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CFD ANALYSIS OF OUTLET FLOW RATE CONDITIONS VARIATION IN HEAT PIPES

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ABSTRACT

Heat pipe is a passive two-phase heat transfer device. It is being used to manage heat transfer between two solid interfaces for that heat pipe combines the principle of both thermal conductivity and phase transition The size of electronic devices are decreasing day by day and throwing challenges on thermal engineers to find and invent better means to challenge heat dissipation rates. This led to give rise to my idea of getting this work on Heat pipe. Heat pipes are promising means to drive the heat from the electronic devise to the environment without using mechanical devices to operate the flow in it. The performance rate is evaluated by changing the characteristics of the heat pipe parametric evaluation. The coatings are done to increase adhesive nature between inner wall of pipe and working fluid etc., in this work, Heat Pipe Design and analysis of the pipe with Aluminum+ TIC, SS+ TIC coatings and Heat transfer characteristics will be determined by CFD analysis. CFD analysis will be done to determine the heat transfer rate, pressure drop, mass flow rate, R134a, R214a, R410a acts as the working fluid. Transient thermal analysis will be done to determine heat transfer rate and temperature distribution

Keywords: Heat pipe, CATIA V5R20, R134a, R 214a, R410a, ANSYS,

1.0 INTRODUCTION

Heat pipes are widely used in wide-ranging applications since their operation is in essence generally passive. High heat transfer rates can be achieved through heat pipes over long distances, with minimal difference in temperature, exceptional flexibility, simple manufacturing and easy control, not to mention, all without any external pumping power. Possible applications range from aerospace to energy conversion devices, and from electronics cooling to biomedical engineering. The development of heat pipes is motivated to overcome the need to presumably manage thermal dissipation in progressively compressed and higher density microelectronic components while preserving the specification temperatures of the components.

Heat pipe working principle:

Heat pipe is generally self-heat recovery devices that are used to transfer heat from one end (heat injection) to another end (destination) with minimal differences in temperature and also to pass the heat through the internal surface. When selecting a pipe for use on industrial products, other words must be taken into account. They are produced in various shapes, such as round or flat forms.

Fundamentals of Heat Pipe:

The operation of a heat pipe is simply explained as an example on the basis of a cylindrical geometry, as shown in Figure however, the shape and size of the heat pipes may differ. The heat pipes consist of a closed tube (pipe wall and end caps), a wick region\structure, and an equilibrium liquid of its own vapour. Depending on the operating temperature, the most widely used form of working fluids are water, acetone, methanol, ammonia, or sodium. The external heat pipe walls are divided into three sections: section of the evaporator, section of the adiabatic portion and portion of the condenser. However, a heat pipe may have no adiabatic portion and may also have multiple sections for evaporation and condensation depending on specific applications and nature.

Heat Pipe Applications:

Compact Electronics Enclosures: Heat Pipe Exchanger offers highly efficient, lightweight cooling system for electronic cabinets and enclosures and, thanks to greater miniaturization, also meets today's increasing demand for thermal power requirements.

Aerospace: Due to their low weight, zero maintenance costs and reliable functionality, heat pipe is a very attractive element in the aerospace area for spacecraft cooling and temperature stabilization. Maintaining isothermal structures in aerospace is a crucial task in relation to the practice of obituary astronomy under adverse solar heating.

Medical: Passive thermal applications (heat pipes) offer valuable advantages in medical / hospital equipment in terms of saving space, minimizing weight and reducing maintenance costs, resulting in lower environmental effects compared to other cooling systems that depend on various technologies such as pumped liquids etc.

Consumer Electronics: Heat pipes are also found in consumer-specific computing products such as power supplies, notebook and mobile computers, computer microprocessors, audio amplifier parts and computer gaming hardware.

Heat Pipe Features And Benefits:

- Tube material: Copper/ Aluminum
- Wick structures:
  - **Grooved–** Low Cost, does not work well against gravity
  - **Wire Mesh –** Most common method
  - **Sintered –** Highest performance and cost
- High thermal conductivity
- Light weight
- Fast thermal response

Heat pipe Advantages:

- Passive Operation
- Long Life
- Zero cross contamination since streams of source and sink are physically separated
- Minimum Maintenance
- Compact Size
- Practically zero back pressure

2.0 LITERATURE REVIEW

Rahul Royal. Sadey [1] The heat pipe is a high thermal conductant that uses vapor transport and latent thermal rejection to efficiently transport thermal energy. Heat pipes theory has been well established. We are used in systems with a cryogenic temperature and production units with a temperature of up to 200^{0}C illustrate that they can work on a substantial part of the temperature range.

M. Goodarzi, M. R. Safaei [2] Thermodynamic irreversibility contributes to entropy, due to the heat transfer and fluid flow through the heat pipe network. For optimal design of a flat heat stream, the minimum entropy generation principle can be used. The purpose of this work is to minimize the entropy generation levels as the objective function with various flat heat pipe parameters subject to certain constraints.

Brian Holley, et al, [3] The variation in channel diameter presented in a pulsating heat pipe with capillary wick is investigated as an improvement means of heat transfer by the model presented here. The model has a slow-flow uniformity in which the momentum equation for each slug is resolved. During a simulation, the number and mass of liquid slugs can vary. In the wall and wick and the working fluid the energy balance has been resolved.

Sejung Kim, et al, [4] The effects on oscillatory flow, temperature and pressure of vapor pipes as well as the latent and reactive heat transfer of a pulsatory heat pipeline were studied. Heating and cooling segment temperature fluctuations The wall temperature variations involve a normal component and an altered component.

T. Kiatsiriroat, A. Nuntaphan [5] The study was conducted to classify the key factors influencing a pulsing heat pipe start-up characteristics The wall surface condition, evaporation within the heating section, superheat, bubble growth and vapor bubbles traped in cavities on the capillary interior wall have been shown to influence the initiation of oscillating movements in the heat pulse.

3.0 METHODOLOGY

The heat pipe is a remarkable achievement of thermal physics and thermal transmission engineering in this century, due to the extremely high heat transfer capacity over large distances without major losses. Hot tubes tackle environmental and energy safety issues, as well as fuel economy, key applications. Thermal pipes are an effective and proven thermal solution, particularly in applications with high thermal fluxes, and where non-uniform heat loading is combined, air flow is restricted over thermal generating components and space or weight limitations. This segment will introduce heat pipe technology briefly and then highlight its basic uses as a passive thermal control device.

Heat pipe design:

When the heat pipe is made, there are several factors to consider. Materials compatibility, operating temperature range, heat pipe length and diameter, power reduction, heat transport limitation of the thermal pipe, thermal resistance, heat pipe bending effect and flattening and the operational orientation are of great importance. The design problems are however reduced to certain important considerations by restricting the selection of the cooling electronics to copper / water heat pipes.

Working Principal of heat Pipe:

Conventional heat pipe is a thermal transfer unit able to carry large amounts of heat with small difference in temperature. Through extracting the exterior particles, the hose is completely drained and filled with the working fluid that suffices to saturate the wick structure. Pressure is the same as the saturation pressure connected to the temperature of the heat pipe. When heat enters the evaporator, the balance is disturbed and steam generates a small higher pressure and temperature. The high vapor pressure allows the vapor to flow through the tube and to the condenser where the vapor condenses and releases the latent vaporizer heat a little lower temperature. The condensed fluid is then returned to the evaporator due to the forces that form through capillary action.

Basic approach to using CFD:

Computational fluid dynamics has become a key tool in virtually every fluid dynamics branch from propulsion into weather prediction through mathematical curiosity. CFD is generally accepted by computational methods as referring to the broad subject of the numerical solution. These guiding equations that describe fluid flow are the equation, continuity equation and other sources such as porous medium or electrical strength.

CAD MODELING

The use of PC frameworks to help develop, change, review or simplify a Plan is helped by PC supported outline (CAD). The computer-aided design program is used to increase the efficiency of the originator, improve the type of configuration, improve documentation-based interchanges and build a database for assembly. As electronic documents for printing, machining or other assembly operations the computer aided design yield is regularly. Additionally, the term CADD is used (for computer-assisted design and drafting).

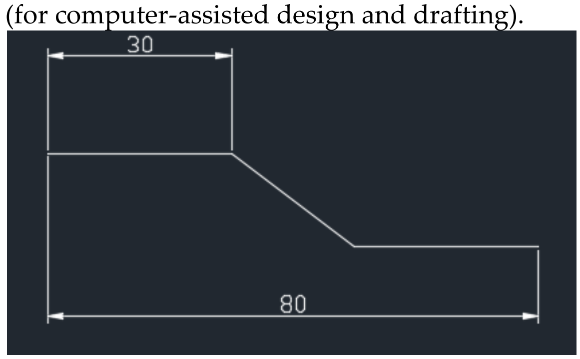

Figure : Layout of the lined tube

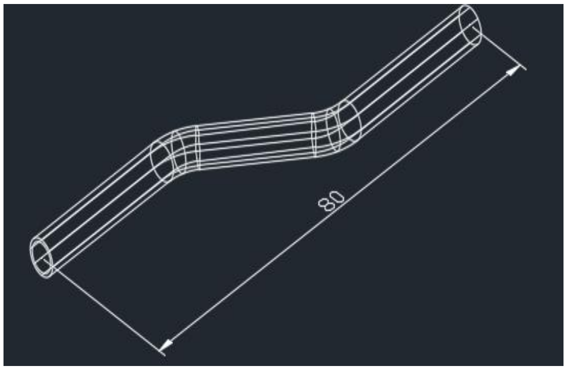

Figure: Layout Layer material deposition

Table: Mesh object properties definition table for finite mesh

Length X	0.08 m
Length Y	0.0273m
Length Z	0.005m
Volume	1.746×10^{-6} m^3
Nodes	14011
Elements	53157
Analysis Type	3-D

Experimental model:

Tube design: The tube outlined by utilizing 3d-demonstrating programming CATIA V5 R20 and the model sent out to IGES record framework to import the numerical model to ANSYS for reenactment

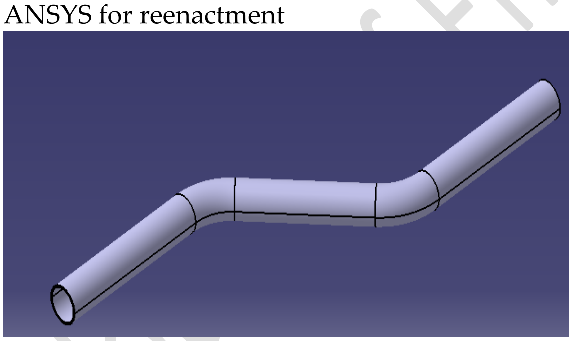

Figure: IGES model for ANSYS conversion in CATIA

Demonstrate investigation has been completed by conferring modular to ANSYS environment. By seeing above tables exhibited the graphs and components were created for fine work.

4.0 RESULTS AND DISCUSSIONS

A heat pipe is a system that can transport large amounts of heat between hot and cold interfaces with a very small temperature difference. It is metal tubes in size pencil that move heat without the aid of a pump from one end of the tube to the other end of the tube. Heat vaporizes a small amount of fluid within the heat tube at the hot end of the tube; the fluid passes to the opposite, slightly cooler end, and condenses through an ice capillary wick before returning to the hot end.

PROPERTIES OF FLUENT MATERIALS:

The fluent materials which are taken for analysis Aluminum+ TIC, SS+ TIC is used taken as heat pipe material and working fluids are R134a, R 214 a,R410a.

Aluminum+ TIC with R134a fluid

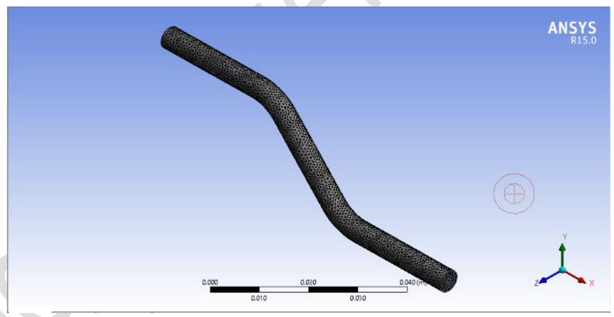

Figure: Meshing of the object Aluminum+ TIC

The above figure shows the meshing of the Aluminum+ TIC R134a as fluid. The meshing is done such that the load is distributed equally on the pipe during meshing so that complete deformation will be done.

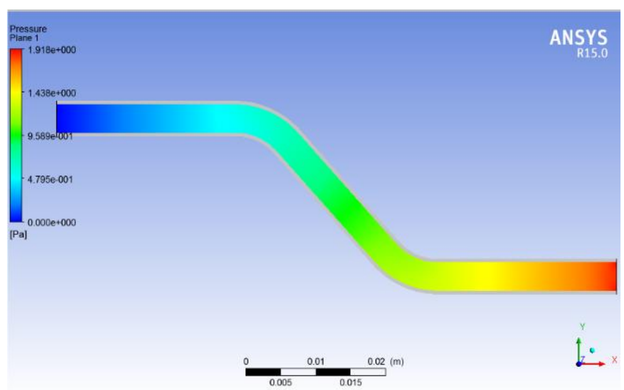

Figure: Pressure flow along Aluminum+ TIC tube

The above figure shows pressure R214a flow along the Aluminum+ Tic tube. Here it is observed the flow of pressure all along the tube and also the variations of pressure along the tube.

JES Journal of Engineering Sciences

Vol 11, Issue 7, July /2020
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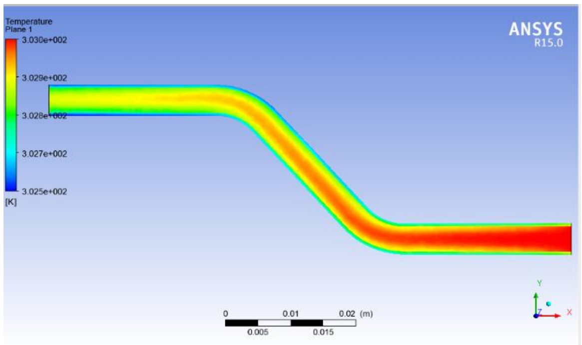

Figure: Temperature inlet vector of Aluminum+Tic tube

The above figure shows temperature inlet along the Aluminum+Tic tube. Here it is observed that the flow of temperature is changing during the flow and varying at different sections.

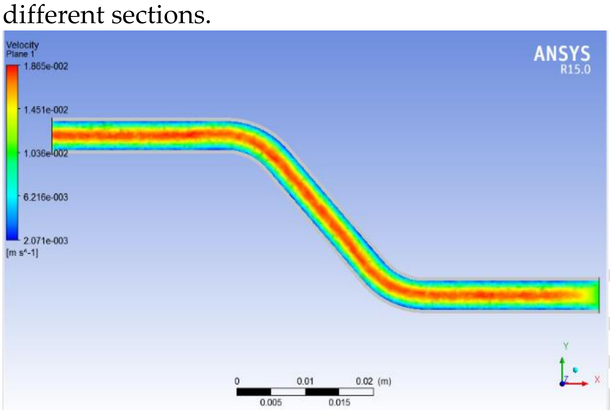

Figure: Velocity flow of fluid along Aluminum + Tic tube

The above figure shows velocity of R134a fluid along the Aluminum+ Tic tube. Here it is observed that the velocity is equal during the flow and varying at all sections.

Aluminum+Tic and R214a Fluid:

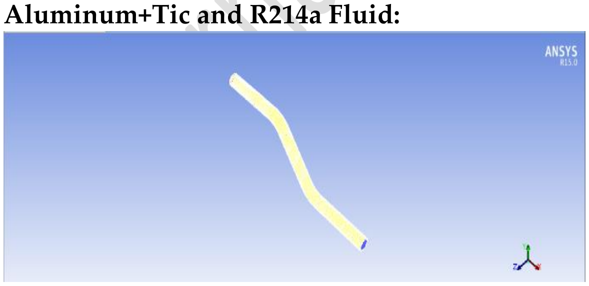

Figure: Meshing of Aluminum+ Tic tube

The above figure shows the meshing of the Aluminum+ Tic material and R214a Fluid. The meshing is done such that the load is distributed equally on the pipe during meshing so that complete deformation will be done.

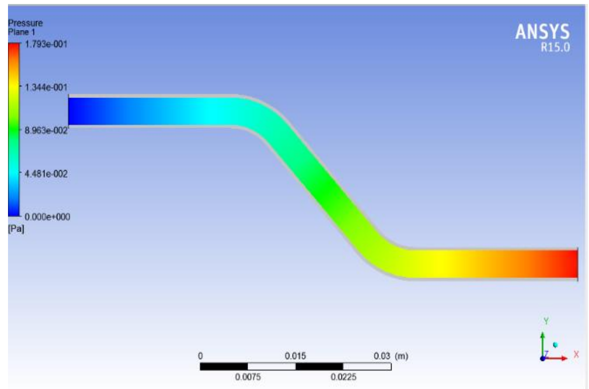

Figure: Pressure inlet along x-direction in Aluminum+ Tic tube

The above figure shows pressure R214a flow along the Aluminum+ Tic tube. Here it is observed the flow of pressure all along the tube and also the variations of pressure along the tube.

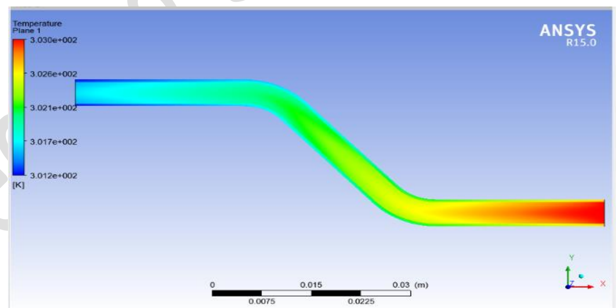

Figure: Temperature inlet along x-direction Aluminum+ Tic tube

The above figure shows temperature inlet R214a fluid along the Aluminum+ Tic tube. Here observed that the flow of temperature is changing during the flow and varying at different sections.

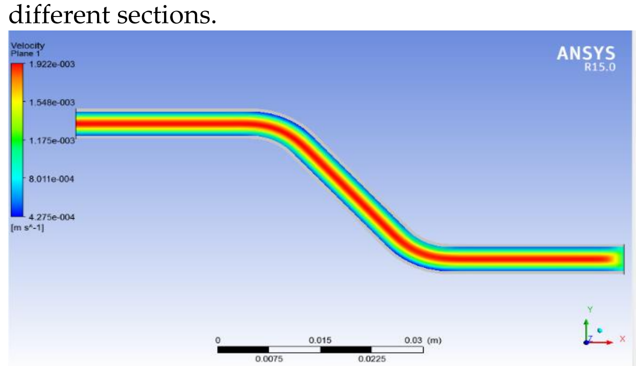

Figure: Continuous Velocity along x-direction in Aluminum+ Tic tube

The above figure shows velocity R214a fluid of along the Aluminum+ Tic tube. It can be observed that the velocity is equal during the flow and equal at all sections with continues flow.

Heat pipe material Aluminum+ Tic with R410a Fluid:

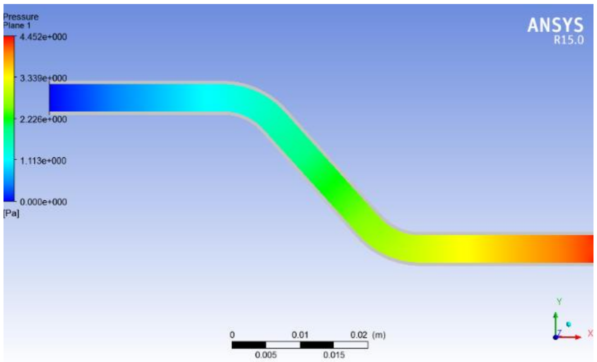

Figure: Pressure inlet along x-direction in Aluminum+ Tic tube

The above figure shows the Aluminum+ Tic with R410a as fluid. This is done such that the load is distributed equally on the pipe during pressure inlet.

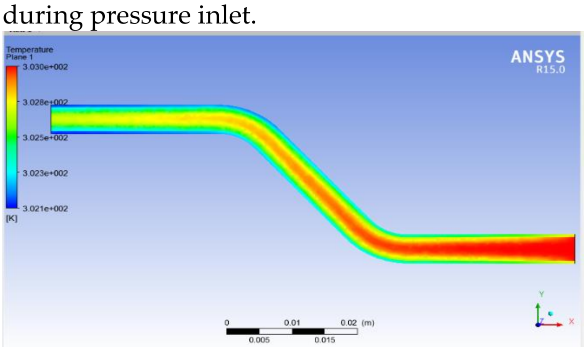

Figure: Temperature inlet along x-direction in Aluminum+ Tic tube

The above figure shows temperature vector of R410a along the Aluminum+ Tic tube it is observed that he temperature vector is varying during the flow is different at sections.

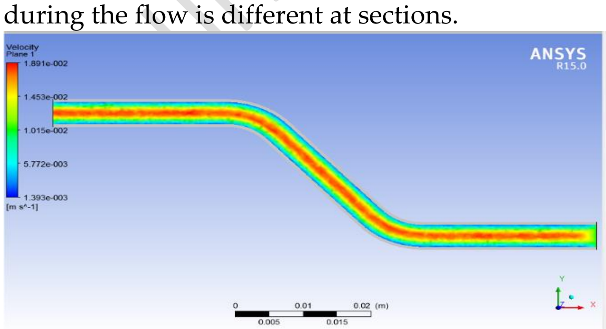

Figure: Velocity inlet along x-direction in Aluminum+ Tic tube

The above figure shows velocity flow in R410a along the Aluminum+ Tic tube. Here it can be observed the velocity is equal during the flow and varying at all sections.

SS+TIC with R134a Fluid:

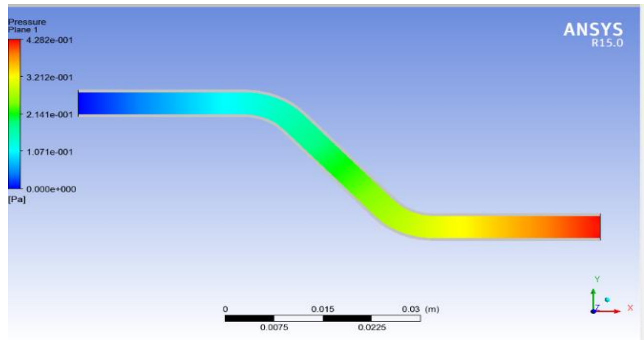

Figure: Maximum pressure inlet x- direction in SS+TIC tube

The above figure shows the SS+TIC with R134a as fluid. This done such that the load is distributed equally on the pipe during pressure inlet and the maximum inlet pressure obtained is 4.282e-001 N/m^2.

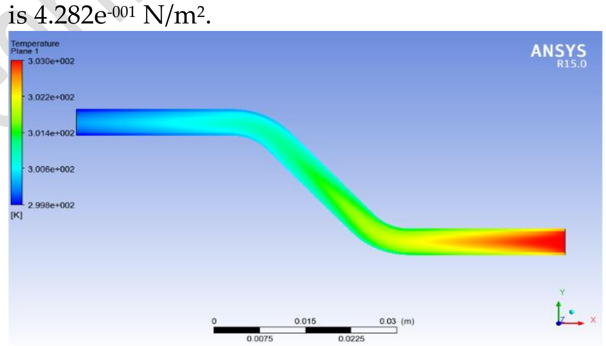

Figure: The temperature contours and flow x-direction in SS+TIC tube

The above figure shows the counter flow of the temperature in SS+TIC which is having R134a as fluid and maximum temperature.

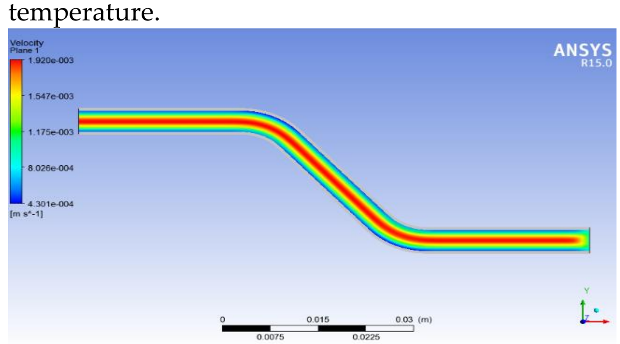

Figure 4 Continuous velocity flow x-direction in SS+TIC tube

Vol 11, Issue 7, July /2020
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The above figure shows the continuous velocity flow of the in SS+TIC tube which is having R134a as fluid and maximum velocity of 1302 m/s.

SS+TIC with R214a Fluid:

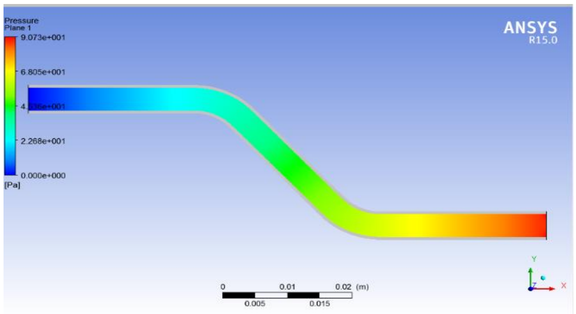


Figure: Pressure input SS+TIC tube in x-direction

The above figure shows pressure flow of R214a along the SS+TIC tube. It can be observed that the flow of pressure all along the tube and also the variations of pressure along the tube.

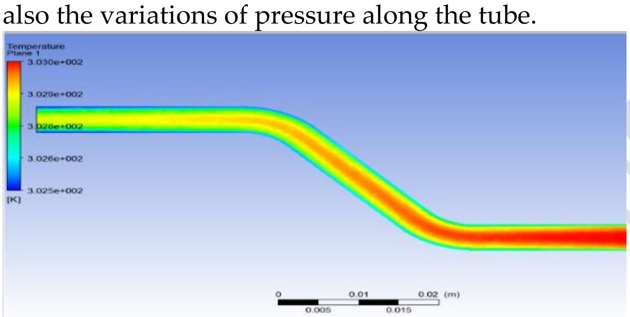


Figure: Temperature variations of SS+TIC Tube in x- direction

The above figure shows temperature inlet R214a along the SS+TIC tube. It is observed that the flow of temperature is changing during the flow and varying at different sections.

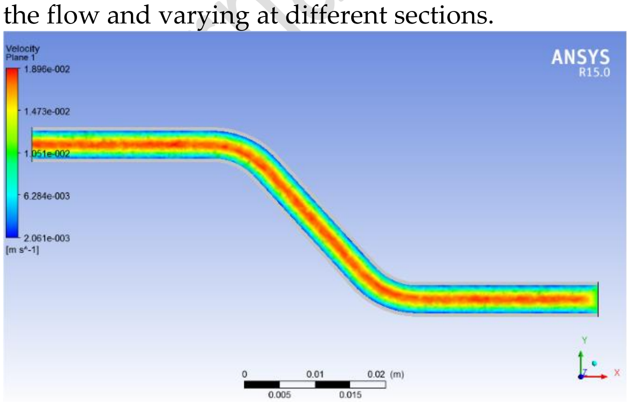


Figure: Velocity flow along x- direction in R214a along the SS+TIC tube

R214a along the SS+TIC tube it is can observed that velocity is equal during the flow and varying at all sections.

SS+TIC with R410a Fluid:

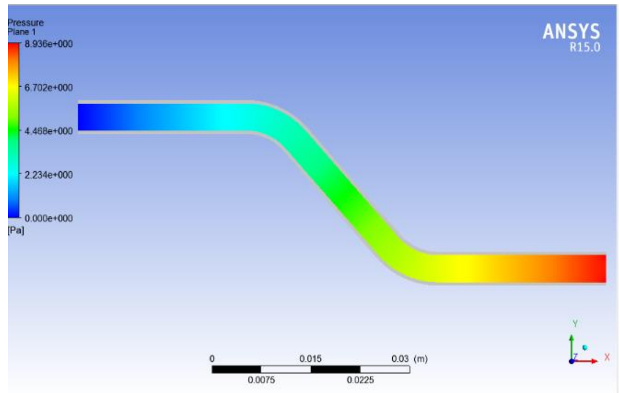


Figure: Pressure flow in x-direction in SS+TIC tube

The above figure shows the SS+TIC with R410a as fluid. This done such that the load is distributed equally on the pipe during pressure inlet and the maximum inlet pressure obtained.

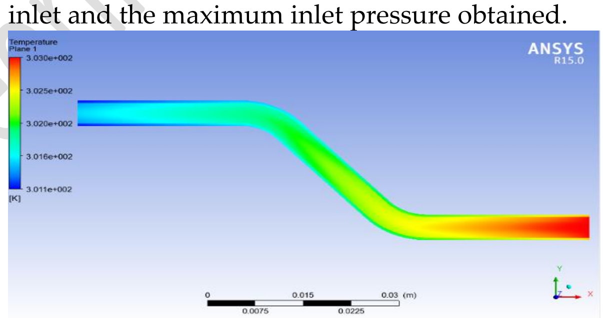


Figure: Temperature flow in x-direction in SS+TIC tube

The above figure shows the counter flow of the temperature in SS+TIC which is having R410a as fluid and maximum temperature.

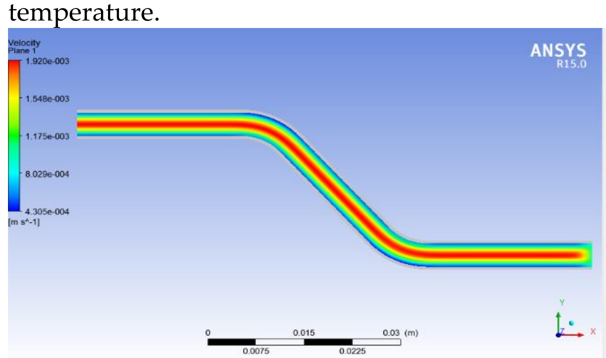


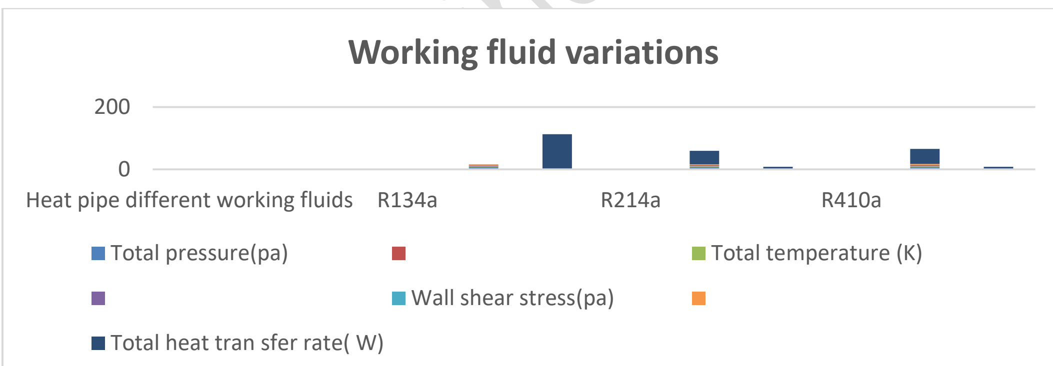
Figure: Continuous velocity in x-direction in SS+TIC tube

The simulations results are interpreted in a tabular form for better optimistic results comparison to continue for work for interface finite element method of heat transfer i.e thermal conductivity application. The results observe by undertaking multiple applications like heat exchangers, automotive and human applications, and a constant pressure of 1.9 Mpa and a constant velocity of 3m /s taken as input parameters for all fluids. The obtain parameters are taken in to accountability and the observations shows the tubes didn't deformed at these pressure and velocity inputs in simulation.

HEAT PIPE ANALYTICAL RESULTS:

Table: Al+Tic heat pipe with different Working fluid variations

Heat pipe different working fluids	Total pressure(pa)		Total temperature (K)		Wall shear stress(pa)		Total heat tran sfer rate(W)
	min	max	min	max	min	max	
R134a	4.38 E+03	1.89 E+06	3.00 E+02	3.01 E+02	0.00 E+00	3.80 E+04	- 0.00 113
R214a	4.38 E+03	2.13 E+06	3.00 E+02	3.01 E+02	0.00 E+00	3.80 E+04	-0.0 0438
R410a	4.38 E+03	2.38 E+06	3.00 E+02	3.02 E+02	0.00 E+00	3.80 E+04	-0.0 049 8

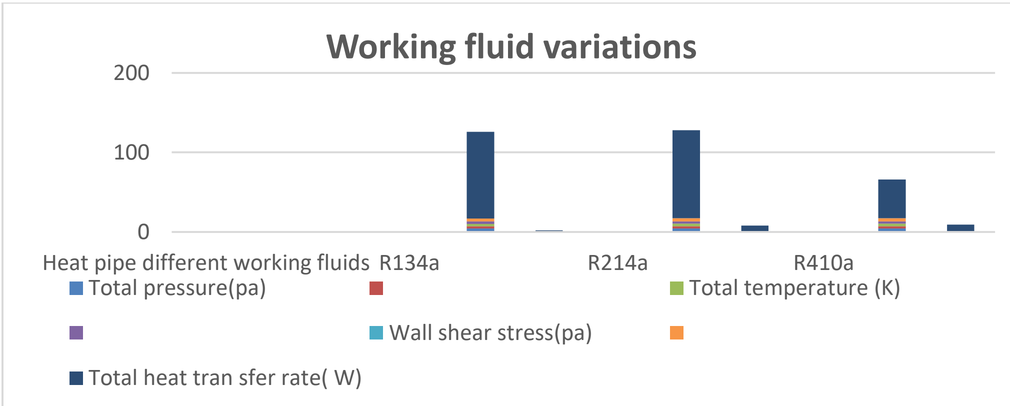


Graph: Al+Tic heat pipe with different Working fluid conditions

Table: SS+Tic heat pipe with different Working fluid variations

Heat pipe different working fluids	Total pressure(pa)		Total temperature (K)		Wall shear stress(pa)		Total heat tran sfer rate(W)
	min	max	min	max	min	max	
R134a	4.38 E+03	2.62 E+06	3.00 E+02	3.02 E+02	0.00 E+00	3.80 E+04	- 109 2

R214a	4.38 E+03	2.87 E+06	3.00 E+02	3.03 E+02	0.00 E+00	3.80 E+04	-0.0 111 8
R410a	4.38 E+03	2.72 E+06	3.02 E+02	3.04 E+02	0.00 E+00	3.82 E+04	-0.0 049 9



Graph: SS+Tic heat pipe with different Working fluid variations

The above tabular form shows the maximum inlet & outlet temperatures of materials Al+Tic & SS+TIC at different fluids like R134a, R214a, R410a. It is observed that maximum input temperature is same in all conditions and is varied during outlet.

CONCLUSION

Heat pipe is a thermo mechanical device which is employed to get thermal equilibrium where huge no of electronic equipment's are present like in space ship, satellite etc. The results obtained can be studied and concluded that heat pipe has the more flow characteristics to evaluate the heat that can be carried away from the heating element is appreciably increased and thus this arrangement yielded better results when compared with single evaporator set-up. My project where I used R410, R214a instead of R134a the temperature that is carried away by the fluid will be added advantage in this project. Hence finally the setup with multiple variations with R134a fluid is better combination which improved heat transfer rate in a heat pipe. By checking the fluid flow and temperature variants a stream line flow has been indicated with continuous flow in both materials. Considerable remarks have been fining with Al+Tic, SS+Tic materials for different fluids taken in to consideration for further interface geometry applications.

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