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Analysis the Enhancement of Heat Transfer Rate in Heat Pipe with Various Wick Materials for Effective Utilization of Waste Heat in Industries

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Abstract:** Miniature Metal Powdered Sintered Wick Heat Pipe (sintered heat pipe) is a passive device which as high thermal efficiency for heat flux in a electronic cooling. In this paper Circular heat pipe with various wick materials such as Poly-Phenylene Benzo-Bisoxazole and Ultra-high-molecular-weight polyehylene and also grooved in wick structure is taken. The necessary numerical computation are accomplished by FLUENT (the CFD solver program) and the result are given. The objective is to study the heat flux of grooved structure with different wick material.
Keywords:** Capillary-driven two-phase systems, isothermal, grooved structure wick, evaporate, Condence.

I. INTRODUCTION

Historically, the utilization of metallic heat sinks has been sufficient to supply the specified thermal management for many electronic cooling applications. However, with the new breed of compact devices dissipating larger heat loads, the use of metallic heat sinks is sometimes limited due to the weight and physical size required. Accordingly, the use of heat pipes is becoming an answer of choice. Capillary-driven two-phase systems provides significant advantages over traditional single-phase systems. With the typically increased thermal capacity related to the phase transition of a working fluid, considerably smaller mass flow rates are required to move equivalent amounts than in single-phase liquid or gas systems for a given temperature range. Moreover, heat transfer coefficients of two-phase systems are much greater than in single-phase flows and end in enhanced heat transfer. Lower mass flow rates and enhanced thermal characteristics provide the advantages of smaller system size (and weight) while providing increased performance. The thermal capacity of a single-phase system depends on the natural process of the working fluid; thus, an outsized gradient or a High Mass flow is required to transfer a large amount of heat. However, a two-phase system can provide essentially isothermal operation no matter variations within the heat load. Additionally, single phase systems require the utilization of mechanical pumps and fans to circulate the working fluid, while capillary-driven two-phase systems haven't any external power requirements, which make such systems more reliable and free of vibration. The best known capillary-driven two-phase system is that the heat pipe, where a schematic of a standard heat pipe. However, the planning of the heat recovery systems with heat pipe units is that the key to providing a device system to figure as efficient needless to say . Without correct design of such systems, heat pipes aren't ready to transport enough heat and should function as a particularly poor thermal conductor within the systems. The performance of natural convection heat sinks is directly dependent on the effective area ; simpler surface area leads to better performance. A heat pipe embedded into the bottom material of a typical aluminum extrusion can reduce the general temperature difference along the bottom material, tending to isothermalize the bottom material. In essence the localized heat source is spread equally along the length of the heat pipe, increasing the general efficiency of the heat sink. Although an embedded heat pipe heat sink is slightly more expensive due to the added cost of the heat pipe, it is an easy method of improving the performance of a marginal extrusion. The more elegant approach is to design a heat sink that utilizes full characteristics of a heat pipe. Typical extruded heat sinks have limited aspect ratios and thick fins, which results in lower surface area per length. The material thickness adds unnecessary weight, and most importantly obstructs the cooling air flow. To alleviate the extrusion limits, bonded fin heat sinks are developed which allow the utilization of a tall, thin fin, which optimizes cooling air flow. But bonded fin heat sinks can also be limited by the conduction losses within the base plate for concentrated heat sources. A heat pipe is utilized for conjunction with parallel plate fins provides more efficient area with minimum volume demands.

This design application is beneficial when there's not enough physical volume, or airflow above the device to use an extrusion, and allows the designe rmuch latitude in component arrangement. The heat pipe can transport the heat to a "remote" parallel plate fin stack which have enough volume to dissipate the heat. Heat pipes can be designed into most electronic devices for various power levels, and should even allow the utilization of a natural convection conductor . Computational fluid dynamics may be a powerful tool for fluid dynamics and thermal design in industrial applications, also as in academic research activities. Based on the current capabilities of the main CFD packages suitable for industry (such as, FLUENT and CFX) and the nature of industrial applications, understanding the physics of the processes, introducing adequate simplifications and establishing an appropriate model are essential factors for obtaining reasonable results and proper thermal design.

II. STRUCTURE AND OPERATION OF HEAT PIPES

A. Envelope

The work of the Envelop**e** is to isolate the working fluid from the outside environment. It is also to be there for leak proof, maintain the pressure differential across the walls, and enable transfer of thermal energy to take place from and into the working fluid.

B. Working Fluid

As the operation of the heat pipe is based on evaporation and condensation of the working fluid, its selection is an important factor in the manufacture and design of the heat pipe. The working fluid is selected based on the working temperature range of the heat pipe.

C. Wick

The wick structure in a heat pipe facilitates liquid and vapour return from the evaporator to the condenser or the condenser to the evaporator . The main purposes of wick are to distribute the liquid around the evaporator section of heat pipe, and to generate the capillary pressure.

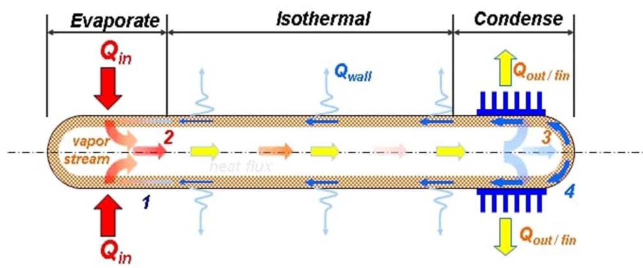

Fig 2.1 Working Of Heat Pipe.

The Fig 2.1 is explained in the below lines, which explaines the working of Heat Pipe.

1) The Thermal Energy is absorbed by Working Fluid and Evaporates to Vapour.
2) Vapour migrates along cavity to lower temperature end of the Heat Pipe.
3) The Thermal Energy is released with help of a external device like fan and Vapour Condenses back to fluid and is absorbed by the Wick.
4) Working Fluid flows back to the higher temperature end of the Heat Pipe.

III. SPECIFICATION OF WORK

Heat pipe material : Copper
Wick material : Poly-Phenylene
Benzo Bisoxazole (a),
Ultra-High-Molecular-Weight
Polyethylene (b).
Type of Wick : Screen Groove
Length of Heat pipe: 210 mm

A. Input Data

Water Velocity = 0.01m/s
Heat inlet Temperature = 300 k
Evaporator Section Temperature = 350 k
Condenser Section Temperature = 280 k

B. Flow Calculation

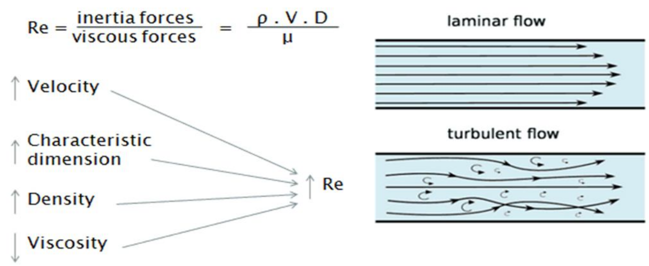

Fig 3.1 Flow Calculation.

$=1.229\text{x}0.001\text{x}0.002/1.87\text{x}10^{-5}=19.7$
The flow is blow 2000 so the Laminar based formula to be used in this Flow analysis.

C. Properties

Table 3.1 Properties Of Wick Materials.

Material	Density(kg/m^3)	C_p(specific heat)(j/kg-k)	Thermal conductivity
Poly-Phenylene Benzo-Bisoxazole	1540	502.48	0.9
Ultra-High-Molecular-Weight Polyethylene	949	1900	0.42

D. Specification of Working Fluid

Distilled Water
Saturation Temperature = 323.15k
Density =0.08306 kj/m^3

IV. RESULT AND DISCUSSION

A. Poly-Phenylene Benzo Bisoxazole

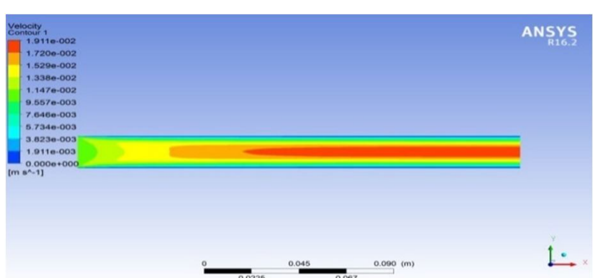

Fig 4.1 Velocity Flow Water.

The above Figure 4.1 shows how the velocity flow of water inside the heat pipe and variations in the chambers is clearly shown for Poly-Phenylene Benzo Bisoxazole material.

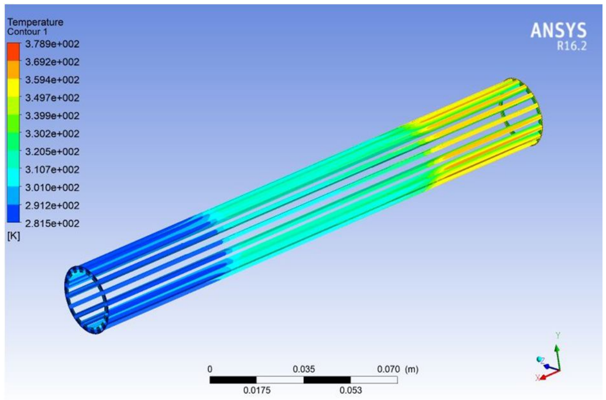

Fig 4.2 Temperature Contour Wick Structure.

The above Figure 4.2 shows how the temperature contour on the wick structure which indicates how the elements have been made and temperature distribution is shown clearly.

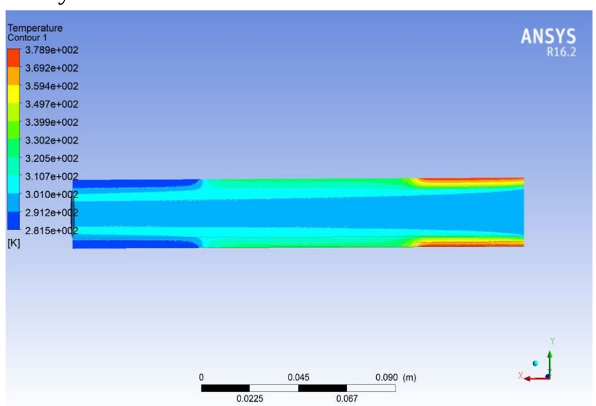

Fig 4.3 Temperature Over Wick Structure.

The above Figure 4.3 shows the temperature over the wick structure and gives the information how it varies from chamber to chamber.

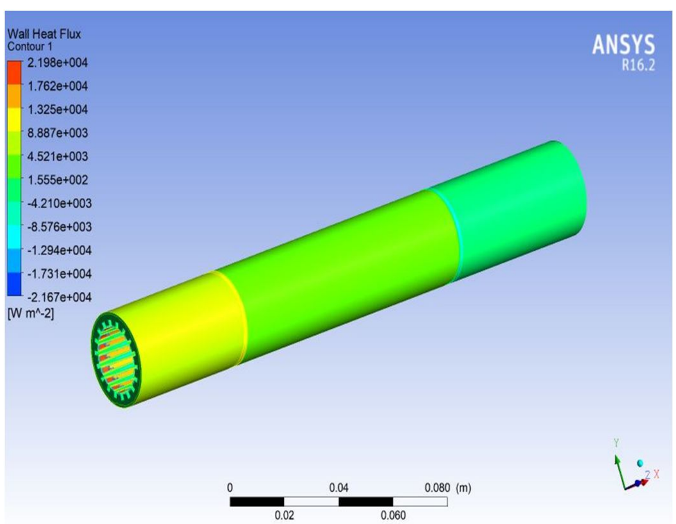

Fig 4.4 Heat Flux.

The above Figure 4.4 shows the heat flux for the given input and shows how it is efficiently transfers the heat as heat flux.

B. Ultra - High - Molecular - Weight Polyethylene

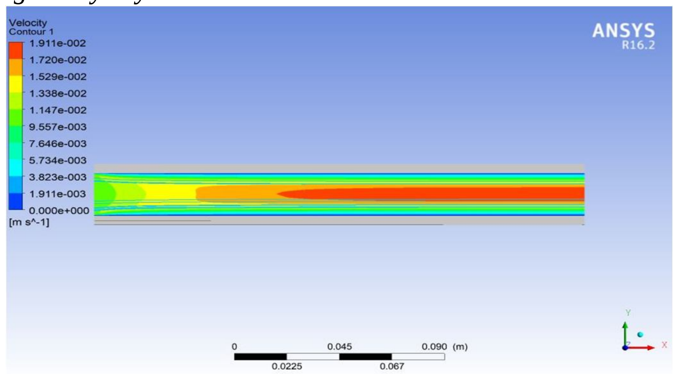

Fig 4.5 Velocity Flow Water.

The above Figure 4.5 shows how the velocity flow of water inside the heat pipe and variations in the chambers were clearly shown for Ultra-High-Molecular -Weight-Polyethylene material.

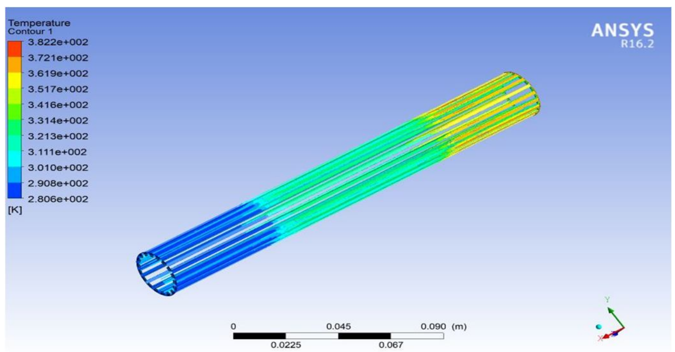

Fig 4.6 Temperature Contour Wick Structure.

The above Figure 4.6 shows how the temperature contour on the wick structure which indicates how the elements have been made and temperature distribution is shown clearly.

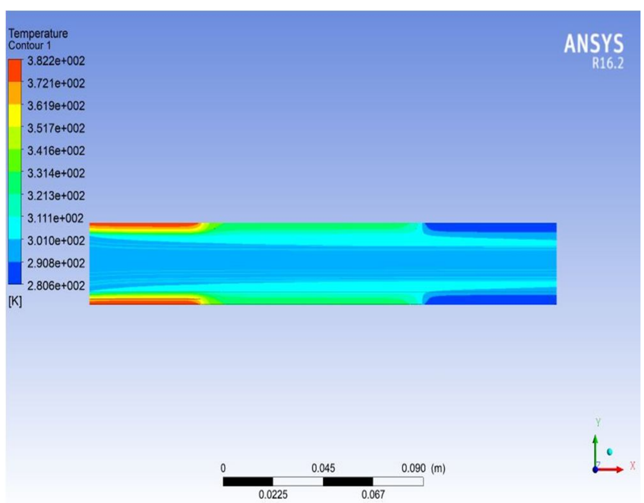

Fig 4.7 Temperature Over Wick Structure.

The above Figure 4.7 shows the temperature over the wick structure and gives the information how it varies from chamber to chamber.

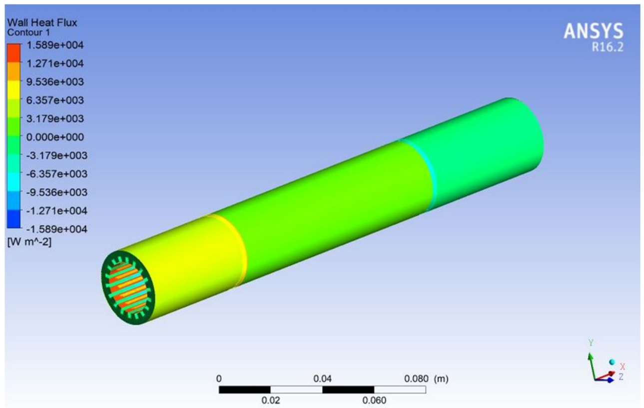

Fig 4.8 Heat Flux.

The above Figure 4.8 shows the heat flux for the given input and shows how it is efficiently transfers the heat as heat flux.

Table 4.1

Material	Heat Flux(W/m^2)	Wick structure Temperature(K)
Poly-Phenylene Benzo-Bisoxazole	2.198×10^4	316.099
Ultra-High-Molecular-Weight Polyethylene	1.544×10^4	317.345

V. CONCLUSION

The study of computional flow dynamics (CFD) is used to analyse the performance of Heat Pipe. The analysis was done for various wick material with grooved wick structure. The heat pipe model is created, simulated using ANSYS FLUENT. The variation of heat flux was observed for various wick materials.

The summary of the present work as follows

A. The CFD result for poly-phenylene benzo-bisoxazole at 300k is 2.198×10^4 (W/m^2) and groove wick structure temperature is 316.099k.
B. The CFD result for ultra-high-molecular-weight polyethylene at 300k is 1.544×10^4 (W/m^2) and groove wick structure temperature is 317.345k.

From the above summary it is clear that poly-phenylene benzo-bisoxazole has high heat flux in comparison with ultra-high-molecular-weight polyethylene.

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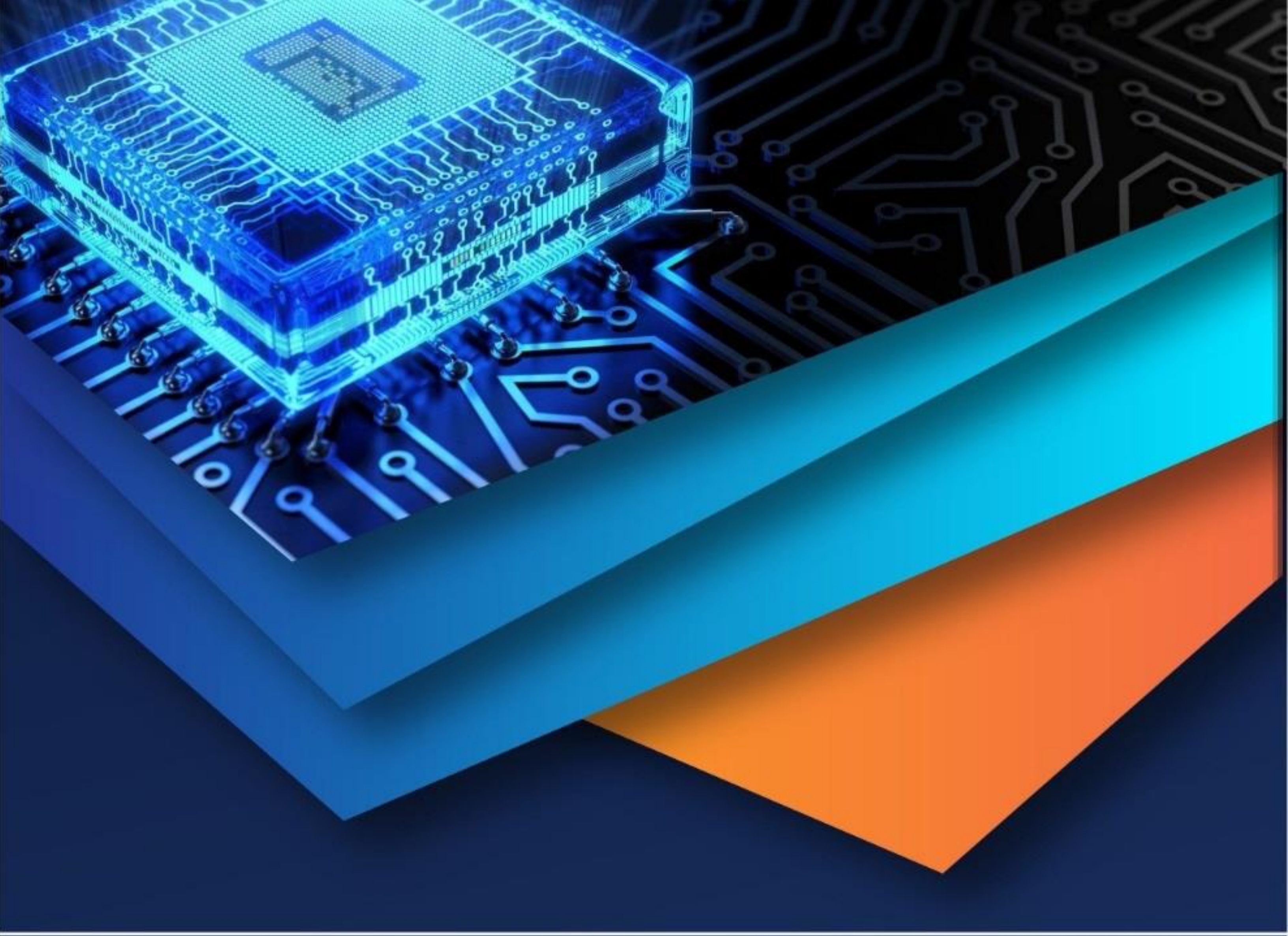

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