Thermal Analysis Of A Nuclear Power Plant Heat Pipe Exchanger Using Ansys

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ABSTRACT
Heat pipes are a unique type of heat transfer device that can transport large amounts of heat through a small cross sectional area, with minimal temperature differences. A heat pipe is made up of a pipe or tube and a base fluid. In practice, the heat pipe is poured into a mould that is compatible with the cooling media. These devices have found uses in a variety of fields, including space apparatus, solar energy systems, electronic equipment, and air conditioning systems, due to their simplicity of design and ease of manufacture and maintenance.
Using heat pipe-cooled micro-reactors in power plants is one of the newest technologies in small power plants. In these power plants, heat is taken from the reactor by several heat pipes and transferred to the working fluid in the main heat exchanger of the power plant.
The present work focused on the design and thermal analysis of heat pipe used in nuclear power plant. Three models namely Model-1, Model-2 and Model-3 were modeled in CATIA software. Thermal analysis was carried out on these models with steel and copper material properties in ANSYS software. Finally optimum model with suitable material was suggested for the heat pipe.

1. INTRODUCTION

Heat Pipes are heat dissipation components that are capable of transferring heat from one location to another relatively quickly by utilizing the phenomenon of thermal energy (latent heat) being absorbed when a liquid changes state into a gas, and being released when a gas changes state into a liquid. With a liquid (referred to as the working fluid) sealed inside a metal pipe enabling operation without use of external power, heat pipes possess a long operational life. In general, when the temperature difference between source and transmission destination locations is small, heat dissipation components and devices are not very efficient, but heat pipes can perform relatively well even in such circumstances. Their thermal conductivity(ease of heat transfer) can be up to an order of magnitude more than copper or silver, which are already known for their high thermal conductivity, and can even exceed that of diamond, which has the highest thermal conductivity of all materials.

2. LITERATURE REVIEW

Aloke Kumar Mozumder et.al. [1] in their study, Heat pipe experiment was conducted both with working fluid and without fluid. Three different working fluids are taken such as distilled water, methanol, and acetone which have varying useful working range of temperature are tested with also different fill ratios. Results show that the operating temperature of the evaporator of a heat pipe should be such that the evaporation of the working fluid can occur in it and in the condenser; the condensation occurs in it. This is important, because, without phase change, heat pipe cannot be used as an effective device for enhancement of heat transfer. At 85% fill ratio, heat transfer is the maximum remaining other experimental conditions constant. For this reason, 85% fill ratio can be regarded as an optimum fill ratio. This study reveals that the dominating parameters for the heat transfer of a heat pipe are saturated boiling temperature of the liquid, evaporator surface temperature, latent heat of vaporization of the working fluids, and fill ratio.

K Snehith and S. Bhanu praksah [2] in their study, an attempt is made to design, fabricate and test a copper heat pipe. Experiments were conducted with and without working fluid for different inclinations to assess the thermal performance of heat pipe. The working fluids chosen for the study are acetone and distilled water. The thermal performance of the heat pipe was quantified in terms of thermal resistance and overall heat transfer coefficient by measuring temperature distribution across the heat pipe. Results shows that the copper heat pipe is found to be effective when acetone is used as working fluid. The optimum inclination angle of heat pipe for maximum rate of heat transfer is found to be 600 for both the working fluids tested and concluded as heat pipe selected showed a better thermal performance with wet run when compared to dry run.

Leonard L. Vasiliev [3] in this study, heat pipes are used as modern heat exchangers to evaluate its performance. Heat pipes are passive, highly reliable and offer high heat transfer rates and concluded as a short review of heat pipe R&D contains mainly data from FSU which testifies, that heat pipes are very efficient heat transfer devices, which can be easily implemented as thermal links and heat exchangers in different systems to ensure the energy saving and environmental protection.

3. MODELING OF HEAT PIPE EXCHANGER IN CATIA

The modeling of space heater was done by using CATIA software. In the modeling process three models namely Model-1, Model-2 and Model-3 were modeled in the part module of the CATIA and were saved separately for analysis. The detailed modeling procedure was discussed below. By varying the number of pipes in between the bases, two more models namelyModel-2 and Model-3 were created in CATIA software.

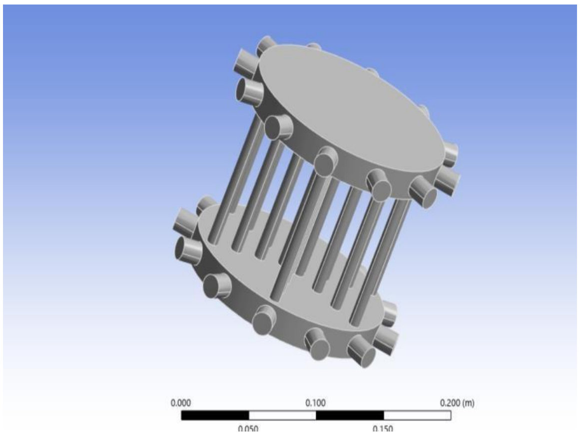

Fig 3.1: Final modeling of Model-1heat pipe in CATIA

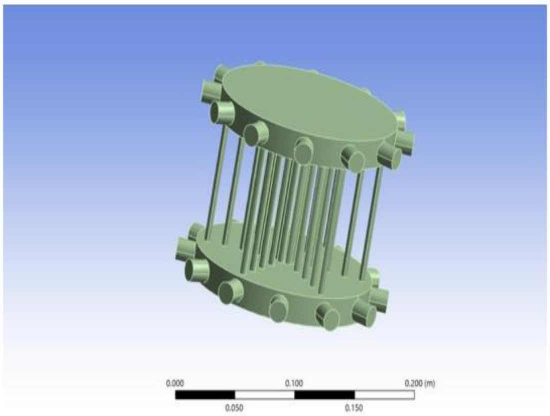

Fig 3.2: Final modeling of Model-2 heat pipe in CATIA

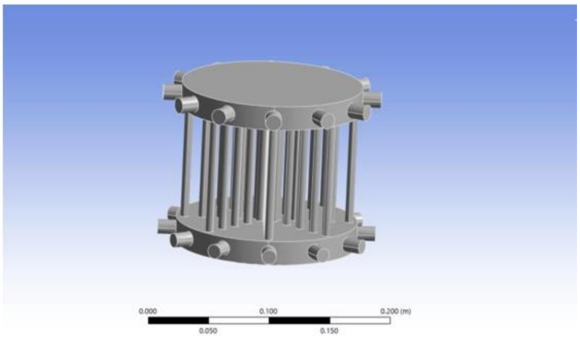

Fig 3.3: Final modeling of Model-3 heat pipe in CATIA

4. THERMAL ANALYSIS OF HEAT PIPE EXCHANGER IN ANSYS

4.1 Analysis of Heat Pipe Exchanger Model-1 in ANSYS

The three dimensional model of space heater modeled in CATIA was exported in the form of .igs file and was imported into ANSYS software for making steady state thermal analysis.

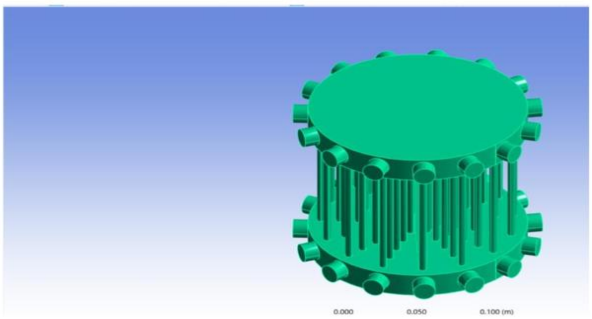

Fig 4.1: Geometry of heat pipe exchanger Model-1 imported into ANSYS

After importing the model into ANSYS, the required material properties are selected from the library and are applied to the model separately to make analysis. In the present work structural steel and copper alloy materials are selected for analysis.

4.2 Material Properties of Steel

Property	Value
Density	7850 kg/m3
Young's modulus	2 e $^{+11}$ Pa
Poisson's Ration	0.3
Thermal conductivity	60.5 W/m ^{0}C

Table 4.1: Material properties of steel

4.3 Material properties of copper

Property	Value
Density	8300 kg/m3
Young's modulus	1.1 e $^{+11}$ Pa
Poisson's Ration	0.34
Thermal conductivity	401 W/m ^{0}C

Table 4.2: Material properties of copper

After applying the material property, perform meshing operation on the model to generate nodes and elements. The meshing was done with tetrahydral shape and fine mesh. The meshed model was shown in the following figure.

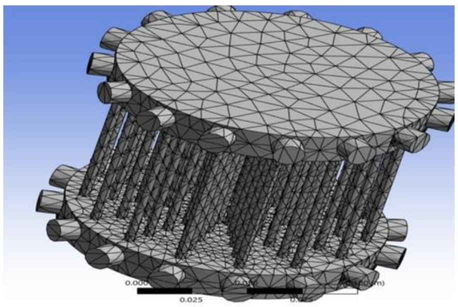

Fig 4.2: Generate mesh for the base model of Space heater

The thermal boundary conditions were applied to the model to make thermal analysis. In the present work, heat flow of 1120 W was applied at the inlet and convection boundary conditions were applied at the outlet.

5. RESULTS

Thermal analysis was performed on the three models of the heat pipe exchanger with two materials by using ANSYS software by considering steady state conditions and the detailed results are shown below.

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5.1 Thermal Analysis of Heat Pipe Exchanger Model-1 with Steel

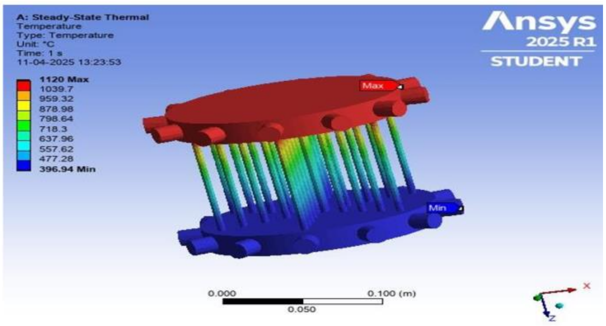

Fig 5.1: Temperature distribution in

Heat pipe exchanger Model-1withsteel

5.2 Thermal Analysis of Heat Pipe Exchanger Model-1with Copper

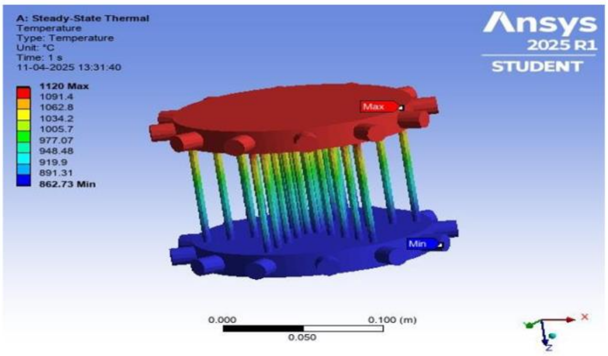

Fig 5.2: Temperature distribution in heat pipe exchanger Model-1with Copper

5.3 Thermal Analysis of Heat Pipe Exchanger Model-2 with Steel

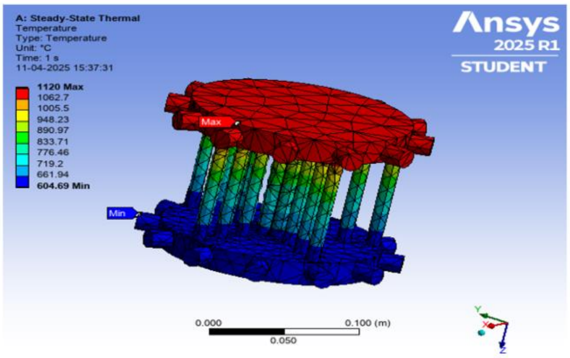

Fig 5.3: Temperature distribution in heat pipe exchanger Model-2 with steel

5.4 Thermal Analysis of Heat Pipe Exchanger Model-2 with Copper

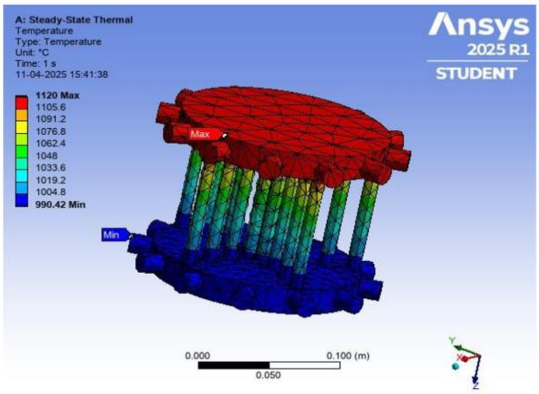

Fig 5.4: Temperature distribution in heat pipe exchanger Model-2 with Copper

5.5 Thermal Analysis of Heat Pipe Exchanger Model-3 with Steel

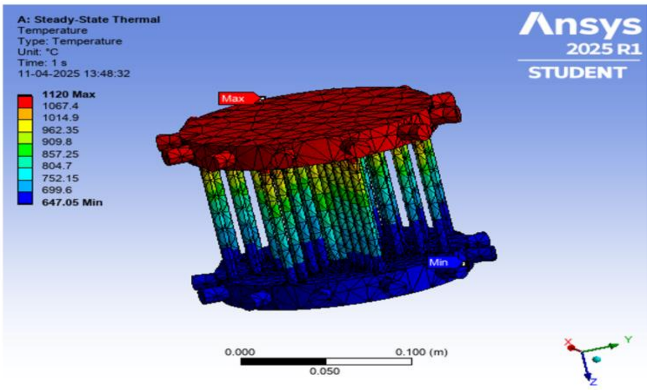

Fig 5.5: Temperature distribution in heat pipe exchanger Model-3 with steel

5.6 Thermal Analysis of Heat Pipe Exchanger Model-3 with Copper

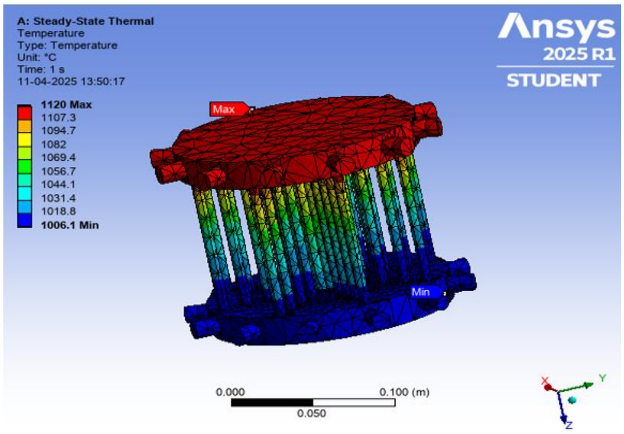

Fig 5.6: Temperature distribution in heat pipe exchanger Model-3 with copper

Material	Temperature distribution (^{0}C)			Heat flux (W/m^2)		
	Model-1	Model-2	Model-3	Model-1	Model-2	Model-3
Steel	396	604.69	647.05	8.307e^5	8.952 e^5	5.410 e^5
copper	862.73	990.42	1006.1	1.640 e^5	1.341 e^5	7.800 e^5

Table 5.1: Comparative results of three models with steel and copper material properties

6. CONCLUSIONS

Heat pipes are a unique type of heat transfer device that can transport large amounts of heat through a small cross sectional area, with minimal temperature differences. Initially the work is focused on study of construction, working principle and types of heat pipes. There are so many applications of heat pipe are there, among heat pipe in nuclear power plant was selected for this project.The modeling of heat pipe was done by using CATIA software. Three models namely Model-1, Model-2 and Model-3 were created with variation in the number of pipes its arrangement. Thermal analysis was performed on these three models with two material properties, steel and copper in ANSYS.From the analysis results it was observed that, heat pipe with copper material gives more heat transfer compared to steel. Among the three models, amount of heat transfer and heat flux are more in Model-3 heat pipe with copper material. Hence it was conclude that Model-3 with copper material is most suitable for heat pipe.

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