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Research Paper

A Review on The Fundamental Concepts of 'Heat-Pipe' and its Modern Applicatons

Engineering

KEYWORDS : Heat-Pipe, Thermosyphon, Thermal Conductance, Thermal Control

G Upadhyay	Professor and Head, Mechanical Engineering Department, L. D. College of Engineering, Ahmedabad
K Mehta	Student, M.E. Mechanical Engineering (CAD/CAM), L. D. College of Engineering, Ahmedabad
U Shah	Associate Professor, Mechanical Engineering Department, L. D. College of Engineering, Ahmedabad

ABSTRACT

Modern day industrial equipment has a pressing need to develop newer technologies. The discipline of thermal engineering is quite fundamental and has very wide applications in the human welfare. The equipment requiring heat transfer amongst its various components is quite common in the thermal industry. One specific requirement is to transfer a large amount of heat across a low thermal gradient. The requirement of very fine thermal control is also in high demand in Industry as well as Research Applications. Heat pipes present a solution to such issues. Heat pipes employ the Heat of Vaporization of a fluid to transfer heat from one part to another. Heat pipes are similar to Thermosyphon, but have an advantage of transferring heat without the dependence on gravity. The present paper reviews various fundamental concepts of Heat Pipe along with their modern day application.

INTRODUCTION

Heat Pipes are devices that have a very high thermal conductance. Thermal conductance is the property of a substance to transfer heat for a low thermal gradient. Heat-Pipes are very agile in achieving an effective thermal control. Heat-Pipes exhibit some unique properties like isothermalisation and high heat transfer rate for smaller temperature differences. These properties have made Heat-Pipes suitable for the modern day industry. Heat-Pipes, nowadays have widespread applications. In the following text some fundamentals of the Heat-Pipes are described. A comprehensive list of the applications of Heat-Pipe has also been presented.

ANATOMY OF A HEAT PIPE

A typical Heat-Pipe anatomy is as shown in figure-1 [2]. The major components include a Pipe or Container (usually metallic), a Wick or Metallic mesh and a Working fluid. The working principle of the heat Pipe is also depicted in figure-1.

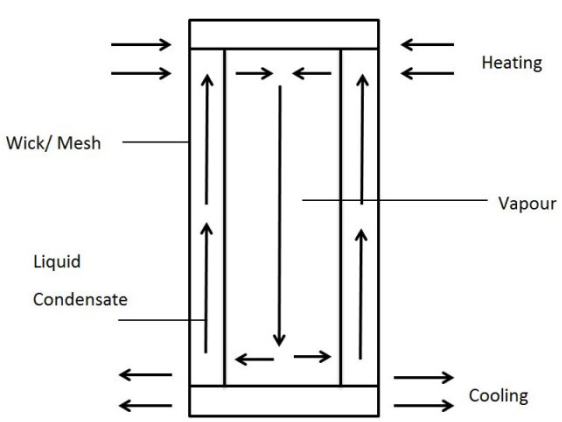


Figure 1: Anatomy of a Heat-Pipe

The Pipe houses a wick which is usually a metallic mesh. A working fluid is also present in the Pipe. The substance is selected primarily on the basis of its vaporising temperature. The vaporising temperature of the working substance must be in the operating range of the Heat-Pipe. The operating range of the Heat-Pipe is decided on the basis of its application. The idea here is to take the advantage of the Heat of Vaporisation of the substance. Since any substance, ideally, vaporises at a constant temperature, it is possible to transfer large amount of heat (heat of vaporisation) across a very small temperature difference, via the working substance. The working substance, just below the vaporising temperature, absorbs heat from the source and gets converted from liquid to vapour. The vapour then loses this heat at the sink, and gets converted from vapour to liquid. The wick or metallic mesh helps to transfer the working substance in liquid form from the sink to the source, by capillary action. This enables the Heat-Pipe to perform in any orientation. Of course, the Heat-Pipe is designed so that the advantage of gravity can also be taken.

TYPES OF HEAT-PIPES

Following is the list of the most commonly used Heat Pipes [2]:

- Variable conductance heat pipes
- Thermal diodes
- Pulsating (oscillating) heat pipes
- Loop heat pipes (LHPs) and capillary pumped loops (CPLs)
- Micro-heat pipes
- Heat-Pipes employing Electrokinetic forces
- Rotating heat pipes
- Miscellaneous types – sorption heat pipe (SHP); magnetic fluid heat pipes

CHARACTERISTIC FEATURES

The most striking feature of the Heat Pipes is to transfer a large amount heat across a very low thermal gradient. Heat-Pipes are highly flexible as far as thermal control is concerned. They can be easily used as heat exchangers and other types of heat transfer devices. Their heat transfer coefficient in the evaporator and condenser zones is 10^3–10^5 W/m^2 K, heat pipe thermal resistance is 0.01–0.03 K/W, therefore leading to compact heat exchangers [4]. Miniature and micro heat pipes are much favourable for electronic components cooling.

FACTORS AFFECTING THE PERFORMANCE OF HEAT PIPES

Various factors influence the performance of Heat-Pipes. One of the major factors is the working fluid itself. The selection of the Working fluid is done based on its thermal properties, stability in the desired temperature range, compatibility with other components of Heat-Pipe etc. [2]. The configuration of the Heat-Pipe container, or the Pipe, also affects the performance of the Heat-Pipe. The number of layers and coarseness of the wick or the metallic mesh also affects the thermal characteristics of the Heat-Pipe. A small increase in the thermal resistance is found when the thickness of the wick is increased [1]. The capillary

pressure in the wick responsible for effective transport of the working fluid, also affects the performance of the Heat-Pipe [3].

MODERN APPLICATIONS

The heat pipes have extensive applications in research and even in industries. The broad areas of application [2] of Heat-pipe include separation of heat source and sink, temperature flattening, temperature control, heat flux transformation, thermal switches, etc. A comprehensive list of the modern application of Heat-Pipe is presented below:

- Heat-Pipes are used in modern day heat exchangers requiring high degree of thermal control.
- These are used in electronic devices for effective cooling.
- These are used as cooling devices wherein the heat must be rejected far away from the main component. These include the cooling of sophisticated laboratory equipment wherein the parts are highly temperature sensitive.
- Heat-Pipes also find applications in the space crafts and satellites.
- Modern day particle accelerators also employ use of Heat-Pipes. In such accelerators the Heat-Pipes are used to produce a highly constant and stable temperature field.
- Heat-Pipe air pre-heaters are also used in thermal powerplants.
- Heat-Pipes also have a promising application in the solar heat collectors. [4]
- Heat-Pipes find application in the cooling of nuclear reactors and nuclear waste. [2]
- These are also used in the passive cooling system for airconditioning.

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