.82 – 0.72)*100) / 0.72

= 13.88%

Percentage enhancement in the value of effective thermal conductivity at q= 600W is:

= ((1.45 – 0.96)*100) / 0.96

= 51.04%

Graph:

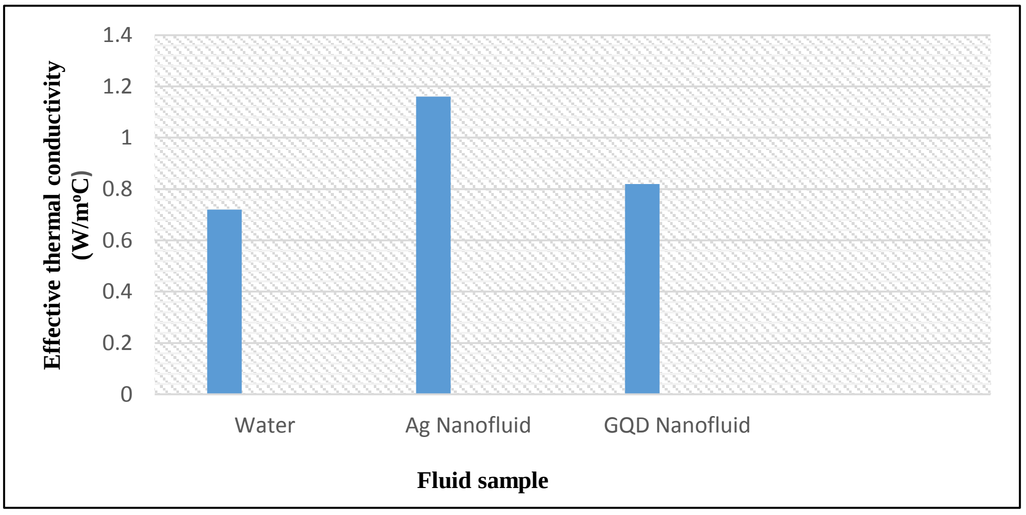

Fig. 8: Effective thermal conductivity of samples at 300W

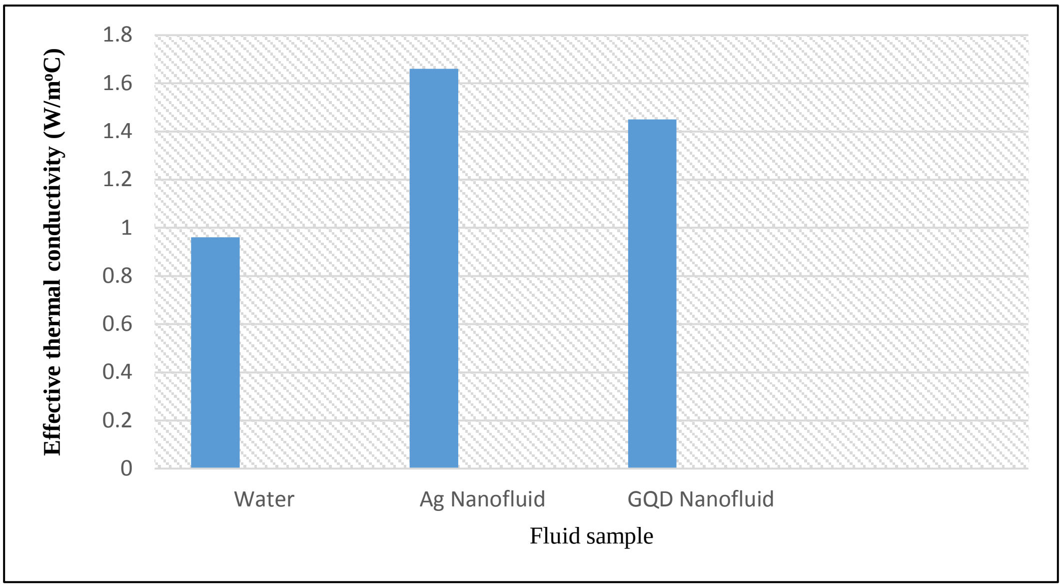

Fig. 9: Effective thermal conductivity of samples at 600W

VII. CONCLUSION

This project presents overview on the fabrication of steady state PPTC apparatus and about nanofluid, as an existing new class of heat transfer fluid. It is concluded that the effective thermal conductivities of nanofluids are higher than the base fluids hence they can be considered as a potential candidate for numerous applications involving heat transfer and their use will continue to grow.

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