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Study of Heat Transfer Characteristics of Heat Pipe Using Water as a Working Fluid

Prathamesh Tendolkar[1], Om Mayekar[2], Shubham Talekar[3], Aniruddha Vaidya[4], Kedar Bhide[5]
U.G. Students, Department of Mechanical Engineering [1,2,3,4]
Assistant Professor, Department of Mechanical Engineering[5]
Finolex Academy of Management and Technology, Ratnagiri, India

Abstract: *Heat pipes are efficient and versatile thermal management devices widely used in various applications to transfer heat. This study focuses on investigating the heat transfer characteristics of a heat pipe employing de-ionized water as the working fluid. The experiment involved analyzing the thermal performance, heat transport capacity, and operational limits of the heat pipe. The aim of the experiment is to assess the heat pipe's performance under different operating conditions, such as varying heat loads. The study aimed to understand the heat transfer limitations and advantages of water-based heat pipes, which can have practical implications for numerous applications, such as electronics cooling, solar thermal systems, and space technology.*

Keywords: versatile thermal management, heat transfer characteristics, thermal performance, heat transport capacity, operational limits, electronics cooling, solar thermal systems, space technology

I. INTRODUCTION

Heat pipes have emerged as a vital component in modern thermal management systems due to their exceptional heat transfer capabilities and energy efficiency. These devices are extensively utilized in applications ranging from electronic cooling and space technology to renewable energy systems. Central to the functionality of heat pipes is the choice of working fluid, which significantly influences their thermal performance.

Water, a readily available and environmentally friendly fluid, has gained attention as a potential working fluid for heat pipes. The study presented here delves into the investigation of the heat characteristics of heat pipes employing water as the working fluid. Understanding the behaviour and limitations of water-based heat pipes is crucial for optimizing their performance in practical applications.

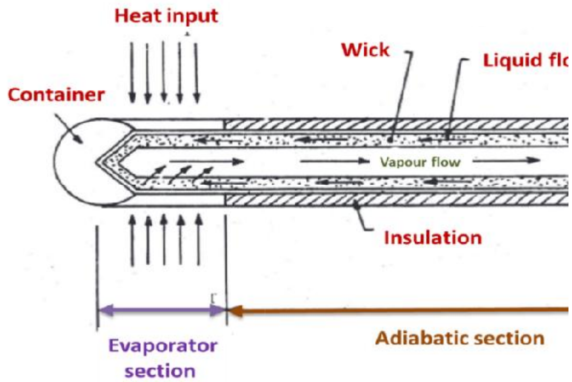
In this study, we explore the thermal performance, heat transport capacity, and operational boundaries of water-based heat pipes under varying conditions. By doing so, we aim to provide valuable insights into the potential advantages and challenges of using water as the working fluid in heat pipes. The outcomes of this research can contribute to the development of more efficient and cost-effective thermal management solutions, with implications for a wide array of industries and applications.

II. PROBLEM DEFINATION

The problem statement for a research project on a Study of Heat Transfer Characteristics of Heat Pipe is: "To investigate and analyze the heat transfer characteristics of heat pipes in various operating conditions and configuration". The study of heat transfer characteristics of heat pipe is essential for improving the efficiency and performance of heat pipe-based heat exchangers and thermal management systems.

III. STRUCTURE OF HEAT PIPE

A typical heat pipe consists of a sealed pipe or tube made of a material that's compatible with the working fluid such as copper for water heat pipes, or aluminium for ammonia heat pipes. Generally, a vacuum pump is used to remove the air from the empty heat pipe. The heat pipe is incompletely filled with a working fluid and also sealed.



Heat pipes are designed for veritably long term operation with no conservation, so the heat pipe wall and wick must be compatible with the working fluid. The pronounced/ recommended operating temperature of a given heat pipe system is critically important. Below the operating temperature, the liquid is too cold and cannot decimate into a gas.
Heat pipes are designed for very long term operation with no maintenance, so the heat pipe wall and wick must be compatible with the working fluid. The stated/recommended operating temperature of a given heat pipe system is critically important. Below the operating temperature, the liquid is too cold and cannot vaporize into a gas.

IV. WORKING OF HEAT PIPE

The heat pipe is a type of heat exchanger that uses the principles of phase metamorphosis and thermal conductivity, to transfer heat in between two interfaces. This device is a sealed vessel which is generally a pipe like structure, consists of two ends and is filled with a working fluid. Bottom end of the heat pipe is connected to the heat source and the upper end is connected to the condenser where heat exchange takes place and a porous material called a wick is present along the inner walls of the pipe. When the evaporator section gests high temperature, the working fluid gets faded and the vapour exerts pressure, this rise in pressure causes the vapour to flow to the condenser region.In this region, the heat is rejected to the sink or the device need to be heated and therefore, the fluid in heat pipe condenses. This condensate is driven back to the evaporator end by the capillary action in the wick. Hence in a heat pipe, the heat transfer occurs through the capillary movement of fluid.
A heat pipe works efficiently when the evaporator end is below the condenser end or when both the ends are in same vertical line, because the return of working fluid from condenser end is due to both capillary action and gravity. However, the fluid must flow against the graveness which decreases the rate of fluid inflow thereby dwindling the heat transfer rate, If the condenser end is below the evaporator end.

V. OBSERVATIONS AND RESULTS

Observations:

Readings of Heat Pipe

Time (min)	T_1 at 100mm (^oC)	T_2 at 200mm (^oC)	T_3 at 300mm (^oC)	T_4 (Water Temp) (^oC)
5	110	85	40	35
6	115	87	43	37
7	118	91	46	40
8	120	94	48	42

Temperature readings after 5 minutes

Length (mm)	Temperature of Heat pipe (^oC)
100	110
200	85
300	35

Temperature readings after 6 minutes

Length (mm)	Temperature of Heat pipe (^oC)
100	115
200	87
300	37

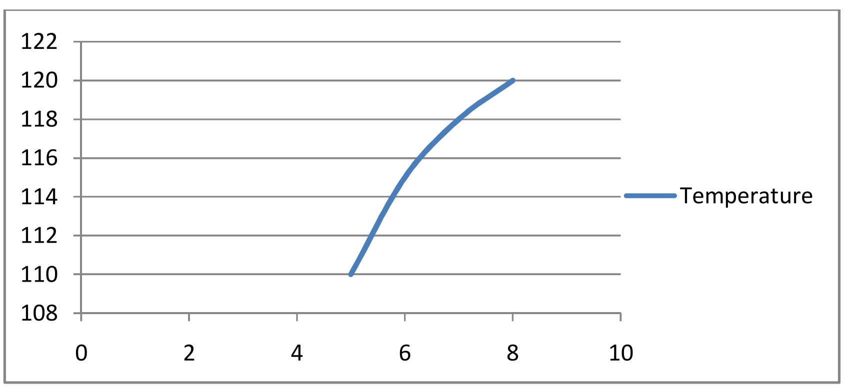
Temperature readings after 7 minutes

Length (mm)	Temperature of Heat pipe (^oC)
100	118
200	91
300	40

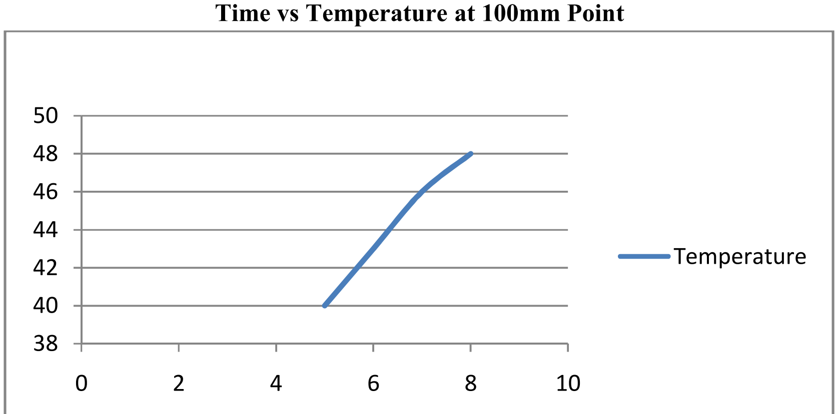
Temperature readings after 8 minutes

Length (mm)	Temperature of Heat pipe (^oC)
100	120
200	94
300	42

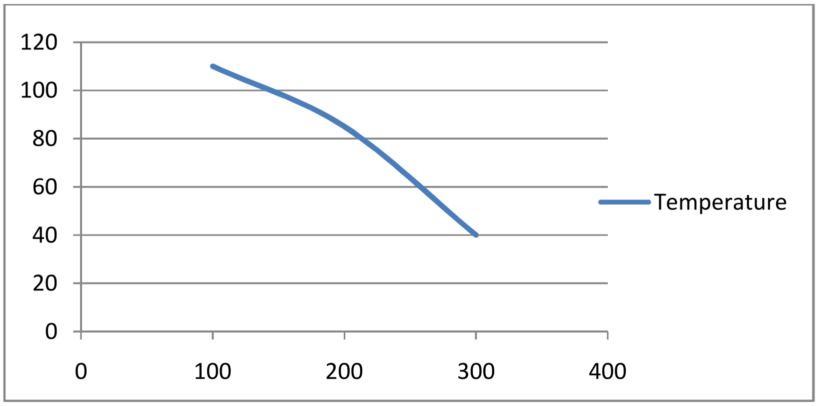
RESULTS: From the above work experimental and Analytical there are different charts that are plotted in Time vs. temperature and length vs. temperature. Graph 1 shows the temperature with time at 100mm length of pipe. Graph 2 shows the temperature at length of 300mm of pipe. Graph 3 shows comparison of analytical and experimental results which clearly indicate small difference in the both the results so results obtained from experimental is validated from above.



Time vs Temperature at 100mm Point



Time vs Temperature at 300mm Point



Length vs Temperature at 5 minutes

VI. CONCLUSION AND FUTURE SCOPE

CONCLUSION

The investigation into the heat transfer characteristics of heat pipes using de-ionized water as the working fluid has yielded significant findings. It is crucial to understand that heat pipes are highly efficient heat transfer devices widely used in various engineering applications, and the choice of working fluid plays a critical role in their performance.

De-ionized water, as a working fluid in heat pipes, has shown itself to be particularly effective. The study has revealed that water-based heat pipes exhibit excellent thermal conductivity and heat transfer capabilities. When a heat pipe is filled with water and subjected to a temperature gradient, it effectively transports heat from the heat source to the heat sink. This property makes them well-suited for applications where efficient cooling or heat dissipation is required. However, it's essential to acknowledge some limitations associated with using water as the working fluid in heat pipes. One significant limitation is the narrow temperature range within which water can operate effectively. Water-based heat pipes are most efficient within a certain temperature range, and outside of this range, their performance may deteriorate. Additionally, one of the inherent issues with water-based heat pipes is the potential for freezing, which can cause problems in low-temperature environments.

In summary, the study underscores the promising aspects of water-based heat pipes in terms of their strong heat transfer characteristics. These characteristics make them a compelling choice for various thermal management applications, particularly in scenarios where high-efficiency heat dissipation or cooling is required. However, engineers and researchers must carefully consider the operating temperature range and the potential for freezing when employing water-based heat pipes in specific applications.

FUTURE SCOPE

Studying the heat transfer characteristics of heat pipes using water as a working fluid holds promising future avenues. Potential areas to explore could include optimizing the design for enhanced thermal conductivity, investigating the performance under varying operating conditions (temperature, pressure, orientation), and assessing its suitability for specific applications such as thermal management in electronics or solar thermal systems. Additionally, you could delve into advancements in materials or manufacturing techniques to improve heat pipe efficiency and durability.

The future scope for water-based heat pipes is quite promising. Here are some potential directions for further exploration:

1. Efficiency Enhancement: Research ways to enhance the efficiency of water-based heat pipes by optimizing their design, materials, and manufacturing processes. This could involve experimenting with different wick structures, working fluids, and surface coatings to improve heat transfer performance.
2. Applications Expansion: Explore new applications for water-based heat pipes beyond traditional thermal management, such as waste heat recovery, HVAC systems, and passive cooling for electronics or buildings. Investigate how water-based heat pipes can be integrated into renewable energy systems like solar thermal collectors or geothermal heat pumps.

3. Environmental Sustainability: Evaluate the environmental impact of water-based heat pipes compared to other heat transfer technologies and identify ways to make them more eco-friendly. This could involve using recycled materials, reducing energy consumption during manufacturing, or developing water-based heat pipes with biodegradable components.
4. Miniaturization and Integration: Investigate methods to miniaturize water-based heat pipes for use in compact electronic devices, wearable technologies, or micro fluidic systems. Explore ways to integrate water-based heat pipes into existing cooling solutions to enhance their performance and reliability.
5. Advanced Materials and Nanotechnology: Explore the use of advanced materials and nanotechnology to further improve the thermal conductivity, corrosion resistance, and overall performance of water-based heat pipes. Investigate how nano material coatings, nano particles, or nano structured surfaces can enhance heat transfer efficiency and prolong the lifespan of water-based heat pipes.

By focusing on these areas of research, we can contribute to the continued advancement and adoption of water-based heat pipes in various industries and applications.

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