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A review on application of nano fluids in pulsating heat pipe

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ABSTRACT: Oscillating or Pulsating Heat Pipes (PHPs) are complex devices, that are used for transfer of heat energy. Working fluids of these oscillating or pulsating heat pipes are found as, one of the major factors affecting the thermal performance. The efficacy of these PHPs can be seen depend, on the type of working fluid employed in the system. In this paper, application of nano fluid as the working fluid in PHPs, and the effect of nano fluid in the thermal efficacy of the system is reviewed. As recently, many research works prove that the usage of nano fluid rise the thermal efficacy of the system. Nano fluid may increase the performance of the PHP, if it is used as the working fluid of the system.

KEYWORDS: Nano fluid, Pulsating Heat Pipes, Agglomeration**.**

I. INTRODUCTION

Two-phase thermal energy transfer devices with higher thermal conductivity are known as heat pipes. There are various types of HPs and PHPs are one of the types. There are three main sections in PHPs; evaporator, condenser and the adiabatic.

The motion of the working fluid filled in the PHP plays a vital role in the performance of the PHP [14]. The fluid filled in the PHP evaporates first and then reaches the condenser and cools down later and this cycle continues and this movement of fluid is caused by differences in temperature [1].

PHPs are of two types. They are,

1. CLPHP (Closed Loop PHP)
2. OLPHP (Open Loop PHP)

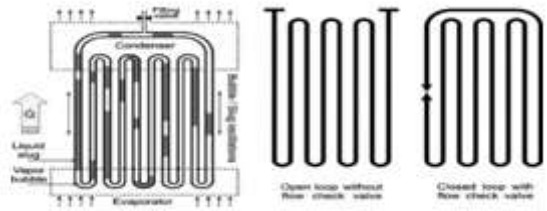
In CLPHPs, the ends of the PHPs are closed i.e. the ends are connected to form a loop and in OLPHPs, the ends of the PHPs are not closed i.e. the ends are not connected and they don't form loop [1,15].

As the working fluid also affects the performance of the PHPs, one must focus on the type, concentration or volume of the working fluid used in the PHPs to ensure maximum performance of the system [19].

Filling ratio is also one of the most important parameter that must be taken into account as a high filling ratio ceases the motion of the fluid and a low filling ratio seeds dry-out of the fluid [1].

II. AN INTRODUCTION TO NANO FLUIDS

A combination of nano particles and base fluid which forms a colloidal solution is called nano fluid. These nano fluids are PC materials (Phase Changing Materials). PC materials are those which change its phase when the temperature is raised. These nano fluids are used for various applications. In PHPs these nano fluids can be used as a tuning agent, which can tune up the thermal performances of the PHPs [21].



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I. A TYPICAL PHP [3].

When the temperature of the nano fluid rises, the Brownian motion of the nano particles stood ups and thus it further rises the thermal conductivity of the nano fluid. Besides this, various factors also affect the thermal conductivity of nano fluids [6,8,21].

III. APPLICATION OF NANO FLUIDS IN PHPS

Yu-Hsing lin et al. in 2008 found that, when 20nm silver nano fluid of 100ppm is used with 60% filling ratio, the performance of PHP stood up. They also found that the viscosity is directly proportional to the concentration and increasing the concentration ultimately leads to the lower performance, as the bubble formation may get hindered due to increase in viscosity [1].

Miguel Gonzalez et al. in their experiment in 2014 found that, the thermal energy transfer performance of evaporator section decreased, when nano fluid is used at higher power rate, because of the raise in viscosity of the fluid, but the thermal conductivity stoop up at lower power rate. In their work, they found that the raise in viscosity of the nano fluid has a greater influence on the thermal performance of the PHP [4].

FIG.2 FACTORS THAT AFFECT THE NANO FLUID'S THERMAL CONDUCTIVITY [21].

In 2019, P. Gunnasegaran et al. experimentally found that the thermal aversion of SiO_2-CuO and Al_2O_3-CuO hybrid nano fluids are lower than water and these hybrid varieties can also attain earlier start-up pulsations according to them [5].

V.K. Karthikeyan et al. in 2013 concluded that the usage of nano fluids as the working fluid in CLPHPs can enhance the thermal accomplishment of the system as these nano fluids create nucleation site which results in higher efficiency of the CLPHPs [7].

Comparing the performance of PHPs with pure H_2O and hydroxylated MWCNT nano fluids as working fluid, Meibo Xing et al. in 2017 found that, the PHP with MWCNT nano fluid showed better result when the concentration is less than 0.3% and nearly 34% reduction in thermal aversion was found by them [9].

Xue Fei Yang et al. in 2008 conducted an experiment with micro-grooved PHP with 0.5%-2% of CuO-DI H_2O as working fluid. In that experiment they found that the CHF (Critical Heat Flux) and HTC of evaporator (Heat Transfer Coefficient) can be raised by 30% and 46% respectively under the working pressure of 7.45 kPa. They also found that, the working pressure can influence the PHP performance and lower working pressure may enhance the performance more than higher working pressure [10].

Jia Hongwei et al. in 2013 conducted an experiment to study the performance of nano fluid when used as working fluid. They concluded that the higher fraction of nano fluid will result in reduced PHP performance [11].

Yuwen Zhang et al. conducted a numerical experiment on the application of nano fluid in PHP in 2013 and found that increasing the volume fraction and decreasing the particles diameter enhances the overall performance. They also concluded that the nano particles size, when decreased, increases the sensible heat magnitude [12].

Kaushal K Srivastava et al. in 2013 through their experiment found that, for vertical PHP with 45^o IA (Inclination Angle), the best suited concentration of nano particles is 1% by weight and for horizontal PHP, the best suited concentration was found as 0.5% by weight [13].

R.R. Riehl et al. in 2012 found that the raise in the number of nucleation sites is caused by the inclusion of copper nano particles in H_2O, which induced more bubble formation. This bubble formation lead to higher pulsation which ultimately makes the overall PHP performance to stood up [20].

Miguel Gonzalez et al. in 2014 found that the thermal aversion reduced at filling ratio of 70% and the overall performance of the system was increased [17].

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Samad Safarmadar et al. in 2016 compared three nano fluids and concluded that among the three, silver nano fluid was found more effective and they also agreed that the usage of nano fluid as working fluid enhanced the efficacy of PHP [18].

TABLE.1 OTHER RESEARCHES IN PHPS WITH NANO FLUIDS [5].

Researchers	Working fluid	Observation
J. Qu et al. 2010	Al_2O_3 Nano fluid	Increase in thermal energy transfer of PHP when compared with water as base fluid at filling ratios of 50%, 60% and 70%. Thermal aversion got reduced by 32.5% to that of water.
M.R Tanshen et al. 2014	MWCNT Nano fluid	It is found that 0.1% of MWCNT nano fluid increased the fluctuation in the temperature which will further increase the PHP efficacy.
M. Alhuyi et al. 2018	Graphene oxide Nano fluid	42% of reduced thermal aversion is found when 0.25% of graphene oxide nano fluid is employed as the working fluid of the PHP. The performance got reduced at higher concentration which is caused by greater viscosity of the fluid.

IV. CHALLENGES IN APPLICATION OF NANO FLUIDS

Now a day, we can find many works regarding the application, properties, type of nano fluids. Though nano fluids can be applied in various fields, there are few challenges that must be resolved for enhanced result. They are,

1. Long term colloidal particle stability in the dispersed medium
2. Thermal conductivity of colloidal nano fluid solution
3. Lower SH of nano fluid (Specific Heat)
4. Viscosity of nano fluids
5. Cost of manufacturing and the
6. Difficulties in manufacturing of nano fluids [2].

According to Vijayakumar.P et al. the agglomeration of particles in the base fluid in the colloidal nano fluid mixture during dispersion is considered as one of the most serious problems which directly affects the thermal performance of the fluid, thus making it unfit for the thermal related applications and thus it must be sorted out and this agglomeration process may happen if the concentration is raised and this will lead to dull performance of the system [21].

Thus for the enhanced result in performance one must sort out these issues as they tend to hinder the thermal related performance of the PHP.

V. FUTURE TRENDS REGARDING APPLICATION OF NANO FLUID IN PHP

Researchers in future may focus on the following issues so that a complete idea on the application of nano fluid in PHPs can be obtained.

1. The comparison between CLPHPs and OLPHPs can be made to understand the nature and also one can choose the efficient PHP between the two to obtain the higher efficiency.
2. The study of PHPs with nano fluid as working fluid must be analyzed theoretical and numerically and must be compared with the existing experimental results for better understanding.
3. Geometrical parameters such as the number of loops, ID and CS of the tube (Internal Diameter, Cross Section), and various other parameters must be investigated as it also affect the performance and is important.
4. Insertion of wicked structures must be investigated in future as it is found to be efficient.

5. Other parameters such as phase change property, oscillatory flow of nano fluids should also be studied in the future.

VI. CONCLUSION

PHPs when nano fluid is made as working fluid seem to perform well and can be used in future in various fields. In this paper, the future trends have been mentioned along with the various parameters that directly affect the thermal related performance of the nano fluid which in turn affects the PHP efficacy. More works which provides detailed investigation regarding the optimum weight or volume concentration of nano fluid to be used, charging or filling ratio of nano fluids and various other aspects must be done in future.

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