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INNOVATIVE DEVELOPMENTS AND HEAT TRANSFER APPLICATIONS OF HEAT PIPE

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***ABSTRACT*: This paper provides a wide-ranging review of the state of the applications, performance and materials of current heat pipe heat transferring devices. Heat pipes are becoming increasingly popular as passive heat transfer technologies due to their high efficiency. The significance of heat pipes as devices for efficient heat transfer has led to progress of various types such as closed loop or loop heat pipes, wick heat pipes, thermosyphon heat pipes, pulsating heat pipes, and variable conductance heat pipes, etc. in a variety of applications. Summary of previous work conducted was to improve different types of heat pipes is brought in. Operational limitations, cost concerns, the need of detailed theoretical, numerical and simulation analysis of heat pipes etc. are covered in this paper. Finally, some of the recent and future developments in the field are discussed.**

Keywords: heat transfer, heat pipe, developments, heat transfer applications

1. INTRODUCTION

Heat Pipes (HP) have emerged as the most reliable, structurally simple heat dissipating device with excellent heat transfer capability. It can offer thermal conductivity several times better than good heat conducting material (copper, silver etc.). Hence, it is named as "Thermal Super Conductor". It has no moving parts and does not require any electricity input. Heat transfer is involved in various energy utilization processes. Heat Pipe is known as an efficient, reliable and passive heat transfer device in which continuous evaporation/condensation cycle with a small temperature drop is accomplished by capillary forces [1]. The idea of the HP was first suggested in 1942 and the first patent was applied in 1944 [2]. Heat pipes are comprised of 3 sections: evaporator, adiabatic section, and condenser. Heat flux enters the heat pipe from the evaporator and causes the evaporation of the working fluid inside the heat pipe. [3]. The most obvious point to the success of the HP is the wide range of applications where its unique properties have proved beneficial [4–6]. Over the past decades, due to the various requirements on thermal control and cooling systems, HPs have been improved significantly towards achieving higher heat flux [7, 8]. The heat pipe is an efficient and energy-saving heat transfer device. Heat pipes are widely used in several applications, such as energy storage systems [9, 10] and waste heat recovery systems [11], particularly in data centers or cooling systems of IT equipment [12–15].

2. LITERARURE REVIEW

Zongwei Han et al. [16] the double source heat pipe composite vapor compression heating unit, which is the key component of a multi-source coupled heat pump system (MSCHPS), is studied experimentally, and the operating performance of the unit under two different heating conditions is tested. They concluded that the heat capacity and COP of the two stage compression unit with vapor injection are always higher than those without the vapor injection unit.

Hamdy Hassan and Souad Harmand [17] this paper presents a study on the effect of using nanofluids on the performance of rotating heat pipe. The effect on heat transfer and liquid film thickness is carried out by use of nanofluids. They used three different solid nanoparticles with different radii and volume fractions with water as working fluid.

Hossein Kavusi and Davood Toghraie [18] a two-dimensional numerical model is developed and studied the performance and the effect of heat pipe by using different prepared nanofluids of different diameters with different concentration by the finite volume method. The results showed that by using a nanofluid instead of water leads to the reduction in heat at wall of the heat pipe and increased thermal efficiency.

Tayfun Menlik et al. [19] a straight copper tube with an inner diameter of 13 mm, the wall thickness of 2 mm and the length of 1 m was used as the heat pipe in their experimental set-up. The thermal performance of magnesium oxide containing nanofluid was better than that of de-ionized water. The difference among the wall temperature of the condenser and the evaporator was slighter using the nanofluid as the working fluid than when deionized water was utilized as the working fluid. Lower thermal resistance of the HP was obtained when the nanofluid was used instead of deionized water.

D. Yin et al. [20] in their investigation, the operating limitation of an Oscillating Heat Pipe (OHP) is theoretically studied to determine its maximum heat transport capability. They concluded that the operation of an OHP depends on its working fluid, operating temperature, latent heat, heat pipe dimensions, number of turns, filling ratio and liquid plug length.

Jian Qu et al. [21] they had designed fabricated and studied experimentally about a hybrid Flexible Oscillating Heat Pipe (FOHP) which was characterized by a hot/cold-end. The adiabatic section was made of fluoro-rubber materials and heating/cooling sections was made of micro-grooved copper tubes. The working fluid used was deionized water.

Valery Kiseev and Oleg Sazhin [22] Experimental investigations were performed using the developed Loop Heat Pipe (LHP) based on composite nickel wick with effective pumping. This paper features the long-life test, covering 41 years with varying operation times. The life test consists of two parts: permanent and periodic LHP operation and LHP stand-by storage.

Shafii et al. [23] experimentally investigated a Magnetically Variable Conductance Thermosyphon Heat Pipe (MVCTHP). The effect of various ball positions in the evaporator and inclination angles on heat pipe performance was studied. Heat input had a direct effect on MVCTHP performance and by increasing it, thermal resistance drops and also by increasing the inclination angle of the MVCTHP, its thermal resistance decreases.

Y. Yu et al. [24] a newly concept of Solid Sorption Heat Pipe (SSHP) applied for continuous heat transfer is proposed and an experimental test system is designed and built up. It can be concluded that the SSHP is characterized by the non-isothermal heat transfer performance. The vertical SSHP had a better overall heat transfer performance than horizontal SSHP.

Narendra Babu N and Kamath HC [25] this paper summarizes the recent developments of lightweight, high performance heat pipes and describes the material of the heat pipe components, various wick materials and its structure. The lightweight materials can help trim down up to 80% the weight of general copper heat pipes. By using such methods the thermal performance of the any heat pipe improved definitely.

H. Jouhara et al. [26] a heat pipe based pyrolysis chamber has been developed and tested as an efficient, cost effective and space saving municipal waste treatment unit. The innovation of the system was to provide efficient domestic applications. The environmental, economic and social effects of current waste treatments had proved their inefficiency.

Shen-Chun Wu et al. [27] they were first to utilize self-rewetting fluid with Polytetrafluoroethylene (PTFE) wick structure applied to Loop Heat Pipe (LHP) System. PTFE wick structure has low thermal conductivity, low sintering temperature thus low cost and high antioxidation production for long term using which can also overcome heat leakage when operating. It had effectively improved the performance of traditional metal wick structure.

Bin-Juine Huang et al. [28] their main aim was to reduce the production cost for commercial applications. In this paper they disclosed an innovative evaporator design of LHP for low-cost manufacturing. Their LHP was successfully used in LED luminaire, solar water heater, and thermoelectric power generator to dissipate heat.

Y. Maydanik et al. [29] the authors developed a LHP of 21 m long equipped with a cylindrical evaporator 24 mm in diameter and vapor and liquid lines with diameters of 8 and 6 mm, respectively. They found that LHPs are passive heat-transfer devices which were used in energy-efficient systems of recovery of low-potential heat.

Kai Zhu et al. [30] a new type of LHP has been proposed in order to reduce the heat leakage from the evaporator and to achieve a longer transport distance. To understand the mechanism of operation, a new mathematical model was established by them.

How-Ming Lee et al. [31] for the purpose of the low-grade heat recovery applications a set of stainless steel tabular heat pipes were successfully fabricated. The fabrication, the thermal performance testing systems, and modeling are presented in the paper. The experimental results showed that the water filling ratio plays a very significant role in the thermal performance of heat pipes.

Harshal Gamit et al. [32] various experiments had been carried out in order to check the influence of filling ratio and input heat flux on the performance of the Closed Loop Pulsating Heat Pipe (CLPHP). Water was used as working fluid. Inner diameter of the copper tube was 2.15mm. Heat transfer mechanism was a natural convection in condenser section. They concluded that the system performs better with lower filling ratio for the same input heat flux.

S. Siva Kumar et al. [33] in this paper the evacuated tube is modelled with heat pipe for the enhancement of the heat generated from the collector. The objective of their research was to design and investigate the heat transfer analysis of Heat Pipe Evacuated Tube solar collector. They concluded that the efficiency of evacuated tube solar collector with heat pipe for water heating can be improved by designing appropriate design of heat transport system from solar absorber to heat storage system. The length of evaporator to condenser section was an important parameter for the design.

3. CONCLUSION

The most importance of the current study is to know how the thermal performance decreases or increases due change in the temperature difference between the evaporator and the condenser. How much effectively works the different working fluids in heat pipe works and the different application of heat pipe as a heat transfer device. If we employ water as a working fluid, titanium alloys and the magnesium alloys, the aluminum alloys, are supposed to have additional protection incorporated during the production process. The use of nanofluid reduces the thermal resistance of the pipe's wall and also reduces its temperature. The addition of nanofluids improves the thermal capacity of the system, the particles may adhere to the wall and increase the thermal resistance over a prolonged period of time. By an increase in the volume fraction of nanoparticles, the pressure in the path of the fluid also increases. The technology has migrated into other applications and although this is positive, the reality of researching all these new formats and technologies is causing a backlog of research to conduct, with obvious research gaps. Low temperature heat pipes are commonly being implemented in cryogenic applications, but could be applied in permafrost regions. The implementation of heat pipes is beneficial for multiple industries, and they can be applied to a range of operation temperatures. Although the range of applications is large, this also means that there is a significant amount of work to be conducted to make the system viable in every combination of temperature and application.

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