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# Improving the thermal efficiency of the heat pipe using a heterogeneous polyethylene fibre wick system

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***Abstract*---**Thermal engineers face a lot of challenges in converting heat with low heat dissipation rate. This idea led me to read and analyse the heat pipe in various forms. "Heat pipes" are used in various mechanical and electronic devices. A small improvement in the "heat pipe design" will result in a drastic change. Can reduce the heat dissipation rate. Many factors affect the "efficiency of the heat pipe". This includes the geometric design, the number of evaporators and capacitors, the working liquid characters, the application of different coatings, the adhesive and the combined forces. A "wick system model" can be created in CATIA (a 3D modelling software). Different heat transfer properties can be determined using "CFD analysis" by changing different types of wick materials. CFD analysis will analyse the best and most effective material with pressure drop, "heat transfer rate and temperature variation" with measured values.

***Keywords*---**improving thermal efficiency, heat pipe, heterogeneous polyethylene, fibre wick system.

## Introduction

Heat pipes are widely used in many industrial applications. Evaporation of the working fluid to convert high heat fluxes with low temperature gradients using latent heat. Despite numerous studies and improvements in the heat pipe over the past 50 years, design is challenging even for conventional technologies. I try to understand the major scientific issues in the heat pipe by reviewing the works


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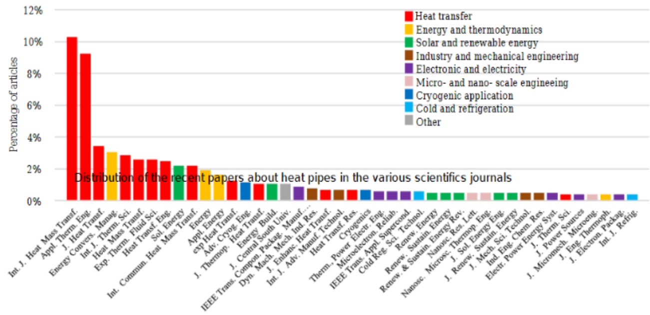
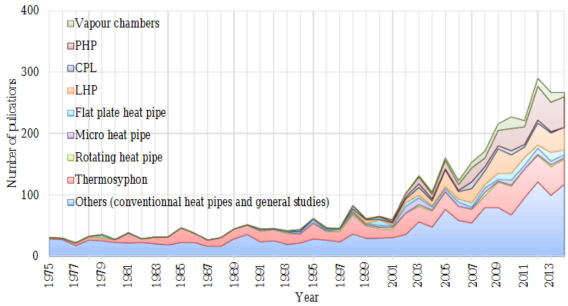
of recent scholars. With the opinions of recent scholars, I attempt to model and analyse various wig systems. This will facilitate efficient heat transfer. Solar power grid is being installed all over the world. And oil exchanges are also done on mega pipes. A small change in the heat pipe will lead to an efficient transfer of heat with minimal scattering.




## Literature survey

In 2007, Rifat & Ma proposed to review developments in heat pipe technology and applications between 2000 and 2005. New types of wick configurations for conventional and flat heat pipes were proposed and new working fluids were added. They highlighted the development of new types of loop heat pipes (LHP and CPL) that are expected to be widely used in industrial applications. They also refer to studies of flexible heat pipes and micro heat pipes. New applications were explored as solar collector systems and heat pipe integrated turbines. Traditional topics such as high temperature heat pipes and space applications were also reported. For air conditioning systems, the connection between phase-change materials and heat pipes was explored. Finally, they reported the development of new models and mathematical methods for the design of different types of heat pipes. Ten years later, the field of research on heat pipes has changed significantly. Figure 1 presents a word cloud perceived from the titles of articles published in Heat Tubes between 2012 and 2014 (approximately 800 sheets). In this word cloud, the size of the words is proportional to the square root of the number of occurrences of each word. Having a general view of a given field is a convenient tool (McNaught & Lam, 2010). Except for terms that are directly related to heat pipes and their key components, experimental tasks dominate compared to simulations, numerical analysis, and modelling. On the other hand, analytical approaches are very rare. Sheets are interested in heat pipe performance, and various applications appear on paper topics (electronic cooling, LED, air conditioning, solar collector, cryogenic applications, vehicles, thermoelectric generators, energy saving ...). One can observe the importance of the working fluid (water, ethanol, alloy) and materials (metal, copper, silicon, aluminium, glass, ceramic, copper oxide (CuO)) used in heat pipes because they are so clear on many paper topics. The relationship between heat pipe science and economics is indicated by the important occurrences of the terms "nanofluid (s)" and "carbon nanotubes", but also by "material", "sintered wick" and "fabrication process". The improvement in production also promotes the development of micro heat pipes and light weight heat pipes.

Dev and Budania (2018) developed a 2D finite element method to analyze the steady-state performances of heat pipes. Naveenkumar (2018) simulated cylindrical heat pipes in CFX software, using various wick structures such as Sintered, V-Groove, Screen Groove. Suresh and Bhramara (2017) numerically modeled a pulsating heat pipe, that removes heat from the evaporator region and transmits it to the condenser region, in ANSYS CFX. Bauman (2017) made a theoretical analysis first for the influence of loop heat pipe resistance to gravity, but fails to provide the experimental data to support. Masataka Mitomi (2014) designed three kinds of length loop heat pipe with the length were 2m,5m,10m. Maidanik (2013) mentioned a miniaturized loop heat pipe, which working medium was ammonia and heat transfer performance was excellent. Asmaie (2013) developed a CFD model to simulate the thermosiphon that provides heat transfer by two phase flow. Jianting Feng (2011) studied the operation characteristics of the loop heat pipe with two reservoirs.

## Methodology

This section follows the rules of the CFD solution technique and uses them to solve and understand the flow around the cylinder with a hard surface. Before coming to a conclusion, we need to understand the nature of the problem we are facing and be a doctor to find the right method or model to eliminate the problem. The current sheet handles the flow around the circular cylinder with different diameters, lengths and different surface roughness. Different velocities are considered to obtain the traction force imposed on the flow liquid air and water cylinder. To do this, we follow a step-by-step process that begins with identifying the goal or problem and ends with the pre-processing, followed by the steps that follow the solution.

## Creation of Model and Domain

The geometric model and computational domain are created using a geometric tool called the design model. This tool has the most important features including easy changing and simplification of the shape, size and dimension of the geometric profile. It adopts model geometry developed using other software such as CAD and Solid Works. Parameter features that assign a name to geometric faces such as inlet and outlet are possible. It involves two basic functions of creating geometry, namely 2D sketching and 3D modelling of solids. The test instrument has a rectangular chest with a round cylinder. A similar geometric model was developed on the ANSYS design model.

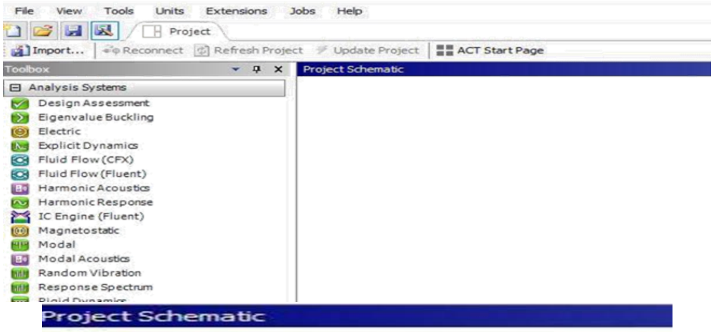
**Computational Analysis of Heat Pipe**

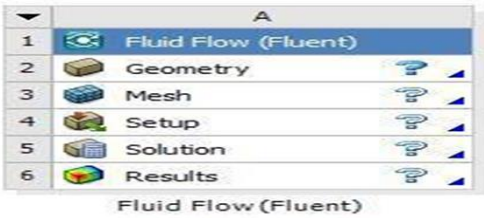
ANSYS CFX is a high-performance, general-purpose fluid dynamics program that has been used to solve a wide range of fluid flow problems for over 20 years. ANSYS CFX is more than a powerful CFD code. The integration across the ANSYS workbench platform provides excellent two-way connectivity to all major CAD systems, with powerful geometric transformation and creation tools with the ANSYS design model, advanced machine technologies at ANSYS Meshing and the ability to easily drag and drop data and results. Between applications. For example, a fluid flow solution can be used to define the boundary load of a subsequent configuration motion simulation. The native two-way connection for ANSYS architecture dynamics products allows you to save on the need to purchase, manage, or operate third-party connectivity software in an environment where even the most complex fluid-configured communication (FSI) issues can be easily used. For more than 20 years, companies around the world have relied on ANSYS CFX technology to provide reliable and powerful computational fluid dynamics (CFD) solutions. ANSYS CFX integrates advanced solution technology with modern user interface and adaptive architecture, making CFD accessible to designers who require general engineering knowledge and fluid dynamics and in-depth model control and options. It is used in a wide range of industries to provide comprehensive insights into equipment and processes that improve performance, improve product longevity and improve processes. CFD analysis is based on basic aerodynamic equations such as energy equation, momentum equation and continuous equation.

ANSYS CFX software is fully integrated with the ANSYS workbench environment, creating a complete set of engineering simulation solutions from ANSYS. Its adaptive configuration allows users to easily set up anything from simple fluid flow analysis to complex interactive systems with simple drag and drop functions. Users can easily evaluate performance at multiple design points or compare multiple alternative designs. In the ANSYS workbench environment, applications of multiple simulation fields can access tools common to all, such as geometry and machine tools. The step-by-step process performed on CFX is described below.

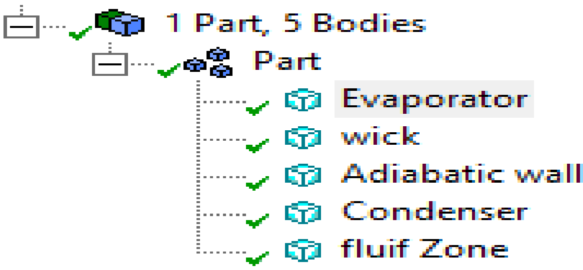
**Geometry**

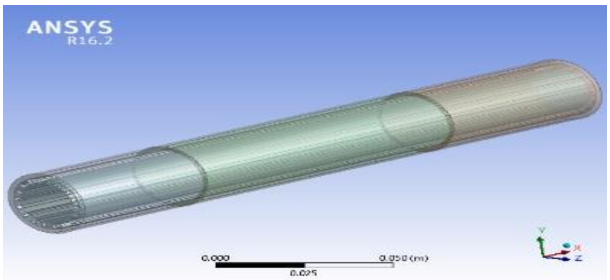
The flow through the rocket nozzle is analysed by fluid-flow analysis (fluent).
Open the ANSYS Workbench to Simulate the ANSYS Workbench! Go to Start> ANSYS> Workbench and open the ANSYS Workbench.
This will open the Start screen as shown in Figure 4.1. After opening this window, we will see all the analytics settings on the left because we are going to analyse with fluency.
To analyse Fluid - Flow Analysis (Fluent), fluently click on the left side, grab it and drag it to the empty space on the right.
After smooth drag, the smooth taskbar is visible in the empty space as shown in Figure.



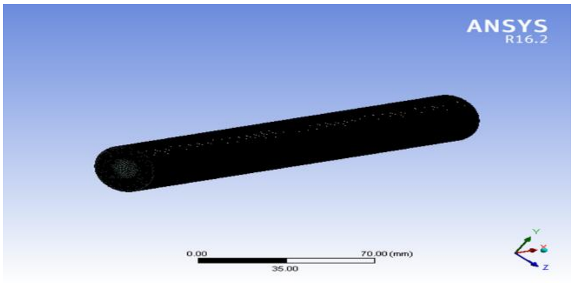

ANSYS Design Modeller software is specifically designed to create and create geometry for simulation. An easy-to-use, complete parameter environment with direct, bilateral links to all ANSYS products and all leading CAD packages that act as a geometry portal to provide a consistent geometric source for all engineering simulations.




**Mesh**

Machine is the process of splitting an entire component into several components so that the load is evenly distributed over the load components. To start the machine, double-click the mesh option below the geometric option, as shown in Figure.




After opening the loop, you will see the project tree with the mesh option. Click on the loop below for the details of the loop as shown in Figure and enter the size values.

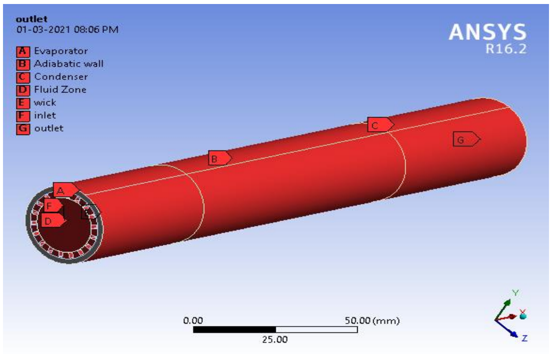
| OBJECT NAME | MESH |
|---|---|
| State | Solved |
| DISPLAY | |
| Display Style | Body Color |
| DEFAULTS | |
| Physics Preference | CFD |
| Solver Preference | Fluent |
| Relevance | 0 |
| SIZING | |
| Use Advanced Size Function | On: Curvature |
| Relevance Center | Medium |
| Initial Size Seed | Active Assembly |
| Smoothing | Medium |
| Transition | Slow |
| Span Angle Center | Fine |
| Curvature Normal Angle | Default (18.0 °) |
| Min Size | 0.10 mm |
| Max Face Size | Default (5.33930 mm) |
| Max Size | Default (10.6790 mm) |
| Growth Rate | Default (1.20) |
| Minimum Edge Length | 0.383210 mm |
| INFLATION | |
| Use Automatic Inflation | None |
| Inflation Option | Smooth Transition |
| Transition Ratio | 0.272 |
| Maximum Layers | 5 |
| Growth Rate | 1.2 |
| Inflation Algorithm | Pre |
| View Advanced Options | No |
| ASSEMBLY MESHING | |
| Method | None |
| PATCH CONFORMING OPTIONS | |
| Triangle Surface Mesher | Program Controlled |

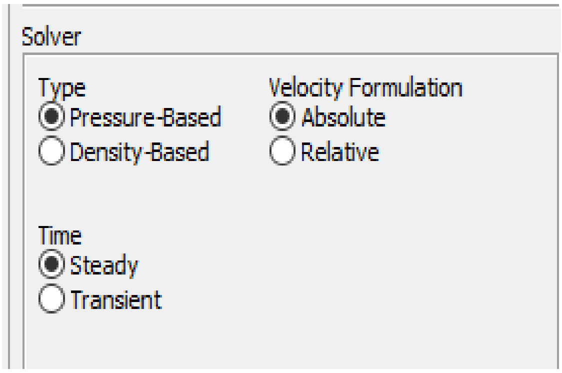
| | |
|---|---|
| PATCH INDEPENDENT OPTIONS | |
| Topology Checking | No |
| ADVANCED | |
| Number of CPUs for Parallel Part Meshing | Program Controlled |
| Shape Checking | CFD |
| Element Midside Nodes | Dropped |
| Straight Sided Elements | |
| Number of Retries | 0 |
| Extra Retries For Assembly | Yes |
| Rigid Body Behavior | Dimensionally Reduced |
| Mesh Morphing | Disabled |
| DEFEATURING | |
| Pinch Tolerance | Default (9.e-002 mm) |
| Generate Pinch on Refresh | No |
| Automatic Mesh Based Defeaturing | On |
| Defeaturing Tolerance | Default (5.e-002 mm) |
| STATISTICS | |
| Nodes | 820638 |
| Elements | 758901 |

| OBJECT NAME | EVAPORATOR | WICK | ADIABATIC WALL | CONDENSER | FLUID ZONE |
|---|---|---|---|---|---|
| BOUNDING BOX | | | | | |
| Length X | 50. mm | 210. mm | 100. mm | 60. mm | 210. mm |
| Length Y | 30. mm | 26. mm | 30. mm | | 21. mm |
| Length Z | 30. mm | 26. mm | 30. mm | | 21. mm |
| PROPERTIES | | | | | |
| Volume | 8796.5 mm³ | 27189 mm³ | 17593 mm³ | 10556 mm³ | 72736 mm³ |
| Centroid X | 25. mm | 105.02 mm | 99.993 mm | 180. mm | 105. mm |
| Centroid Y | -1.1657e-015 mm | 2.658e-003 mm | -4.0643e-003 mm | 5.5703e-015 mm | -2.9685e-017 mm |
| Centroid Z | -1.2602e-015 mm | -1.1175e-002 mm | 1.3183e-002 mm | 6.5055e-003 mm | -3.6856e-016 mm |
| STATISTICS | | | | | |
| Nodes | 55328 | 264600 | 109440 | 66272 | 422226 |
| Elements | 42390 | 182468 | 84309 | 50868 | 398866 |

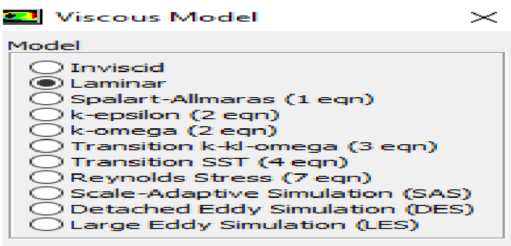
**Setup**

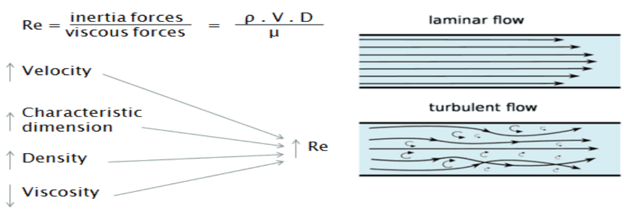
This is the most important step in creating simulation, during which the properties of the fluid, boundary conditions and the calculated area take place. Now go to the first window and double click on Settings so that another window can enter the properties discussed above. Create flow at atmospheric level at normal pressure.




**Laminar Flow condition**

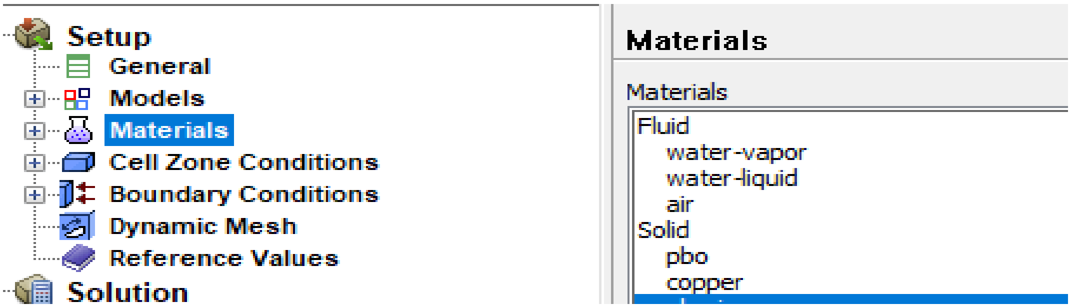


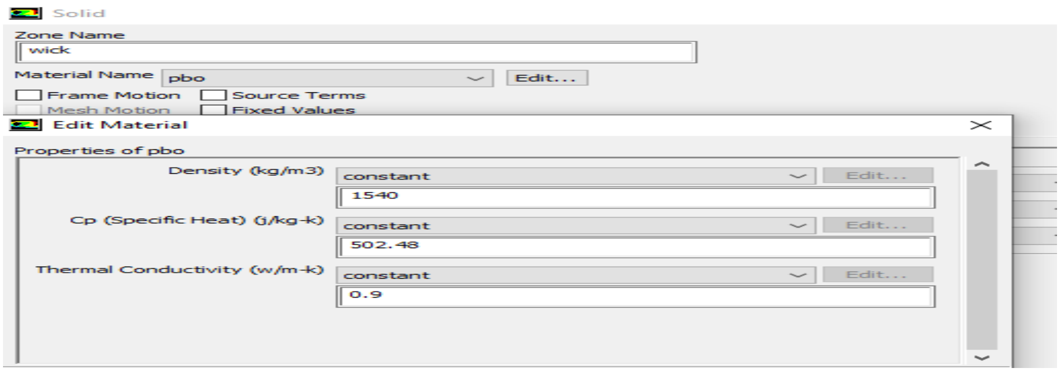

$=1.229 \times 0.001 \times 0.002/1.87 \times 10^{-5}=19.7$

The flow is blow 2000 so the Laminar based formula tube used in this Flow analysis.

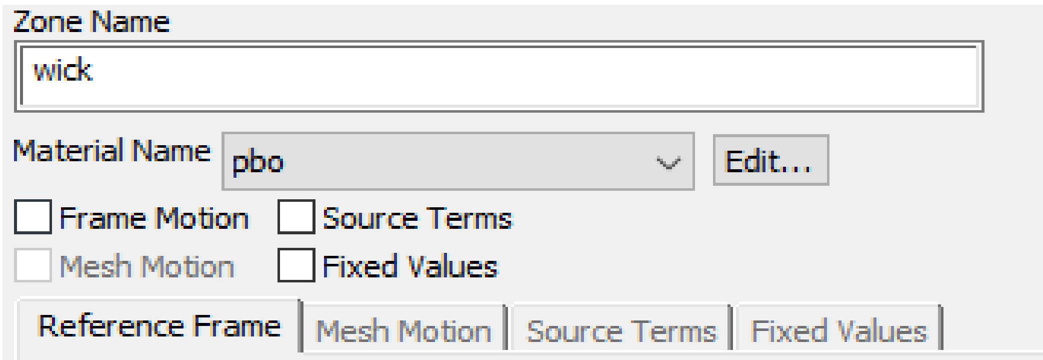
**Material used**




**Material properties of PBO (Polyphenylene Benzo isoxazole)**

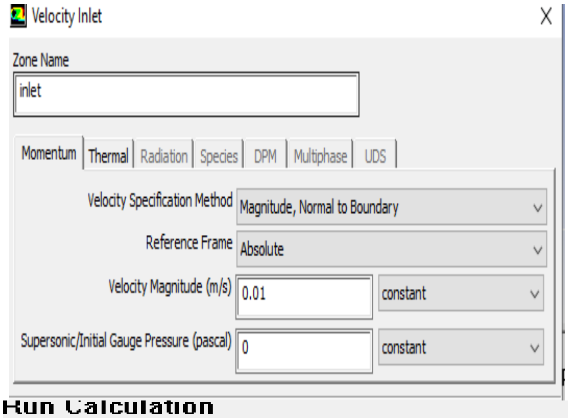


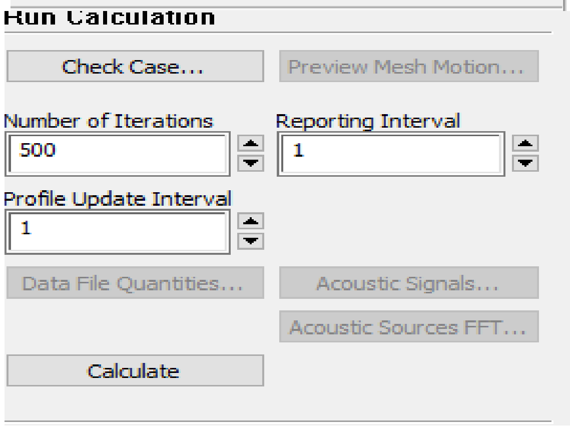

**Material assigning for wick structure**




**Inlet condition**

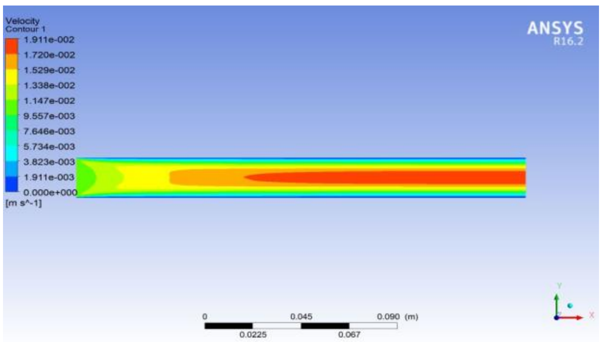
Water Inlet Condition flow velocity of 0.01m/s

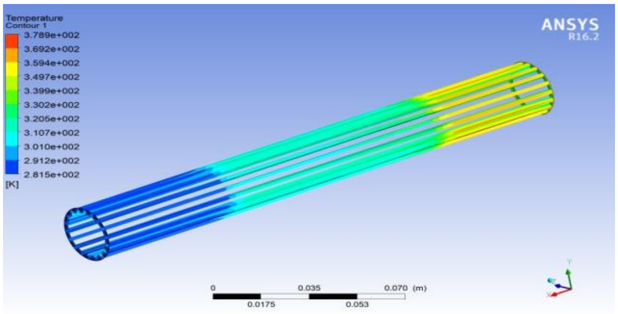


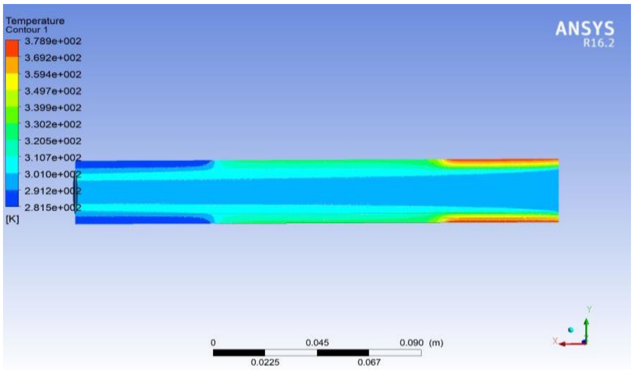

## Result and Discussion

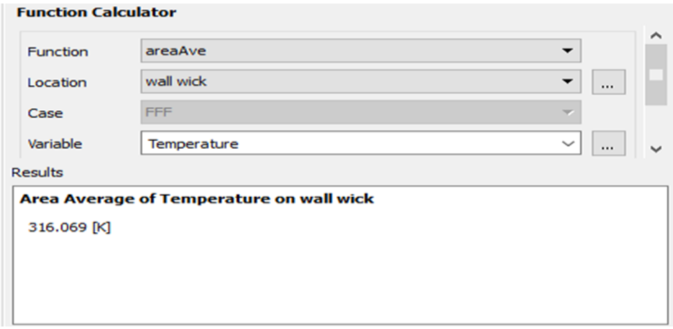
PBO material, Velocity flow water.






**Temperature over wick structure**





**Function Calculator**

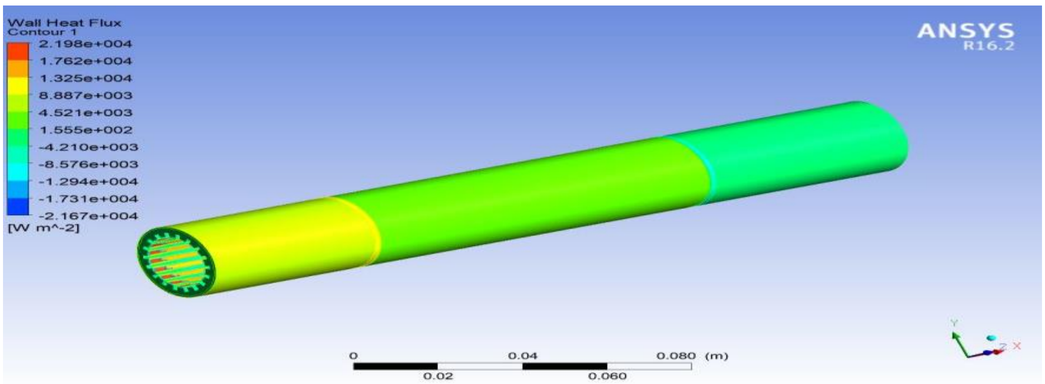
| | |
|---|---|
| Function | areaAve |
| Location | wall wick |
| Case | FFF |
| Variable | Temperature |

Results

**Area Average of Temperature on wall wick**

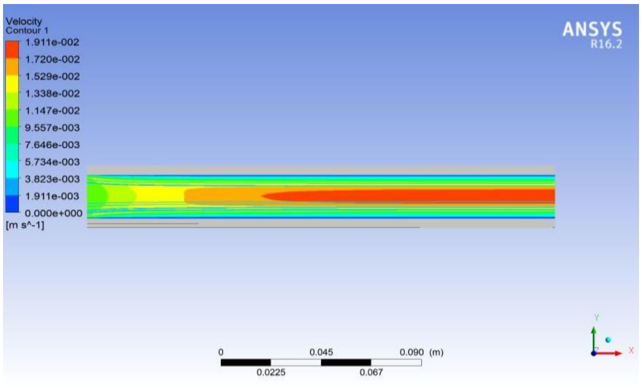
316.069 [K]

**Heat flux**

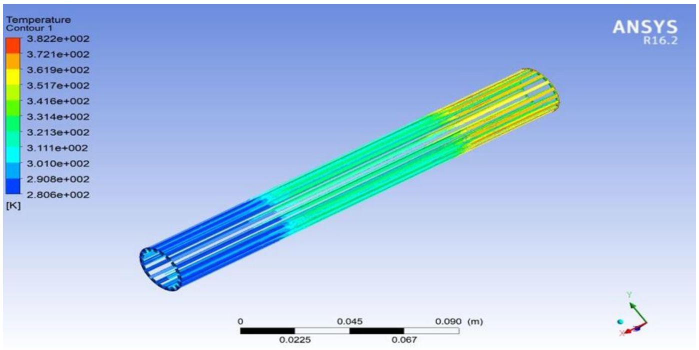


**Ultra-high-molecular-weight polyethylene**

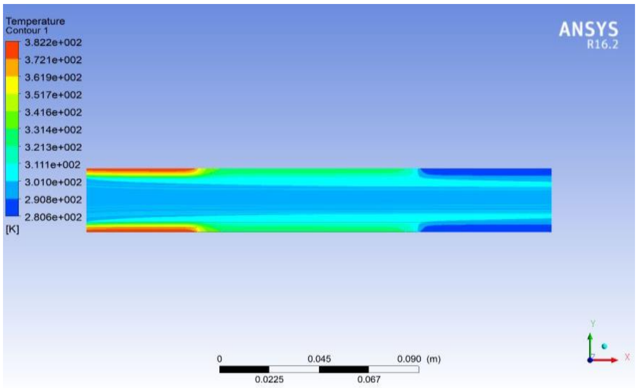
**Velocity**

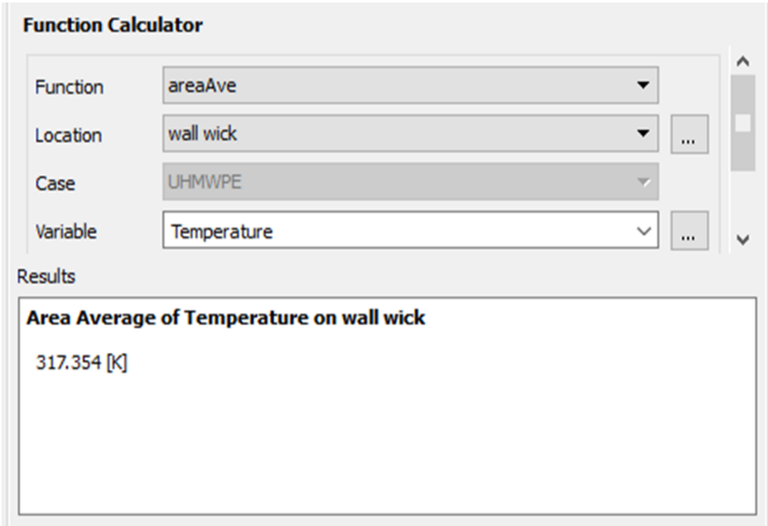



**Temperature Contour Wick Structure**

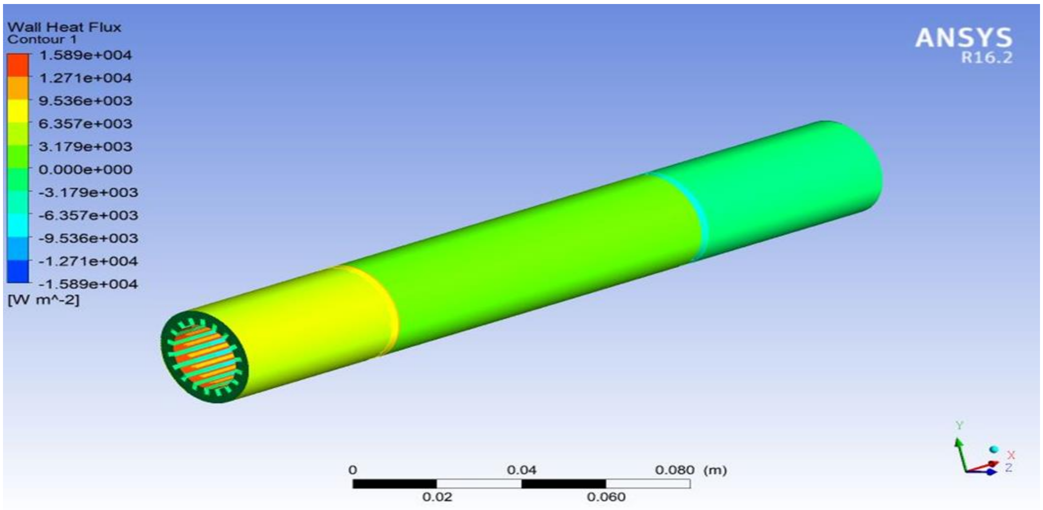



**Temperature Over Wick Structure**






**Heat Flux**




| Material | Heat Flux (W/m²) | Wick structure Temperature (K) |
|---|---|---|
| Poly-phenylene benzo-isoxazoles | $2.198x10^4$ | 316.099 |
| Ultra-high-molecular-weight polyethylene | 1.544x104 | 317.345 |

**Need for innovation**

The One Sun One World One Grid (OSOWOG) is a transnational electricity grid supplying power all over the world. The idea was first proposed by Prime Minister Narendra Modi's during the first assembly of the International Solar Alliance (ISA) in 2018. As per the draft made by the Ministry of New and Renewable Energy (MNRE) the scale of the OSOWOG is ambitious, aiming to provide energy to about 140 countries through a common grid that will transfer solar power.

**Statement of limitations**

The most important heat pipe design consideration is the amount of power a heat pipe is capable of transferring. Heat pipes can transfer much higher powers for a given temperature gradient than the best metallic conductors. The maximum power that the heat pipe can carry can be set either by the heat source and heat sink conditions or by internal heat pipe limits (can be minimized through proper design). The temperature drops across a heat pipe are Conduction through the envelope wall and wick, Evaporation, Vapor Space Temperature Drop is usually small compared to the temperature drops required to conduct heat into and out of the heat pipe, Condensation, Conduction through the envelope wick and wall. A Heat Pipe Assembly used to move heat away from the hot side of TEC to an external heat sink. In addition, there are further temperature drops to bring the heat to the heat pipe evaporator, and reject the heat from the condenser, for example, using a finned heat sink and forced convection at the condenser. *Critical Design Point:* Ensuring that the heat pipes meet your maximum system requirements. If operating conditions cause the heat pipe to exceed its power capacity, the effective conductivity of the heat pipe will be significantly reduced. There are five primary heat pipe transport limitations that must be considered during design: viscous, sonic, capillary, entrainment/flooding and boiling; These limits are a function of many variables including operating temperature, wick selection, and fluid properties. The most common limit for terrestrial applications is the capillary limit. ACT developed a heat pipe calculator for terrestrial copper-water heat pipes to help customers design accordingly.

**Discussion**

Over the past decade heat pipe models have been designed in a varied shape. both Numerical and analytical models. The purpose of the present article is not to describe precisely the set of complete equations based on the models published in the literature, but rather to provide a brief overview in the group of models still in development today. They are studies of two types of conventional heat pipe (thermosyphons and capillary heat pipe). CFD modelling advances have enabled us to create 3D thermal and hydraulic models. But in parallel, several analytical models have been proposed. There are three different approaches to compliment the typical heat pipe model of looped heat pipes. Some other specific studies aim to detect Wick properties through detailed thermal and hydrodynamic models at the pore level. Such tests can be reproduced, but they are limited by the wick properties (permeable and effective thermal conductivity), the cutting coefficient of the working fluid and the absence of thermal contact between the wall and the wick structure. The best rule is found when the two-faced liquid-vapor zone interacts with the evaporator sheath. Their simulation helps to design new wicks models for looped heat pipes. Evaporation models of looped heat pipes are proposed at the computer level. On the other hand, 3D CFD models are proposed and even models are BEING implemented. Extensive models already exist to understand the events, but their verification remains a challenge.

## Conclusion

Recent research and improvements in heat pipes have helped to identify key approaches used by researchers to improve their understanding of various systems. Both experimental and theoretical. Over the decade, some significant improvements have been made: evaporation and compression events at the capillary level have been understood and improved. This is mainly due to the new setup of visualization and tools. New wick systems and nano fluids have been successfully designed and implemented to increase the efficiency of heat pipes. The evaporation and compression processes representing thin liquid films are not yet fully understood, especially the influence of wall properties in these cases. If complete wetting of fluids is supported by some theoretical background, partial wetting in real engineering systems should be further understood. To answer these questions, more research is needed. Lack of data at the micro level is still a big problem. For example, without the data of the housing coefficient, the heat samples of the phase-to-phase heat transfer across the three contact lines cannot be verified.

Apart from this, the heat transfer coefficient can be predicted in small and curved tubes in the absence of real conventional capacitor models at low flow rates, i.e., LHP capacitors. Combining micro-size models with a computerized model can be another challenge. This problem is caused by data on materials whose geographical, physical and chemical properties are less well known. To answer this question, grater collaboration is needed between the heat pipe research community and the material science research community. Advances in other areas of research are expected to bring in new tools and ideas. For example, the development of high frequency microelectronics led to the active control of heat pipes and calculates the growth of new materials. However, one can conclude that heat pipes and its developments will be a challenging and exciting topic for at least the next few decades. This article is not a complete solution for effective heat transfer. But every new research scholar is implementing new ideas.

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