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Experimental Analysis of Heat Pipe for a Computer Processing Unit

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Abstract: ***Heat generated by electronic devices and circuitry must be dissipated to improve reliability and prevent premature failure. Techniques for heat dissipation can include heat sinks and fans for air cooling, and other forms of computer cooling. The thermal resistance of materials is of great interest to electronic engineers, because most electrical components generate heat and need to be cooled. Some electronic components malfunction when they overheat, while others are permanently damaged. It aims at thermal analysis of a heat-pipe and heat sink of Computer Processing Unit (CPU) which is particularly useful in energy-conservation equipment where it is desired to recover heat from hot gases for air-preheated or supplemental heating applications. In some cases the heat-pipe can take the place of more costly combinations of pumps, piping and dual heat-exchange configurations, further in this regard, design and theory is vital. Design of different heat pipes, heat sinks and heat transmitting systems are important based on the geometry and profile. It has to be designed optionally. In this CATIA software is used for designing various heat-pipes and heat sink systems which are used in heavy machinery. Secondly, thermal analysis is made by using ANSYS 8.1 software which calculates the temperature distribution and related thermal quantities in a system or component.***

Keywords: Heat Pipe, Designing, Analysis

1. Introduction

1.1 Definition

The term 'heat pipe' as the name implies, is a simple device having high thermal conductivity to transfer heat very quickly from heat source to heat sink by means of evaporation and condensation of a fluid in a sealed system. Basically heat pipe can be considered as a super thermal conductor that transmits heat by the evaporation and condensation of a working fluid.

1.2 Working of Heat Pipe

The heat pipe operating principle is that a liquid is heated to its boiling point, vaporizes and gives of useful heat, condenses and returns to the heat source. The heat pipe is a closed and operates in vacuum.

The boiling point of a liquid is a function of the pressure surrounding it .Because of the strong vacuum (about 10-3 microns of Hg), the working fluid is virtually in a state of liquid – vapor equilibrium. Consequently, a slight increase in temperature will cause it to boil and vaporize.

Inside the container is a liquid under its own pressure, which enters the pores of the capillary material wetting all internal surfaces. Applying heat at any point along the surface of the heat pipe causes the liquid at that point to boil and enter a vapor state. When that happens, the liquid picks up the latent heat of vaporization. The gases, which then has a higher pressure, moves inside the sealed container to a colder location where it condenses.

Thus, the gas gives up the latent heat of vaporization and moves heat from the input to the output end of the heat pipe. The performance of heat pipe is affected by gravity. Optimum performance is achieved when the pipe is vertical with the condenser section directly above the evaporator. In this position gravity aids the pumping action in the wick.

However, heat pipes can operate in any position and are bi-directional. If a heat pipe doesn't take advantage of the gravitational forces, a high power rating is required. The heat pipe operation is as shown in figure no.1

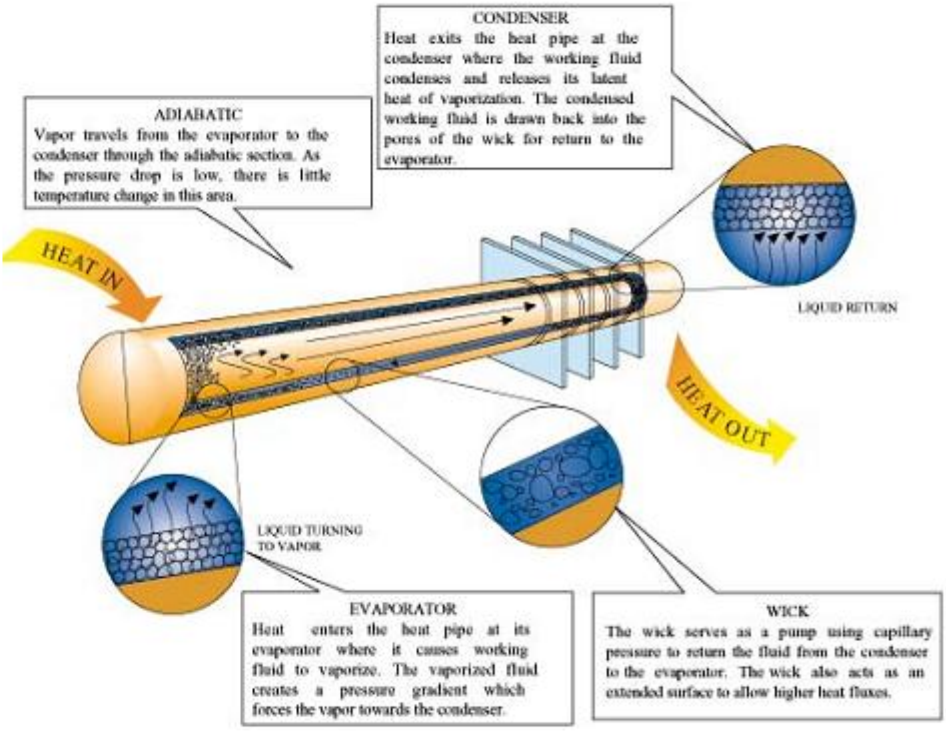

Figure 1: Heat Pipe Operation

2. Experimental Setup

Experimental apparatus for heat pipe testing is shown schematically in figure.2 and consists of a computer; scanning thermocouple thermometer stainless steel wires of 0.1 mm diameter were wound around the evaporator section to supply heat to the heat pipe. Between the heater and the heat pipe surface was a layer of 0.05mm canton electric insulation. Both the evaporator and adiabatic section were thermally insulated with asbestos paper. The heat loss from the insulation surface to the ambient was determined by evaluating the temperature difference and the transfer coefficient of natural convection between the insulated outer surface and ambient. Within the test range the heat loss is negligible i.e. about 0.3w. The condenser section of the heat pipe was placed in a water cooling jacket. The thermocouples were installed along the heat pipe length to measure the surface temperature distribution. The results of the experiment as clearly mentioned in the graphs.

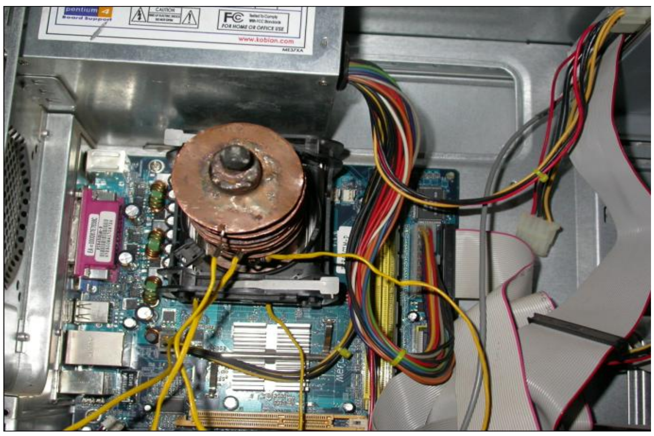

Figure 2: Heat Pipe Operation

2.1 Experimentation

The following results are valid for the following specifications as shown in figure .3

Material of heat pipe : Copper

Working fluid used : Water

Total length of the heat pipe, L : 105mm

Adiabatic length L_a : 35mm

Evaporator length L_e : 35mm

Condenser Length L_c : 35mm

Evaporator temperature T_e : 55^0C

Processor temperature T_p : 62^0C

Condenser temperature, T_a : 38^0C

A simple model for calculating the thermal performance of heat pipe is as follows:

Approximately, the thermal resistance of heat pipe can be calculated using the equation,

$$Rhp = (1/he\ Ae) + (1/hc\ Ac) \text{ --------(1)}$$

Where, Ac = internal surface area of the condenser (m^2)

Ae = internal surface area of the evaporator (m^2)

hc = condensation heat transfer coefficient (W/ m^2 ^{0}k)

he = evaporator heat transfer coefficient (W/ m^2 ^{0}k)

Rhp = thermal resistance of heat pipe (^{0}C/W)

The evaporating heat transfer coefficient he and condensation heat transfer coefficient hc are estimated to be about 5000W/m^2 ok.

The rate of heat transfer from the processor to the atmosphere is given by:

$$Q = dT/Rhp \text{ --------(2)}$$

Where Q = rate of heat transfer (W)

dT = Temperature difference between the processor surface temperature and condenser temperature.

Thermal resistance (Rhp):

from eq(1): Rhp= $(1/(5000*(\pi/4)(0.017)2))+(1/(5000*(\pi/4)(0.017)2))$

= 1.762 ^{0}C/W

Heat transfer rate (Q):
from eq(2): Q = (62-38)/1.762
= 13.62 W

Heat pipes has many advantages compared to other cooling devices such as fans, fin heat sinks and thermo modules are that it has simple structures, no moving parts and does not use electricity. The heat pipe has merit in that it can be freely designed, that is, it can be of any length, size and easy to bend or flatten to suit the design. It can also easy to install and is of free of maintenance.

2.2 Heat Transfer Rate Through Fins

The following assumptions are made for the analysis of heat flow through the fin,

1) Steady state heat conduction
2) No heat generation within the fin
3) Uniform heat transfer coefficient (h) over fin surface.
4) Homogeneous and isotropic font material.
5) Negligible contact thermal resistance.
6) Heat conduction one-dimension.

As per the design considerations, the fin is considered as the long fin. Since the tip of fin temperature is approximately equal to the ambient temperature.
Heat transfer rate through one fin,
Qfin = √ (PHKACS) (Te – Ta)
Where,
P = Perimeter of fin (m)
h = Coefficient of heat transfer of Cu (w/m^2 ^{0}C)
k = Thermal conductivity of Cu (w/m ^{0}c)
Acs = Area of cross section (m^2)
Te = Evaporator temperature
Ta = Ambient temperature

Qf= √ (50+1)10-3 x 20 x 386 x (50x50x10¯6)-π/4$(0.017)^2$ x (55-38)
= 15.21watts
No of Fins = 9
Total rate of heat from through fin Q = 136.0watts

This means that the transistor can dissipate about 28 watts before it overheats. A cautious designer would operate the transistor at a lower power level to increase its reliability. This method can be generalized to include any number of layers of heat-conducting materials, simply by adding together the thermal resistances of the layers and the temperature drops across the layers.

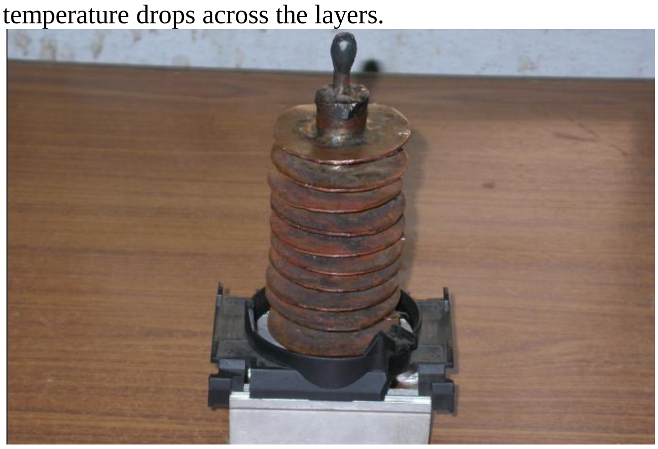

Figure 3: Heat pipe with copper plates

2.3 Expermentel Analysys

Table 1: Temperatures at various sections of heat pipe when processor max temp is 62^{0}c

Different Sections of Heat pipe	*Length (mm)*	*Difference in temp (^{0}C)*	*Resistance of H.P (^{0}C/W)*	*Q (w)*
Evaporator	0-35	7	1.762	3.9
Adiabatic	35-70	8.5	1.762	4.824
Condenser	70-105	24	1.762	19.18

Table 2: Temperatures at various sections of heat pipe when processor max temp is 64^{0}c

Different Sections of Heat pipe	*Length (mm)*	*Difference in temp (^{0}C)*	*Resistance of H.P (^{0}C/W)*	*Q (w)*
Evaporator	0-35	7.8	1.762	4.426
Adiabatic	35-70	89.7	1.762	5.502
Condenser	70-105	26.9	1.762	15.266

Table 3: Temperatures at various sections of heat pipe when processor max temp is 61.5^{0}c

Different Sections of Heat pipe	*Length (mm)*	*Difference in temp (^{0}C)*	*Resistance of H.P (^{0}C/W)*	*Q (w)*
Evaporator	0-35	7.5	1.762	4.426
Adiabatic	35-70	8.8	1.762	4.99
Condenser	70-105	26.2	1.762	14.87

Table 4: Temperatures at various sections of heat pipe when processor max temp is 63^{0}c

Different Sections of Heat pipe	*Length (mm)*	*Difference in temp (^{0}C)*	*Resistance of H.P (^{0}C/W)*	*Q (w)*
Evaporator	0-35	6.5	1.762	3.68
Adiabatic	35-70	6.8	1.762	3.85
Condenser	70-105	23.2	1.762	13.39

Table 5: Temperatures at various sections of heat pipe when processor max temp is 61.5^{0}c

Different Sections of Heat pipe	*Length (mm)*	*Difference in temp (^{0}C)*	*Resistance of H.P (^{0}C/W)*	*Q (w)*
Evaporator	0-35	6.5	1.762	3.68
Adiabatic	35-70	4.4	1.762	2.49
Condenser	70-105	22.3	1.762	12.66

3. Modeling and Analysis

3.1 Design of Heat Pipe

Height of the pipe : 150mm
External diameter of the vertical pipe : 20mm
Internal diameter of the vertical pipe : 19mm
Thickness of the base plate : 1mm
Diameter of the base plate : 75mm

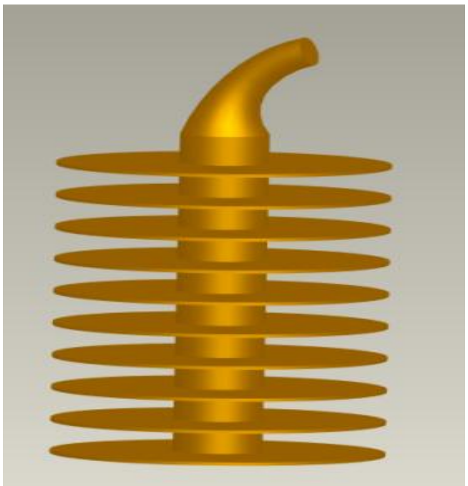

Figure 4: Design of a Heat pipe

3.1 Data considered for the analysis of heat Pipe

1. The fins are made up of Copper.
2. Thermal conductivity of the copper is 393W/mK
3. Specific Heat of copper is 385.2J/KgK.
4. Density of the copper is 8900Kg/m3.
5. The fim Co-efficient is 50W/m2K
6. Heat pipe is assumed to be a thermal mass solid of Brick 8Node 70
7. Heat lost from the base is 5.44W
8. Heat flux is -753.045W/m2
9. The base of the heat pipe is circular and base dimensions are Φ 75x150mm long

4. Results

Temp distribution Vs along the length of the heat pipe

This graph present some representative testing results for the heat pipe in terms of temperature distribution along the length of the heat pipe. The evaporator and condenser lengths were respectively, 0-35mm and 70-105mm.

Figure.4 Length Vs Temperature

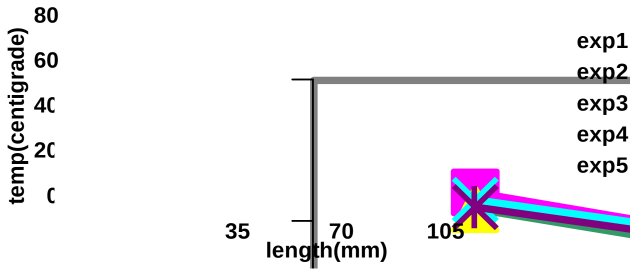

Figure 4: Length Vs Temperature

The experiments were undertaking for different temperatures through the adjustment of coolant bath temperature. At each temperature the power input to the heat pipe was gradually increased from a lower level to a higher level until the temperature drop across the heat pipe length reached about 30-35^{0}C. It should pointed out that the heat pipe was still able to work steadily at this range of temperature drops.

Heat Input Vs Temperature Distribution.

This figure 5 shows the test results. The y-axis of the graph represents the temperature difference (^{0}C) between an atmosphere and the processor temperature and the heat input (W) is represented along x-axis. The variation in the difference in temperatures with heat pipe and without heat pipe are represented in the graph. It should be pointed out that the temperature drop is very less when heat pipe is in use and the temperature drop is more for the system without heat pipe.

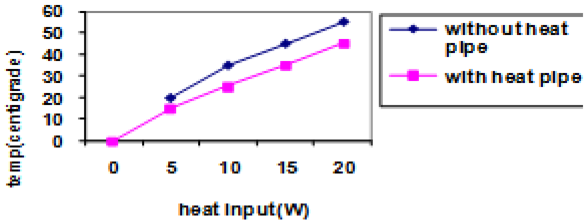

Figure 5: Heat Input Vs Temperature distribution

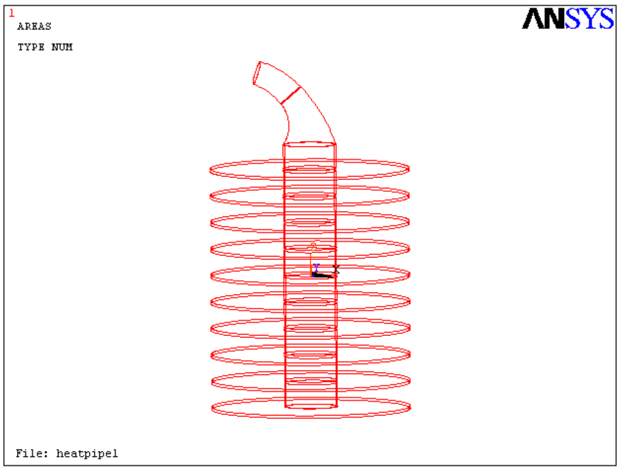

Figure 6: Heat Pipe used in CPU is designed for the analysis

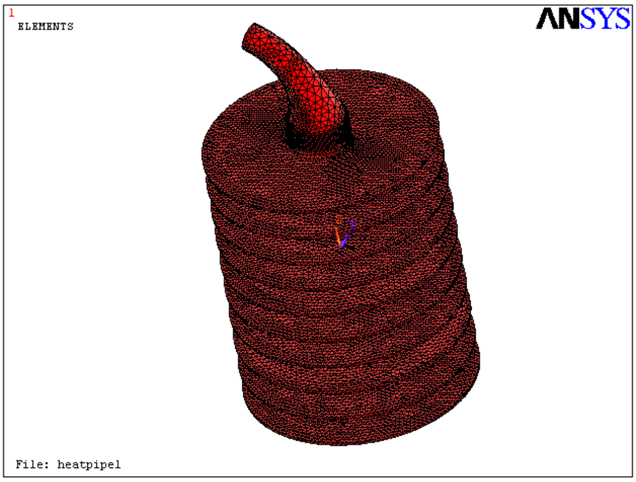

Figure 7: Heat pipe is meshed for the analysis

The above figure shows the meshing of a heat pipe with mesh size as 4, which used for the analysis.

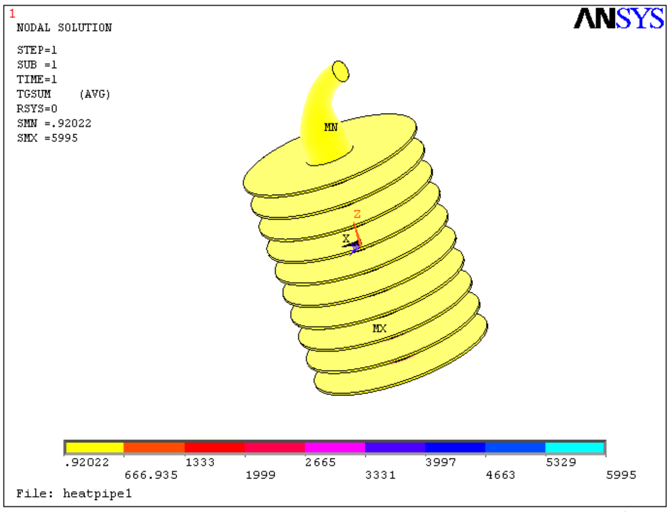

Figure 8: Temperature distribution of the heat pipe at 62 ^{0}C

The above figure shows temperature distribution along the heat pipe with max stress value of 5995 at 62^{0}C.

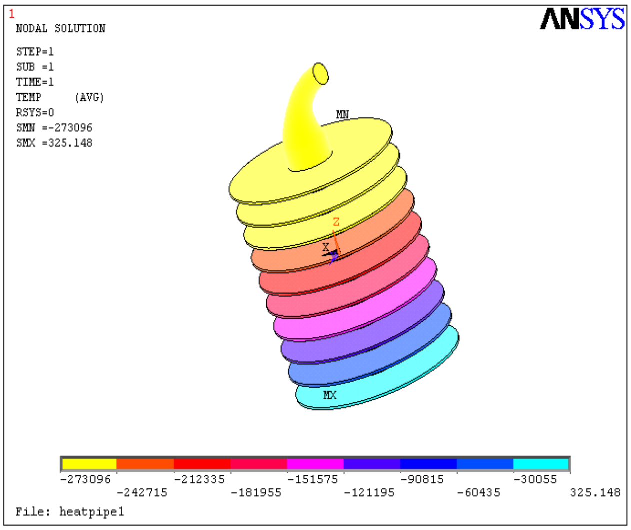

Figure 9: Thermal Flux of the heat pipe at 62 ^{0}C

The above figure shows thermal flux along the heat pipe with maximum value of 325.148 at 62^{0}C.

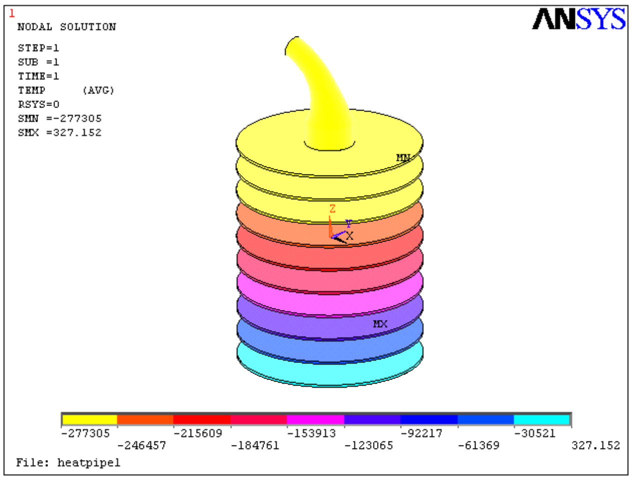

Figure 10: Temp distribution of the heat pipe at 64 ^{0}C

The above figure shows temperature distribution along the heat pipe with max stress value of 327.152 at 64^{0}C.

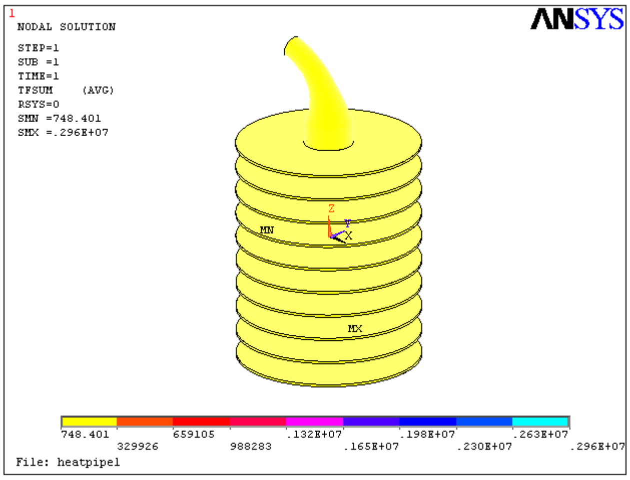

Figure 11: Thermal Flux of the heat pipe at 64 ^{0}c

The above figure shows thermal flux along the heat pipe with maximum value of 743.401 at 64^{0}C

Fig No. 6.7 Thermal Gradient of the heat pipe at 64 ^{0}C

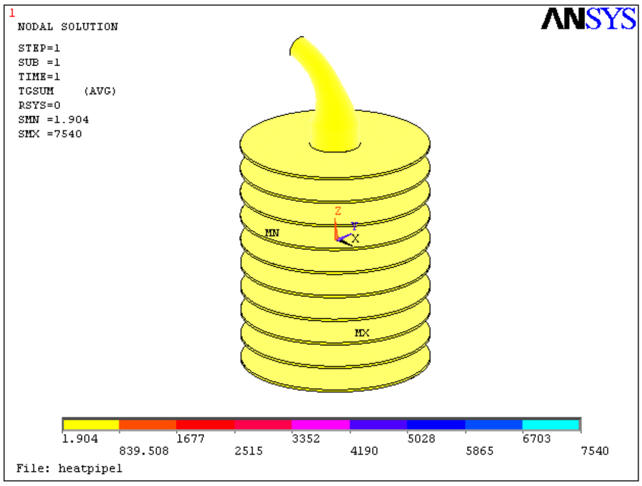

Figure 11: Thermal Gradient of the heat pipe at 64 ^{0}C

The above figure shows thermal gradient along the heat pipe with maximum value of 7540 at 64^{0}C

5. Conclusion

The fabrication of heat pipe has been carried out and experiments were done comparing with heat pipe and heat sink of the computer processing unit (CPU). The temperature without using heat pipe is reduced from 64^{0}C to 46^{0}C and by introducing heat it is reduced further to 36^{0}C. The obtained values are tabulated in the tables. As a result, overall heat transfer rate was calculated. Experimental calculations are also done and results are represented in graphs. As a result of the tests, maximum heat transfer rate and reliability of the heat pipe developed were obtained and it was indicated that the heat pipe can be applied to electronic equipment cooling.

When used properly, heat pipes can do wonders. However, they are certainly not the ultimate solution to all cooling related problems. Due to the number of factors to consider when applying heat pipes, our advice is: Use ready-made heat pipe-based coolers only if you are absolutely sure that they are suitable for your particular cooling problem. Do not try to build your own heat pipe-based cooling system, unless you really know what you are doing.

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