CFD Analysis of Heat Pipe with different Wick Structures and Nanofluid

[1]Ankur A Trivedi, [2]Prof. Praveen Zinzala,
M.E Scholar, [2]Assistant Professor,
[1]Mechanical Department of Post-Graduation Section,
[1]L.J.Institute of Engineering and Technology, Ahmedabad, Gujarat, India

Abstract: The heat pipe is widely used heat transfer device in many applications such as air handling unit, solar energy coefficient thermal energy storage, power plant, chemical plant, etc. Almost all fields related to mechanical are suffering from low heat transfer problems. We can use heat pipe with nanofluids as working fluid for higher performance of heat pipe. So, to fulfil our highest need for higher heat transfer and enhancement in efficiency, in this work, we are going to analyse the heat pipe with CFD software ANSYS. In past studies, researchers perform an experiment in order to find the basic characteristic of the fluid but in this analysis, we will take 3 different wick structure with the 3 different working fluid i.e. traditional host fluid, Nanofluid, Hybrid Nanofluid to compare the properties i.e. thermal conductivity, heat transfer gradient, compatibility, etc. The research will help us to get the available, economic and required combination of different wick structures and working fluids.

Index Terms - Heat Pipe; Nanofluids; Hybrid Nanofluid

I. INTRODUCTION

The heat pipe is a mechanism that can transport heat fluxes at a very fast speed. A heat pipe is a mechanism having a very high value of thermal conductivity that enables the transportation of heat and also maintains an almost uniform temperature along its heated (Evaporator Section) and cooled (Condenser) sections. Heat pipes can be used either as a means to transport heat from one location to another or to isothermalize the temperature distribution. Heat pipes are also called "thermal superconductors" cause of their ability to transfer heat with high rate across small temperature difference across the heat pipe.[1] Heat pipes are termed as "thermosyphons" when their operation relies on gravity, and heat can only be transferred from the lower end of the heat pipe to the upper end of the pipe.[2] A nanofluid is a combination of nanoparticles into a base fluid to enhance the thermal performance of the fluid.[3] A nanofluid is a colloidal dispersion of a two-phase system where nanoparticles are in solid phase (usually in powder form) and the base fluid (traditional host fluid) is in the liquid phase.[3] In 2013, Kahani, Zeinali Heris, and Mousavi [4] stated the effect of helical coils and nanofluids (combined) to enhance the thermal performance and found that the energy efficiency of equipment increased rapidly. Heat transfer through a fluid medium always plays a vital role in any type of heat exchanger. Solid metals have higher thermal conductivity than the traditional host fluids. Thus base fluid will have poorer transfer characteristics than Nanofluid as working fluid. Although, by using a hybrid type of Nanofluid we can have higher performance in the heat pipe. So, we can enhance the heat transfer coefficient and other required characteristics by using Nanofluid as working fluid. Apart from this week structure also affects the heat transfer characteristics.

II. PROBLEM FORMULATIONS

The work of Prof. Praveen Zinzala and Ankur A. Trivedi throws lights on the heat transfer device heat pipe and different factors affecting on the heat transfer in heat pipe i.e. working fluid and wick structure used in the heat pipe. The paper describes Analytical work on heat pipe with suitable dimensions for the different parameters and material as well as working fluid and also shows the comparison for different properties i.e. water heat flux for water and vapour, water volume fraction at water vapour and wick, water velocity. Although general studies shows that the hybrid fluid can give better efficiency than the nanofluid and the base fluid. Apart from this wick structure also affects on the heat transfer and performance of the heat pip. Thus for an evaluation of better performance different wick structures and the different working fluids are must be considerable.

III. METHOD OF SOLUTION

The designing part of the heat pipe is carried out in the Spaceclaim and the whole Analytical Work is carried out in the Ansys 18.2 with the discrete phase method and the realizable k-epsilon method.

III.I Selection of Dimension

C.H. NaveenKumar et al. [5] have taken 2 different length of 190 mm and 200 mm for heat pipe and different wick thickness of 0.7 mm, 1 mm and 1.3 mm in his research paper for the CFD Analysis of a Heat Pipe with different lengths and various wick structures in which 200 mm pipe length and 1.3 mm wick thickness gives optimum result. From the heat conduction formula we can say that with more surface area more heat can be absorb i.e. by applying comparatively more absorb area to the evaporator we can get better result. So, we can have 70 mm of evaporator, 70 to adiabatic section and 60 mm to the condenser section. In another research paper [4] he completed simulation and CFD Analysis of Heat Pipe with different wick geometry using CFX in which he had taken Outer Diameter of 10 mm and Pipe Thickness 2 mm thus inner diameter he can get is 8 mm.

III.II Selection of Material

Selection of Material is depends on different factors like Compatibility of Material with the material of other part and, Compatibility with Working Fluid, Compatibility with atmosphere, Operating Temperature of Heat pipe. Compatibility of Copper with working fluid we are using is high. Thus we can select Copper as Wick material as wick comes in direct contact with working fluid and the envelope material also.

III.III Selection of Working Fluid

We are going to select three different Working Fluid as per its availability and applications among which first is Base fluid, second is Nanofluid and third is Hybrid Nanofluid. Leonard M. Poplaski[6] et al. have researches on the thermal performance of heat pipe using nanofluids in which they concluded that Maximum decrease in total thermal resistance can be achieved by adding Al2O3, CuO and TiO2 is 83%, 79% and 76%. So, for this project, as base fluid we have selected water, as nanofluid we have immersed nanoparticle of alumina (Al2O3) in water and Copper Oxide (CuO) in water, as hybrid nanofluid we have mixed up and immerse the nanoparticles of alumina (Al2O3) and Copper Oxide (CuO) as per their availability, properties, applications, operating temperature range etc.

III.IV Modelling of Heat Pipe

Heat pipe material: Copper
Wick material: Copper
Wick thickness: 1.3 mm
Wick structures: Sintered Groove, Screen Groove, V-groove,
Working fluids: Water, Al_2O_3/Water, CuO/Water, Al_2O_3-CuO/Water
Lengths of Heat pipes: 350 mm
Outer diameter: 10 mm
Thickness of Heat pipe Material: 2.0

III.V Mesh file of Heat Pipe

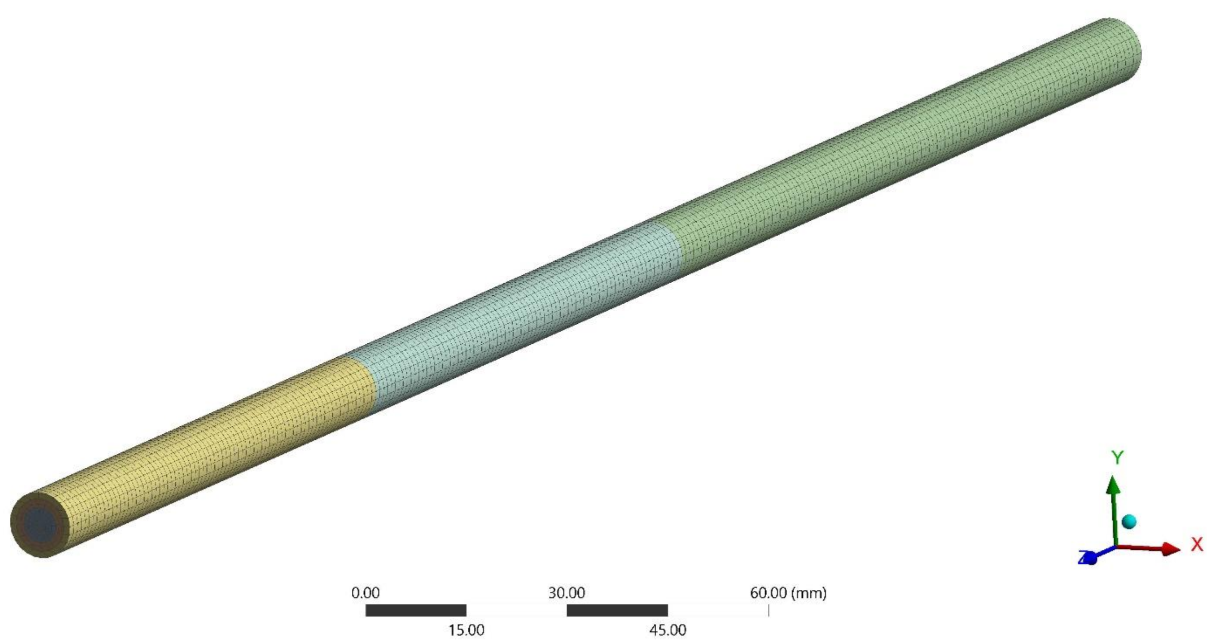

Figure 1 Mesh of the Heat Pipe

For optimum mesh size for a particular Heat Pipe (Sintered Groove Heat Pipe) we have taken different sizes for the mesh. In which 0.5 mm, 0.8 mm, 1.0 mm and 1.5 mm sizes are selected for the greed independence test and the results is shown in following table by which we can say that 1.5 mm gives optimum and stable result for the simulation. Except this some greater mesh size also selected for the greed independence test but the result was not stable. In table we can see that for 1.5 mm mesh size we can get a stable result than all the other mesh size and in 0.5 mm there is almost no difference at water volume fraction at water and volume. While for it only in vapour velocity there is almost next to 0. In Figure 1 we can see the example of meshes in heat pipe.

III.VI Analytical Work

Case I: Analytical Work for the Alumina as the working fluid with sintered groove type wick structure

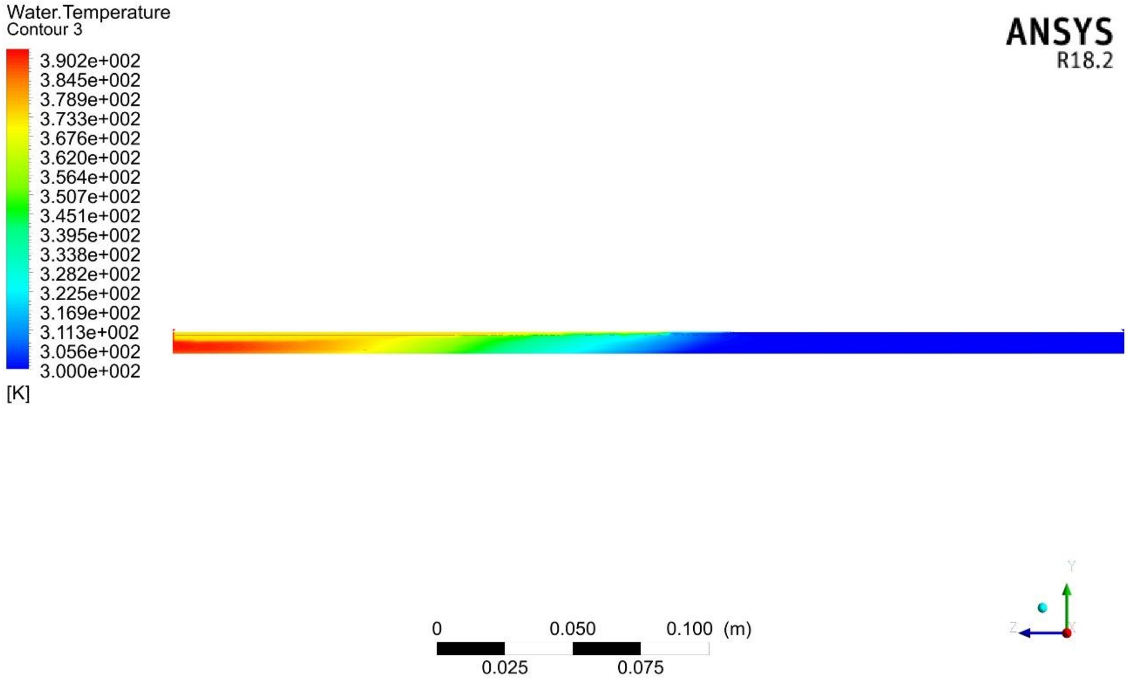

Figure 2 Water Temperature of Sintered Groove type Wick Structure with Alumina as Working Fluid

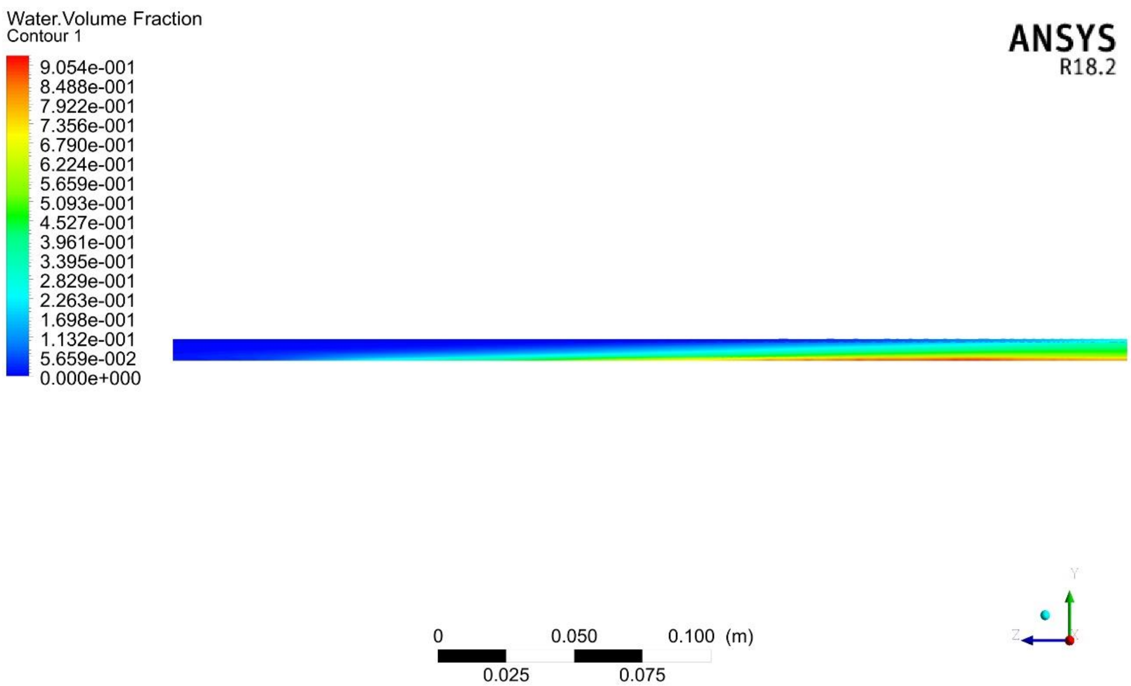

Figure 3 **Water Volume Fraction of Sintered Groove type wick structure with Al2O3/Water as working fluid**

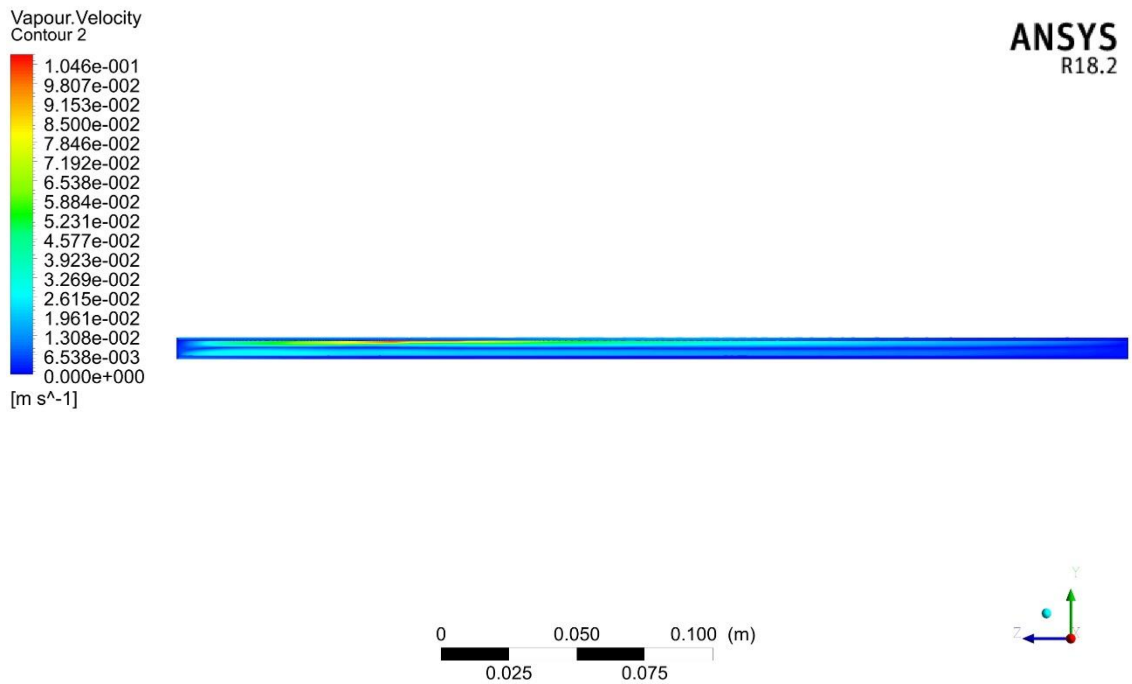

Figure 4 **Water Velocity of Sintered Groove type wick structure with Al2O3/Water as working fluid**

All this above 3 figures of contour gives the overview of properties water temperature, water volume fraction and the water velocity for the sintered groove type wick structure and alumina as working fluid. Among all the four working fluid we have taken we can get alumina as optimum for the sintered groove type of wick structure.

Case II : Screen Groove type of Wick Structure with Alumina as Hybrid Fluid

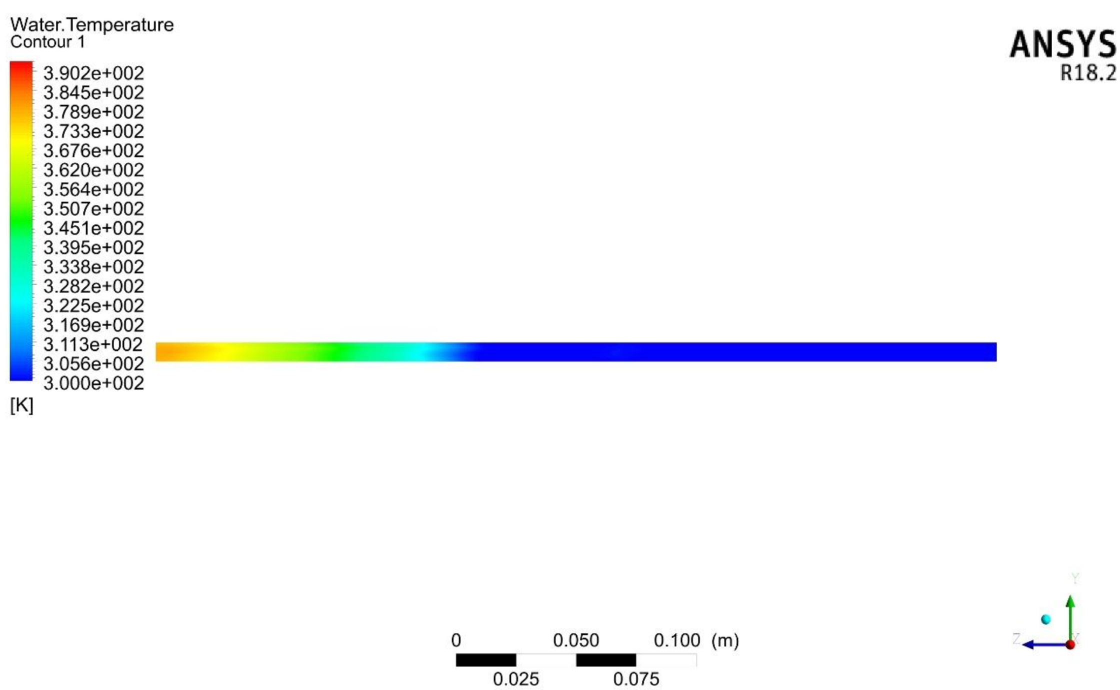

Figure 5 Water Temperature of Screen Groove type Wick Structure with Alumina as Working Fluid

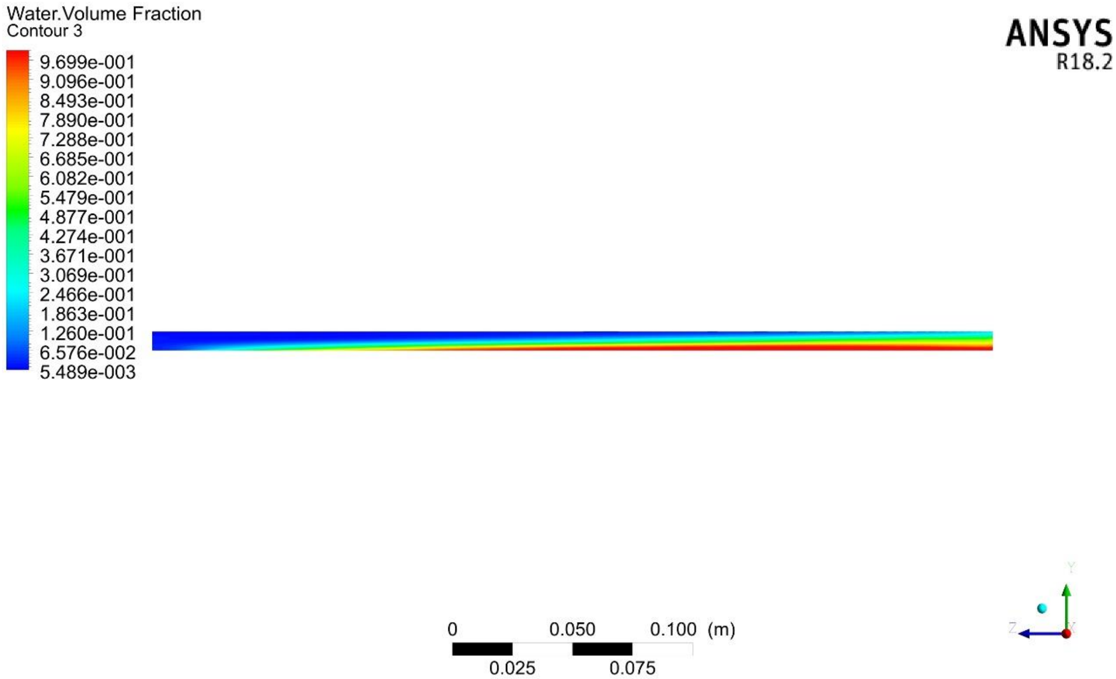

Figure 6 **Water Volume Fraction of Screen Groove type wick structure with Al2O3/Water as working fluid**

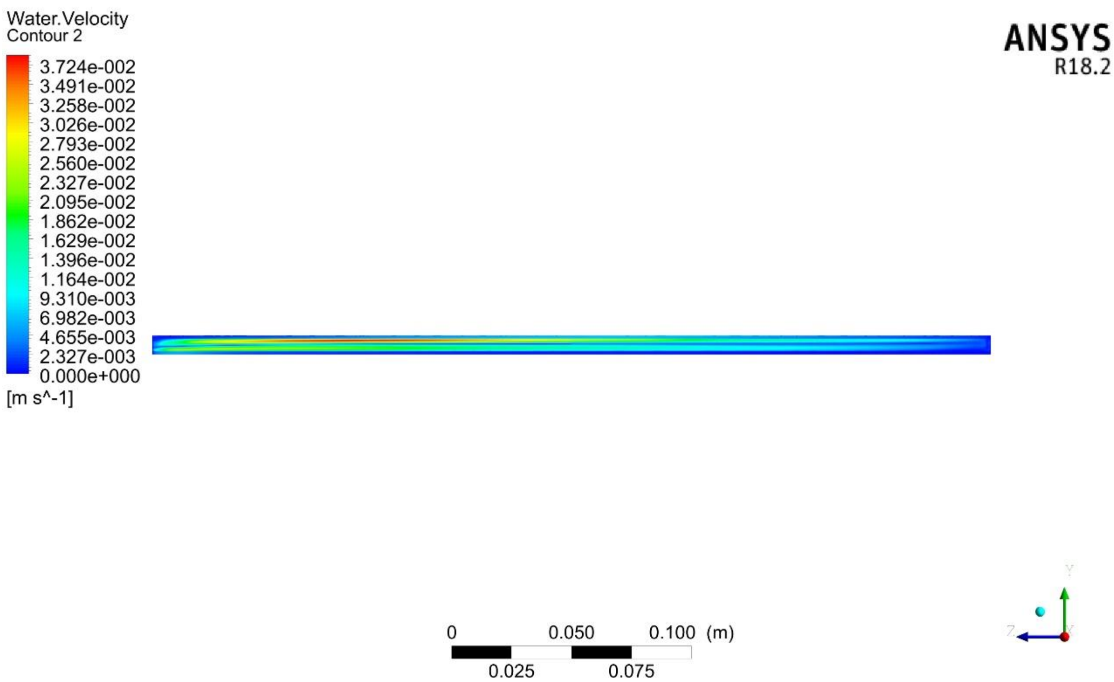

Figure 7 Water Velocity of Screen Groove type wick structure with Al2O3/Water as working fluid

All this above three figures shows the contour of water temperature, water volume fraction and the water velocity in screen groove type wick structure and alumina as working fluid. From which we can say that alumina also perform best as working fluid with screen groove type wick structure. Apart from this hybrid nanofluid we have chosen also can perform best as working fluid with screen groove type wick structure.

IV. CONCLUSION

From all the analytical work, we can come to some conclusion as follows.

- In sintered type wick structure we can have best fluid in the manner of performance is water.
- Among all the three wick structure, in screen groove type of wick structure we can get good performance compare to other sintered groove and v groove type wick structure.
- In v groove type wick structure we can get any drastic or we can say measurable change.

V. ACKNOWLEDGEMENT

We take this opportunity to express our gratitude to our loving parents who are the centre of our inspiration.

REFERENCES

[1] Stephen U.-S. Choi, Energy Technology Division, "Nanofluid Technology: Current Status and Future Research", Argonne National Laboratory, Argonne

[2] Hussam Jouhara, "Heat Pipes"

[3] I. M. Mahbubul, "Introduction to Nanofluids"

[4] Ch.Naveenkumar, P.Vijay Kumar and K. Dilip Kumar, "Simulation and CFD Analysis of Heat Pipe with Different Wick Geometry using CFX", International Journal of Thermal Technologies, Sept 2015

[5] Ch.Naveenkumar, R.Vijay Krishna, A.Madhuri, K.Vidya, "CFD Analysis of a Heat Pipe with Different Lengths and Various Wick Structures", International Journal of Engineering Trends and Technology (IJETT), February 2016

[6] Leonard M. Poplaski, Steven P. Benn, Amir Faghri, "Thermal performance of heat pipes using nanofluids", International Journal of Heat and Mass Transfer, 2017