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Optimization of Wick Shape in a Heat Pipe for High Heat Transfer

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Abstract

Heat pipe is a device and it has high ability to dissipate the heat. In modern days electronic systems generate more heat in the electronic components, to remove that heat from the electronic devices we use heat pipe. Heat pipe plays very important role in cooling of the electronic systems like computers, laptops, cell phones, T.V Circuits, transformers. In this work inside of the heat pipe the wick structure is modified. The copper fins are fitted to the wick structure in the inside of the heat pipe. The length of the heat pipe is divided into the three sections evaporator section, adiabatic section and condenser section. The heater is fitted in the evaporator section and power is supplying to the heater. The thermocouple wires are attached in the different sections of the heat pipe.Working fluids are used in this work is water and nano fluid (Al2O3). First we use working fluid as water and we take temperature readings at different sections after that we use nano fluid as working fluid and we take temperature readings at different sections. After completion of taking the temperature readings, we calculate the heat transfer rates for both working fluids for water and nano fluid. And then comparison of the heat transfer rates of the working fluids water and nanofluid. By using the nano fluid as working fluid in the heat pipe the heat transfer rates are increased.

Key Words: *Heat Pipe, Water, Nano fluid, Thermocouple wires and Heat Transfer Rate*

I. Introduction

Now a days modern electric component generates high heat in the electronic devices. So this generation of high heat from the electronic components causes the damage of the electronic devices. So to prevent this damage and dissipate more heat from the electronic devices we use heat pipe. Heat pipe is a device and it has more ability to dissipate the heat and removes the heat from the electronic devices. Heat pipe is a very important device to transfer the large quantities of heat through a small area with small temperature difference.Heat pipes are very frequently used in the space applications. The main characteristic of heat pipe is, heat pipe works in the absence of gravity also and liquid flow does not depend on gravity. Heat pipe has ability of accepting the heat in non-uniformly manner. Heat pipe is a very simple mechanical device and it has no moving parts. Heat pipe is a simple device it makes the change of phase heat transfer. Heat pipe works in the absence of gravity of also. The heat pipe is very much useful in branches of Electronics, Air-conditioning systems, I.C Engines, Gas turbines and Building industries. Heat pipe is an ideal device for removing heat from either a concentrated heat source or from a low temperature heat source. This is the salient feature of heat pipe and this feature is very much useful in the space applications. Heat pipe has a circular cross section and it has a layer of wicking material covered at the inner surface of the heat pipe. Heat pipe is very simple in construction. Heat pipe is a two phase heat transfer device. Transports heat from a heat source to the heat sink. Effective heat transfer takes place in the heat pipe. There is no external pumping power in the heat pipe. It is a self regulating device. There is no vibration and noise in the operating of the heat pipe. The important features of the heat pipe are good reliability and it has capacity to work in weightless condition in the space and it also works in the under isothermal conditions without need of the any external power input device. This heat pipe is very good for environment, because there is no pollution caused by the heat pipe. The main important features of the heat pipe are it has no moving parts, it requires no external energy source to start, reversible in operation, completely silent, high reliability. There are no corrosive materials inside of the heat pipe.

The different types of working fluids can be used in the heat pipe. The working fluid and wick structures are located inside of the heat pipe. There is no mechanical and chemical degradation in the heat pipe. Gravity does not affect the working of heat pipe. Heat pipes are very frequently used in the space applications, cooling of computers, mobiles, laptops and cooling of solar collectors. This heat pipe works based on the conduction and convection process. Heat pipe is a passive device and it transport heat from evaporator to the condenser. A heat pipe contains three sections heating section (evaporator section), adiabatic section, cooling section (condenser section). The main parts of the heat pipe are enclosed container, wick material and working fluid.

II. WORKING PRINCIPLE OF HEAT PIPE

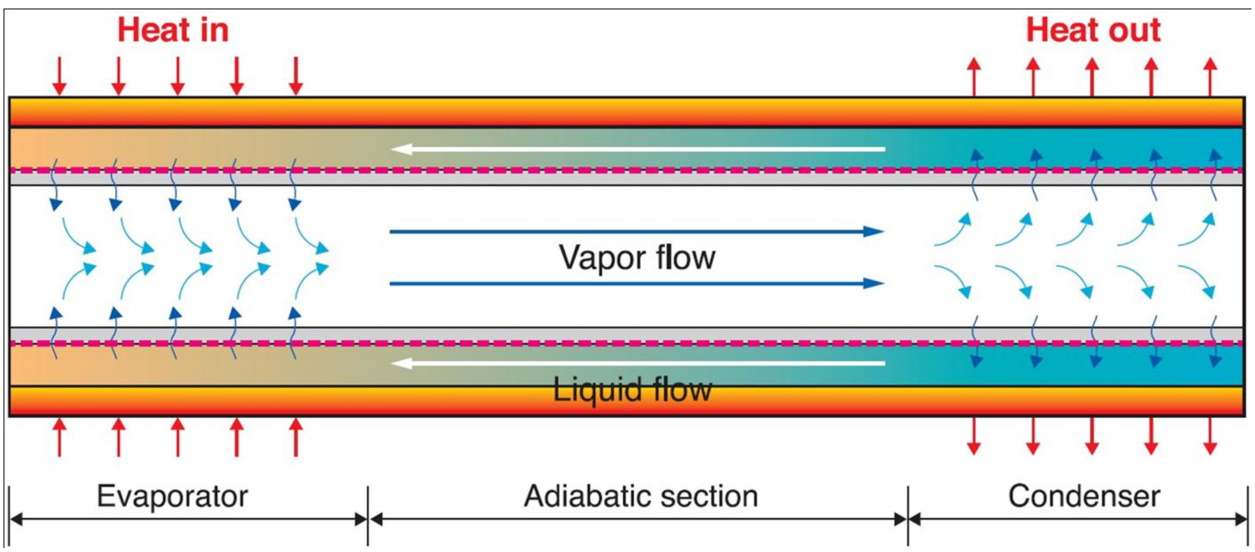

Figure 1 Working Principle of Heat Pipe

The device it makes the change of phase heat transfer is called the heat pipe. Heat pipe is a highly passive device for the transport the heat from the evaporator to condenser. Very large quantities of heat can transport from the heat source to heat sink with minimum temperature drop. The heat pipe is in the circular shape. This circular heat pipe contains the layer of wick material at the inner side of heat pipe. The main components of the heat pipe are enclosed container, wick structure and working fluid. A heat pipe contains three sections heating section (evaporator section), adiabatic section, cooling section (condenser section).

The heat pipe is in the circular shape. This circular heat pipe contains the layer of wick material at the inner side of heat pipe. The main components of the heat pipe are enclosed container, wick structure and working fluid. The liquid means working fluid is placed in the inside of the heat pipe. When heat is added in the evaporator section the liquid gets heat and this liquid converts into vapor. This vapor moves in the wick material and it enters into the adiabatic section. In the adiabatic section, there is no heat loss occur because the heat pipe is insulated with insulated rope in this adiabatic section. And then this vapor is enters into the cooling section. In this section the vapor converts into the liquid by the condenser. After that this liquid came back into the evaporator section and then again liquid gets heat and it converts into the vapor and again this vapor travels into the condenser section and converts into the liquid. This cyclic process occurs in the heat pipe.

Heat pipe has a most advantage that one is heat pipe works in the absence of gravity. The absence of gravity does not affect the operation of heat pipe. Liquid flow does not depend on the gravity. Heat pipe does not require any external energy for operating and it is reversible in operation. Heat pipe is very good reliable device for high heat dissipations. No noise produces in the heat pipe operation so heat pipe is the environmental friendly device.

III. EXPERIMENTAL WORK

Figure 2 Experimental setup of heat pipe

The above figure shows the experimental setup of the heat pipe. In this experiment first of all we take one copper pipe. The heat pipe is made with copper pipe. The length of the heat pipe is the 50cm. The inside of this heat pipe the wick structure is modified; the four fins are fitted to the wick structure in the inside of the heat pipe. Fins increase the rate of heat transfer. The length of the heat pipe is 50cm. The length of the heat pipe is divided into three sections. The heat pipe is divided into the evaporator section, adiabatic section and condenser section. In the above figure evaporator section is fitted with the heater, this heater gets heat from the autotransformer. From the autotransformer two connection wires are attached to voltmeter (V) and ammeter (I). Autotransformer gives power supply to the voltmeter and ammeter. On upper side of the autotransformer there is rotating plate type device is located, if we rotate this plate on the autotransformer the indicators on the voltmeter and ammeter changes.

The indicator on the ammeter changes form 0.1 Amperes to 0.2 Amperes, simultaneously indicator on the voltmeter changes from 70V to 80V. So the current (I) comes from the ammeter and voltage (V) comes from the voltmeter by adjusting the autotransformer. The power supply comes from the both current and voltage. The power (P) =Voltage (V) x Current (I), so from the autotransformer one wire is connected to the voltmeter and other wire is connected to the ammeter. The heater is fitted to the heat pipe in the evaporator section. The wires from the ammeter and voltmeter are connected to the heater. So the power is supplying to the heater. In this work we use two working fluids. The working fluids used in this experiment are water and nanofluid (Al_2O_3). Inside of this heat pipe first we take water as working fluid. The working fluid water gets heated in the evaporator section and then it converts into the vapor. This vapor moves to the adiabatic section. In the adia batic section there is no heat loss occur, because insulated rope is winded in the adiabatic section. And then this vapor moves to the condenser section. In the condenser section the steel pipe is fitted externally to the heat pipe. Water is supplying externally to the steel pipe from the small bucket. Small bucket is filled with water, from this bucket one pipe is attached to the steel pipe. Through pipe water is supplying to the steel pipe continuously. This steel pipe is fitted to the heat pipe because for the heat dissipation. The vapors in the condenser section are cooled by the external supplying of water through the steel pipe. So the vapor gets cooled and converts into the liquid. This liquid is collected from the heat pipe through the water container. The thermocouple wires are attached to the heat pipe in the different sections. The thermocouple wires are used for the measuring of temperatures in the different sections of the heat pipe. After taking temperature readings of working fluid (water), we remove the working fluid (water), and create vacuum in the heat pipe. And then taking aluminum oxide (Al_2O_3) nano powder and mix with 270 ml of water, so after mixing this convert into nano fluid. The volume capacity of the heat pipe is 270 ml. So this nano fluid is filled in the heat pipe through the valve, and then valve is closed. The pressure regulator is fitted to the heat pipe. After that again the heater gets heated in the evaporator section. The nano fluid is located inside of the heat pipe. So this nano fluid gets heated and converts into the vapor.

Figure 3 Digital temperature indicator

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Figure 4 Heater is fitted to the heat pipe in the evaporator section

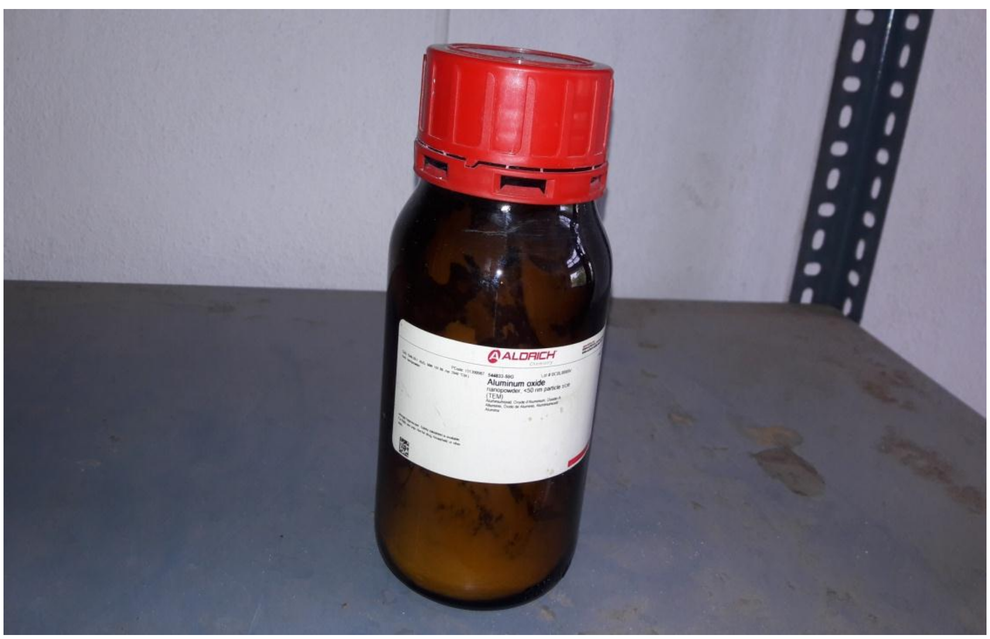

Figure 5 Aluminum oxide (Al2O3) nano powder

Figure 6 Aluminum oxide (Al_2O_3) nano powder

This vapor moves to the adiabatic section, in the adiabatic section there is no heat loss occur, because insulation rope is winded in the adiabatic section. And then vapor moves to the condenser section, in the condenser section vapor gets cooled and converts into the liquid. The vapors in the condenser section are cooled by the external supplying of water through the steel pipe. This liquid is collected from the heat pipe through the water container. And then we take the temperature readings of working fluid (Al_2O_3) by using thermocouple wires. The temperature readings are displayed in digital temperature indicator. All thermocouple wires are attached to the digital temperature indicator. We take all the temperature readings and note down in the book. The temperature readings are shown in the following tabular columns.

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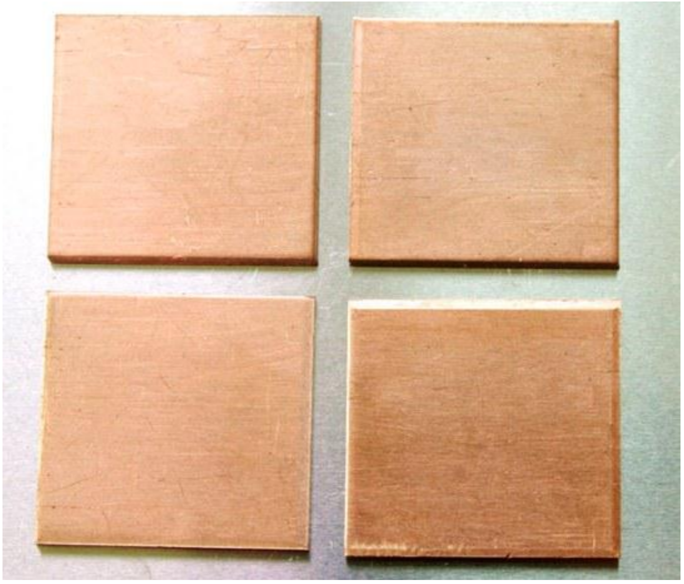


Figure 7 Copper fins

Tabular Columns

Table 1. Temperature readings of the working fluid (water) in the heat pipe

S.No	Volts (V)	Amperes (I)	Power (P)=VXI (W)	(T1) (ºC)	(T2) (ºC)	(T3) (ºC)	(T4) (ºC)	(T5) (ºC)
1	80	0.22	17.6	55	31	35	43	45
2	110	0.27	29.7	66	24	30	42	48
3	150	0.35	52.5	82	17	23	38	53
4	180	0.41	73.8	96	8	15	35	53
5	220	0.46	101.2	117	5	7	38	63
6	280	0.55	154	150	4	6	33	70

Where T1, T2, T3, T4, T5 are Temperature readings in different sections of the heat pipe

Table 2. Temperature readings of the working fluid (Nano fluid (Al_2O_3)) in the heat pipe

S.No	Volts (V)	Amperes (I)	Power (P)=VXI	(T1) (ºC)	(T2) (ºC)	(T3) (ºC)	(T4) (ºC)	(T5) (ºC)

			(W)					
1	80	0.21	16.8	60	48	34	41	45
2	110	0.28	30.8	74	57	29	42	50
3	150	0. 34	51	93	68	22	43	57
4	180	0.4	72	110	78	12	39	61
5	220	0.46	101.2	127	96	5	33	65
6	280	0.54	151.2	165	110	5	37	72

Where T1, T2, T3, T4, T5 are Temperature readings in different sections of the heat pipe

Table 3. Properties of Nano Particles

Type of Nano particle	Density of particle (kg/m^3)	Specific heat of particle (J/kg.k)
Al_2O_3 (44nm)	3600	765
Sio_2 (20nm)	2220	745
Zno (77nm)	5600	514

The Specific heat of water is 4.187 kJ/kg.K

The Specific heat of Nano fluid (Al_2O_3) is calculated by using following formula.

The widely used models of Pak and Cho [5] assume that nanofluids are homogeneous substances that could be calculated by mixing theory as follows

$$C_{p,nf} = Ø\, C_{p,np} + (1 - Ø)\, C_{p,b}$$

Where $C_{p,nf}$ is the specific heat of nanofluids, $C_{p,np}$ is the specific heat of nanoparticles, $C_{p,b}$ is the specific heat of the base fluid and Ø is the concentration by volume.

3.2 Sample calculations:

We used concentration 0. 1% in this experiment and volume of working fluid is 270 ml. So we can calculate Ø as

$$Ø = 0.1/270 = 3.7037 \times 10^{-4}$$

Substitute Ø value in the below equation, we can get

$$C_{p,nf} = Ø\, C_{p,np} + (1 - Ø)\, C_{p,b}$$

$$C_{p,nf} = 3.7037 \times 10^{-4} \times 765 + (1 - 3.7037 \times 10^{-4}) \times 4.187$$

$$C_{p,nf} = 0.28333305 + (0.99962963) \times 4.187$$

$$C_{p,nf} = 0.28333305 + 4.1854499261$$

$$C_{p,nf} = 4.468782311 \text{ KJ/ kg.k}$$

Heat transfer rate for working fluid (water):

The Specific heat of water is 4.187 KJ/ kg.k

$$Q = mC_p\Delta T$$

$$\Delta T = T1 - T5$$

Mass of the liquid = 1000 gms

At power 17.6 W

$\Delta T = T1 - T5$

$\Delta T = 55 - 45$

$\Delta T = 10\ ^{o}C$

1) $Q = mC_p\Delta T$

   $Q = 1000 \times 4.187 \times 10$

   $Q = 41870$ J

   $Q = 41.87$ KJ

At power 154 W

$\Delta T = T1 - T5$

$\Delta T = 150 - 70$

$\Delta T = 80\ ^oC$

2) $Q = mC_p\Delta T$

   $Q = 1000 \times 4.187 \times 80$

   $Q = 334960$ J

   $Q = 334.960$ KJ

Similarly We are Calculating Heat transfer rate for working fluid (Nano fluid (Al_2O_3)):

The Specific heat of water is 4.4687 KJ/ kg.k

$$Q = mC_p\Delta T$$

$$\Delta T = T1 - T5$$

Mass of the liquid = 1000 gms

At power 16.8 W

$\Delta T = T1 - T5$

$\Delta T = 60 - 45$

$\Delta T = 15\ ^oC$

1) $Q = mC_p\Delta T$

   $Q = 1000 \times 4.4687 \times 15$

   $Q = 67030.5$ J

   $Q = 67.0305$ KJ

At power 151.2 W

$\Delta T = T1 - T5$

$\Delta T = 165 - 72$

$\Delta T = 73\ ^oC$

2) $Q = mC_p\Delta T$

   $Q = 1000 \times 4.4687 \times 73$

   $Q = 415589.1$ J

   $Q = 415.5891$ KJ

Heat transfer rate difference between the working fluids water and Nano fluid (Al_2O_3)

$$Q = Q2 - Q1$$

Q1 is the Heat transfer rate of water

Q2 is the Heat transfer rate of Nano fluid (Al_2O_3)

Q is the Heat transfer rate difference between the working fluids water and Nano fluid (Al_2O_3)

At power 16.8 W

$Q = Q2 - Q1$

$Q = 67.0305 - 41.87$

$Q = 25.1605$ KJ

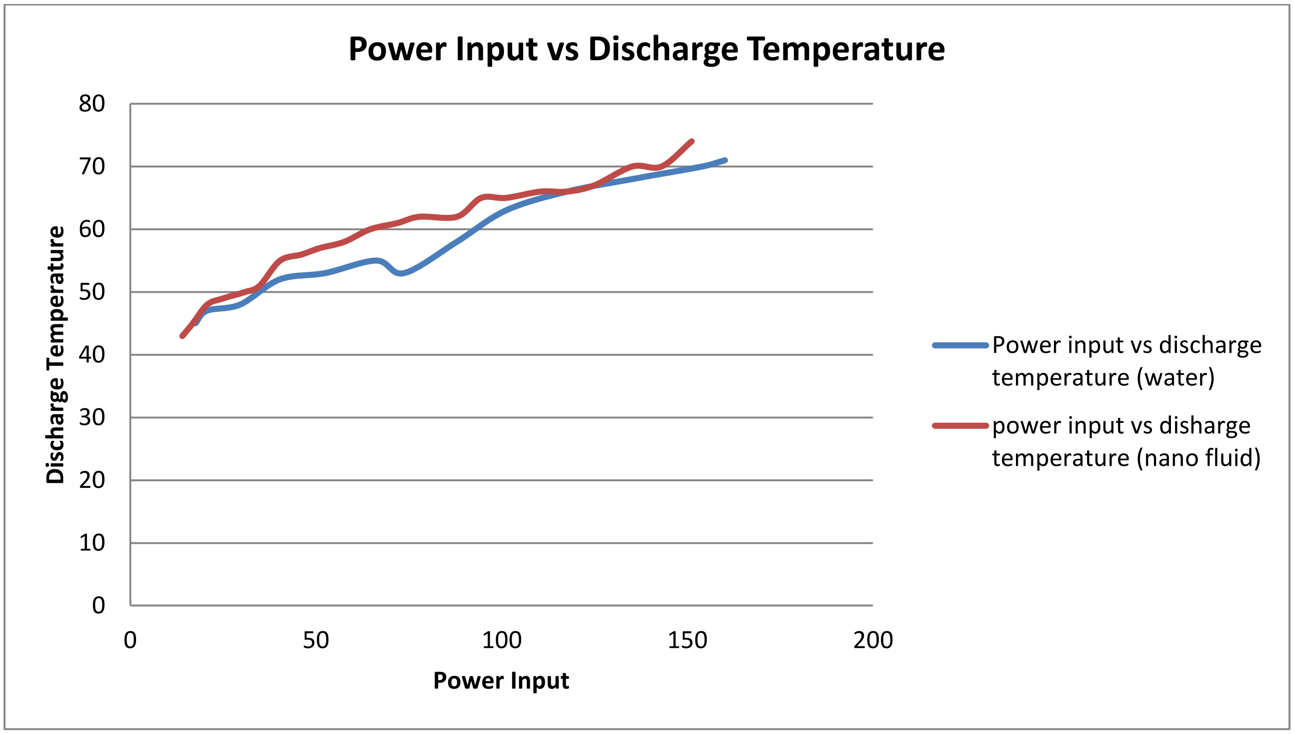
At power 151.2 W

$Q = Q2 - Q1$

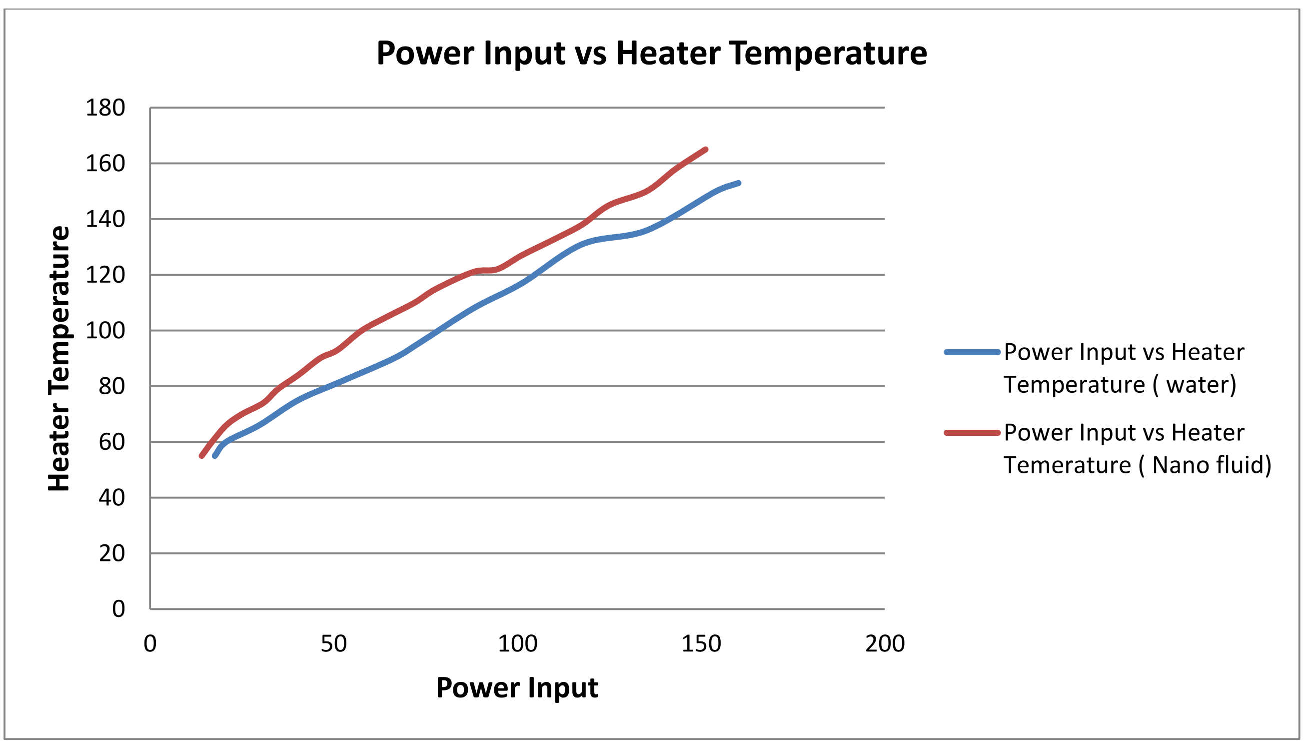
$Q = 415.5891 - 334.960$

$Q = 80.6291$ KJ

Graphs Plotted between Power input Vs Heater temperature and Power input Vs Discharge temperature



Graph 1 Power input Vs Discharge temperature



Graph 2 Power input Vs Heater temperature

Above graphs shows that Nano fluid has high heat dissipation capacity and Nanofluid increases the Thermal Conductivity Performance.

IV. RESULTS

The comparison between the working fluid (water) and working fluid (Nano fluid(Al_2O_3)) heat transfer rates are calculated. The heat transfer rate of the Nano fluid is very high. In this work the maximum heat transfer rate of the working fluid (water) is 334.960 KJ and the maximum heat transfer rate of the working fluid (Nano fluid(Al_2O_3)) is 415.5891 KJ.

V. CONCLUSION

The heat transfer rates of the working fluid (water) and working fluid (Nano fluid(Al_2O_3)) are observed and Nano fluid increases the Thermal Conductivity Performance and Nano fluid has the high heat dissipation capacity because Nano Powder has high Thermal Conductivity Property so Nano fluid gives the high heat transfer rate.

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