Experimental Measurement of Alumina Based Nanofluid Heat Transfer and its Application

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Abstract. The paper reveals the experimental measurements of heat transfer performance of multi loops Oscillating Heat Pipe (MLOHP). Aqueous alumina (Al₂O₃) and a combination of Al₂O₃ with multi-walled carbon nanotubes (MWCNTs) particles were charged individually into OHP. Experimental results showed that thermal characteristics are significantly inter-related with pressure distribution and strongly depend upon the number of pressure fluctuations inside oscillating heat pipe (OHP) per unit time. Also the Alumina nanofluid was used in general heat exchanger with shell and tube type with various temperature range.

Introduction

The uses of nanofluids are placed in most of the high efficient heat transfer devices since the innovation of this new heat transfer fluid by Choi [1]. Lately many experiments have been studied in the field of OHP because of its specific features. Extended investigations of OHP have been investigated since the first OHP developed by Akachi in 1990 [2]. Comparing OHP with other conventional heat transfer pipes, the unique feature of OHPs is that there is no wick structure to return the condensate to the evaporator and therefore there is no countercurrent flow between the liquid and the vapor flows because both operates in the same direction [3]. Khandekar et al. [4], Rittidech et al. [5] and Tong et al. [6] had discussed the effects of many parameters on thermal performance, such as internal diameter, number of turns, working fluid and inclination angle of the device. Wang and Nishio [7] investigated the effect of length ratio of heating section to cooling section on the ultimate heat transport capability of OHP. Besides the input heat is also a strong parameter that affects dynamic instability especially in density wave oscillation [8, 9].

Gi et al. [10] conducted flow visualization for closed-loop PHP made from Teflon tube of 2 mm internal diameter and partially filled with the refrigerant of R142b.

The article concentrates on optimizing operational angle of OHPs investigation pressure characteristics inside the oscillating heat pipe charged with aqueous Al₂O₃ and combined Al₂O₃/MWCNTs working fluids. The present work reports few significant new findings in optimization of angular orientation with the explanation of the inside phenomena of OHPs in terms of pressure.

Experimental Setup

Experimental Apparatus and Procedure

The installation of multi loop OHPs shown in Figure 1 consists of an evaporating section powered by plate type heater and a condensing section connected with a constant cooling bath where the middle
section between evaporator and condenser is thermally insulated. The heat pipe is made by copper with inner diameter of 3 mm having the total length of 6 meter. Evaporative section is made by two aluminum plate grooved the inner part precisely to set OHPs like sandwich and both parts are perfectly attached with a flat plate type electric heater with the help of a thin layer of highly thermal conductive glue.

Data Treatment Reduction

The overall thermal resistance (R) has been calculated for constant wall temperature following the equation given below

\[ R = \frac{\bar{T}_c - \bar{T}_e}{Q} \]

where R is a dimensionless parameter and it expresses the thermal resistance and \( \bar{T}_c, \bar{T}_e, Q \) are average OHP wall temperature in evaporator, average OHP wall temperature in condenser and power input supplied to evaporative section respectively.

Result and Discussion

The heat input in the evaporator, filling ratio of working fluid as well as the shape, diameter, angle of installation have great influences on performance of OHP.
The all above mentioned parameters are interrelated with inside pressure fluctuation for the best performance of OHP. The Figure 2 ~ Figure 3 show that the pressure fluctuation and thermal resistance of the charged fluid between DI water and nanofluid.

![Graph](image)

**Figure 3.** Thermal resistance at different experimental orientation with different nanofluids at 60% filling ratio.

- a) Aqueous Al₂O₃, b) Aqueous Al₂O₃/MWCNTs combined working at different angular orientation

The following Figure 4 and Figure 5 show that the experimental set-up and heat exchanger performance with various Alumina nanofluid.

![Diagram](image)

**Figure 4.** Heat exchanger characteristics in shell & tube heat exchanger with Alumina nanofluid.

![Graph](image)

**Figure 5.** Basic heat exchanger performance test and heat transfer rate distribution with different alumina concentration.

### Summary

An experimental investigation is carried out to optimize tilting angle of OHPs measuring the thermal resistance and fluctuation of pressure inside oscillating heat pipe. In oscillating heat pipe heat transfer occurs because of repeated pressure fluctuation and the more repetition of pressure fluctuation means more heat transfer.
i) Lowest thermal resistance has been achieved by mixing a little fraction of MWCNTs to the aqueous Al$_2$O$_3$ Nanofluids. A little inclusion of MWCNTs into aqueous Al$_2$O$_3$ makes the fluid noble to transport heat efficiently. And this little change in characteristics by the mixture of non-uniform MWCNTs particles having higher thermal conductivity of working fluid contains more energy to form a vapor slugs into the fluid. 30º and 60º tilting angle performs better than any other orientation for all variations of working fluids.

ii) Higher frequency of pressure and mean pressure inside OHPs are achieved by combined Nanofluids at angular orientation of 30º and 60º in this experiment. Thermal characteristics are significantly inter-related with pressure distribution and strongly depend upon the number of pressure fluctuations with time.

iii) Nanofluids offer challenges related to production, properties, heat transfer, and applications. This report exhibit the high convective heat transfer compared to the base fluid, and the heat transfer rate of the micro tube heat exchanger can be increased by using small amount of Alumina particles.

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References