EVALUATING THE EFFECT OF DIFFERENT PROCESS PARAMETERS OF HEAT PIPE THROUGH NUMERICAL ANALYSIS

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***Abstract*: Heat pipe is basically divided in to three sections that are evaporation zone, condensation zone and adiabatic zone. In evaporation zone working fluid absorbed latent heat and get vaporized and move toward the condensation zone. In adiabatic zone no heat transfer takes place in between system and surrounding, whereas in case of condensation zone, fluid loses its heat and get condense. For increasing the performance of heat pipe many researchers have performed different work. Here in this work effect of different materials used for the manufacturing of heat pipe was performed. For analysing the effect of different material, it considered three most commonly available materials that are aluminium, copper and stainless steel. Through analysis it is found that heat pipe made from copper is the most efficient heat pipe system for heat transfer as compared to other.**

***Keywords*: heat pipe, working fluid, materials, power input, optimization**

1. Introduction

A heat pipe is a passive heat transfer device having a high effective thermal conductivity. The heat pipe is a closed, evacuated cylindrical vessel with the internal walls lined with a capillary structure or wick that is filled with a working fluid as shown in Figure 1.1. The heat pipe is evacuated and then filled with the working fluid prior to being sealed; the internal pressure is set by the vapour pressure of the fluid. The heat acts as input at the evaporator and it makes the fluid to vaporize by creating a pressure gradient in the pipe. This forces the vapour to flow along the pipe to a cooler section where it condenses and giving up its latent heat of vaporization. It is then returned to the evaporator due to the capillary forces developed in the wick structure. In other words, the heat pipe is an evaporation – condensation device for transferring heat, in which the latent heat of vaporization is exploited to transport heat over long distances, with a corresponding small temperature difference.

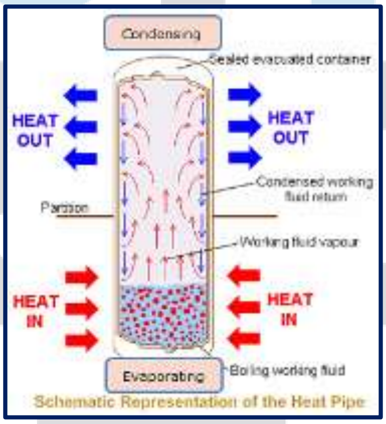


Figure.1 Schematic of a heat pipe

Heat pipe is basically used for the heat transfer from primary heat source. Heat pipes have high specific heat transfer properties as compared to heat sink and different heat exchangers. It is mainly used for devices where specific heat transfer requirement is very high. For enhancing the performance of heat sink many of the researchers have performed different work and optimized the different process parameters. So, in order to further improve the performance of heat pipe, here in this work effect of different material used for the construction of heat pipe was calculated and on the basis of different temperatures value of equivalent thermal resistance was also calculated. This work also discusses the effect of different working fluid on the performance of heat pipe. For analyzing the effect of different working fluid most commonly available fluid which can be used inside the heat pipe were analyzed like water, ethyl alcohol, ammonia and R134 refrigerant. For analyzed the effect of different heat input on the performance of heat pipe 20, 40, 60 and 80 W of power is considered in each case. For each power input and different working fluid, value of thermal resistance was calculated.

2. Effect of different material used for heat pipe manufacturing

For analyzing the effect of different materials used for the manufacturing of heat pipe, here in this work three commonly available materials were used for the manufacturing of heat pipe that is aluminium, copper and stainless steel. For each material four different power inputs that is 20, 40, 60 and 80 W was considered and for each case value of equivalent thermal resistance was calculated.

2.1 For Aluminium material

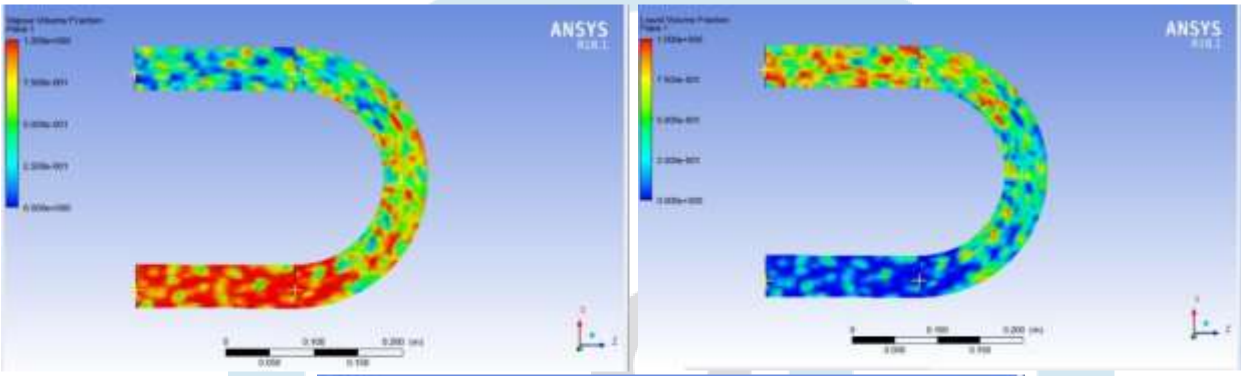
In case of aluminium used for the manufacturing of heat pipe, effect of different heat input on heat pipe was analyzed. During validation analysis, aluminium is considered for the manufacturing of heat pipe. The temperature, vapour fraction and liquid fraction contour was already mention in above section.

2.1.1 For 60 W heat input

Here in this case of analysis 60 W power input is given to heat pipe. The contours of different process parameters is mention in the below figures. The value of equivalent thermal resistance for different heat input in case of aluminium heat pipe is also mention in table.

Fig.2 (a) shows volume fraction of vapour for 60 W power input, (b) shows liquid fraction of vapour for 60 W power input

Above fig. shows the variation of volume fraction of liquid and vapour at 60 W power input. Through contour plots it is found that for 60 W power input volume fraction of vapour increases as compare to 40 W power input.



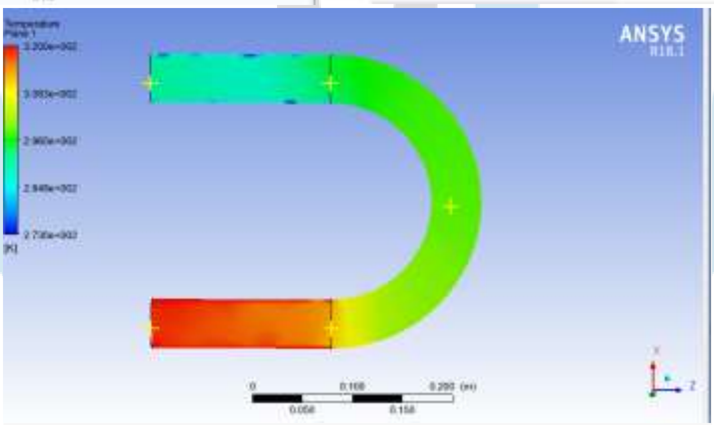


Fig.3 temperature variation throughout the heat pipe

Table.1 Value of thermal resistance for aluminium

S.No.	Power input (W)	Thermal Resistance (K/W)
1	20	0.34
2	40	0.2
3	60	0.175
4	80	0.158

Above table shows the value of thermal resistance at different power input, through table it is found that as the power input increases the value of thermal resistance for aluminium heat pipe decreases. Which means that at higher power input the value of thermal resistance is low and heat pipe work more efficiently as compared to lower power input.

2.2 For Copper

Here in this case of analysis copper is considered for the manufacturing of heat pipe. Here in this case of analysis other boundary conditions will remain same as considered during Numerical CFD analysis of aluminium. It calculates the value of equivalent thermal resistance for different power inputs. The contours of different performance parameters is shown in the below section. Through analysis it is found that volume fraction of vapour in copper heat pipe is mush higher as compared to aluminium heat pipe, whereas as volume fraction of liquid is lesser in all zone as compared to aluminium heat pipe. This trend shows that the heat transfer in copper heat pipe is higher as compared to aluminium pipe. The variation of temperature at different position of copper heat pipe with respect to time is also less as compared to aluminium pipe. In case of copper, steady state condition reaches much faster than the aluimium.

Table.2 Value of thermal resistance for copper heat pipe

S.No.	Power input (W)	Thermal Resistance (K/W)
1	20	0.31
2	40	0.188
3	60	0.162
4	80	0.145

2.3 For Stainless steel

Here in this case of analysis stainless steel is considered for the manufacturing of heat pipe. Other boundary conditions will remain same as considered during Numerical CFD analysis of aluminium and copper heat pipe. It calculates the value of equivalent thermal resistance for different power inputs. The contours of different performance parameters mention in below section. Through volume fraction contours of liquid and vapour, it is found that in case of stainless steel the volume fraction of liquid in different zone of heat pipe is higher than the aluminium and copper heat pipe, whereas it has lower vapour fraction as compare to other two material. This conclude that the heat transfer in stainless steel heat pipe is less as compared to copper and aluminium pipe.

Table.3 Value of thermal resistance for strainless steel heat pipe

S.No.	Power input (W)	Thermal Resistance (K/W)
1	20	0.43
2	40	0.26
3	60	0.19
4	80	0.158

3. Comparison of different material

After analyzing the different materials individually used for the manufacturing of heat pipe at different power input comparison was done. Here value of equivalent thermal resistance at different power input was compared. The value of thermal resistance for different material at different power input is shown in the below fig.

Table.4 Comparison of different material used for heat pipe

S.No	Power input (W)	Thermal resistance for Aluminium (K/W)	Thermal resistance for Copper (W/K)	Thermal resistance for Stainless steel (W/K)
1	20	0.34	0.31	0.43
2	40	0.2	0.188	0.26
3	60	0.175	0.162	0.19
4	80	0.15	0.145	0.158

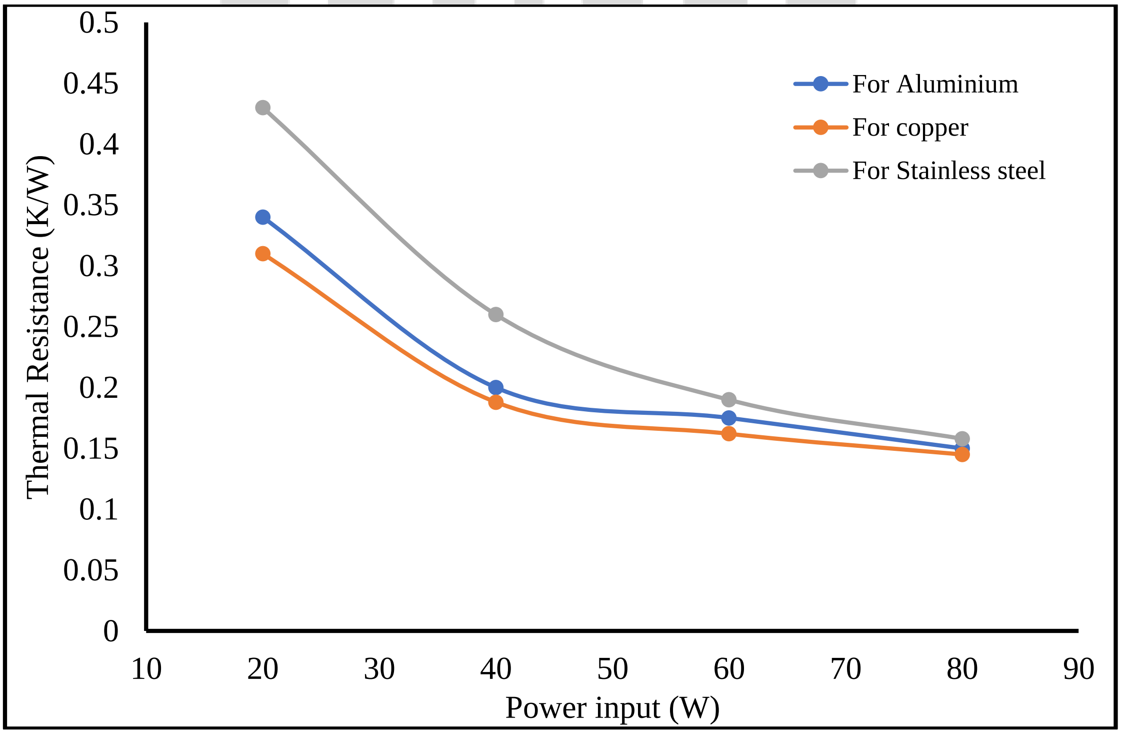


Fig.4 comparison of value of thermal resistance for different materials

From above graph it is found that the value of thermal resistance for copper heat pipe is less as compared to aluminium and stainless steel. It is also found that slope of thermal resistance decrement is faster up to 40 W power input, whereas after 40 W power it is less. So it is concluded that copper heat pipe shows better performance as compared to other materials heat pipe.

4. Conclusion

CFD analysis of heat pipe gives the brief information regarding the evaporation and condensation mechanism of heat pipe. Through analysis it is found that the material used for the manufacturing of heat pipe effect the performance of heat pipe. Through analysis it is found that copper heat pipe shows low equivalent thermal resistance as compared to other materials and it also shows the uniformity in volume fraction of liquid as well as vapour, which increases the performance of heat pipe. Higher the vaporization volume fraction inside the heat pipe, greater is the heat transfer capacity, which is more in case of copper heat pipe. It is concluded that heat pipe made from copper have higher performance as compared to other.

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