MANUFACTURING & PERFORMANCE ANALYSIS OF THERMOSYPHON HEAT PIPE CHARGED WITH Z NO FOR HEAT TRANSFER ENHANCEMENT

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ABSTRACT

This study presents the experimental performance of a thermosyphon heat pipe charged with the ethanol-methanol mixture. The objective of this work is to study the combined effect of coolant flow, tilt angle and thermal load on the thermal performance of the thermosyphon. Thermosyphon was manufactured using a 1000 mm long copper tube with inner and outer diameters of 24 mm and 26 mm respectively. The working fluid used in the thermosyphon is a binary mixture of ethanol and methanol. Experiments were carried out on the inclination angle 40° to 90°, the flow rate of the coolant 3.6 kg / h to 21.6 kg / h, the thermal load from 25 W to 200 W. The distribution diagrams thermal and thermosyphon heat transfer efficiency and measured. The results showed that the maximum heat transfer efficiency is 86.39%, which is greater than 3.6 kg / h of coolant with a tilt angle of 80° and a heat load of 190 W. The binary mixture has a better thermal conductivity of the pipe thermosyphon.

Index Terms —Thermosyphon Heat Pipe; Ethanol; Methanol, Nanofluids;

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1. INTRODUCTION

The waste heat is heat generated in the process by fuel combustion or chemical reaction and released into the environment, although it can be reused for useful and economic purposes [1,2,3]. The essence of heat is not quantity but rather its value. This heat recovery strategy is partly dependent on the temperature and economic aspects of the waste gases. Direct and indirect benefits are involved in heat recovery [4,5]. Remaining heat recovery has a direct impact on the efficiency of processes and the indirect benefits include pollution reduction, equipment size and excess air consumption.

2. HEAT PIPE HEAT EXCHANGERS

Heat exchanger heat exchangers have regular winding channels, but each consecutive pipe is independent and is not connected to other pipes. Each tube is made with internal capillary material. The tube is drained, filled with a compatible liquid according to the temperature range and closed separately. When the pipes are horizontal, half of the heat exchanger acts as an evaporator and the other side acts as a condenser [6]. The high-temperature airflow runs from the vapor generator side and the low-temperature air flow passing through the condenser side. High temperature air flow passes half of all pipes. When the operating fluid is reheated and vaporized in half of the evaporator, the internal vapor pressure gradient drives the gas into the condenser. At the end of the condenser, the liquid releases hidden vapor energy when sealing, whereby the air flow is heated at a low temperature. The liquid returns to the vaporizer end through the inner recess [7,8].

Figure1: Heat pipe heat exchanger

3. HEAT TRANSPORT IN NANOFLUIDS

A. Models for Thermal Conductivity of Nanofluids

Following models have been proposed by various researchers, which give the explanation for enhancement in thermal conductivity of nanofluid [9].

- Brownian motion of the particles
- Interfacial layering of liquid molecules.

B. Thermo Physical Properties of Nanofluid

Property	Water	Ethylene Glycol	Cu	Al ₂ O ₃	CuO	TiO ₂
C(J/kg K)	4179	2415	385	765	535.6	686.2
ρ (kg/m ³)	997.1	1111	8933	3970	6500	4250
λ L(W/m K)	0.605	0.252	400	40	20	8.95338
α (m ² /s)	1.47	93	1163	1317	57.45	30.7

Table1. Thermo physical Properties of Nanoparticles.

4. WORKING OF HEAT PIPE

Figure 3: Working of Heat Pipe

The heat pipe is excellent in thermal conductivity; the other end of the heat pipe is the evaporation part and the other end of the condensation section. When the vaporizer is heated, the heat pump fluid evaporates quickly. This vapor releases its heat to the condenser with a small vapor pressure

difference and condenses back into the liquid. The condensed liquid in the condensation part then flows back to the vaporizing section along the inner wall of the heat pipe and ends up in the endothermic evaporation in the evaporation part. The heat transfer of the heat pipe uses a working fluid that changes the steps in a continuous endothermic and exothermic cycle, whereby the heat pipe is excellent heat transfer.

5. DEVELOPMENT OF TEST SETUP

Heat exchangers are devices that made the energy exchange (waste heat) from the waste heat source to the colder source. Figure 4 is a schematic diagram of an experimental system. The system consists of three main parts: air heater (for boiler production), heat pipe heat exchanger and parameter measuring and control equipment. The installation has two recyclable liquids: hot substance (waste water) in the lower chamber of the heat exchanger and refrigerant in the upper heat exchanger (cold air).

Figure 4: Schematic diagram of the experimental setup.

The heat pipe heat exchanger was equipped with eight heat pipes arranged vertically at an angle of 90° (Figure 4). The working fluid used in heat pipe is ZnO/H₂O nanofluid.

6. TEST PARAMETERS

Experimentation was carried on the TPCT HRHX. Working fluid is important parameter in the experimentation. BN/H₂O nanofluid was used as a working fluid, other parameters and its description as follows.

Parameter	Description
Heat load (W)	250 W to 1500 W
Source temperature	25 to 65 0C
Mass flow rate (m)	0.0512 to 0.2749 kg/s
Discharge of Blower	100 to 500 cfm
Velocity	1.04 to 5.24 m/s

Table 2.Test parameters

7. CALCULATIONS

A. Heat Load Calculation

While designing the heat pipe heat exchanger, we have to calculate the total heat load for proposed heat pipe heat exchanger. Assuming maximum inlet hot air temperature 60°C and corresponding ambient temperature 25°C with maximum mass flow rate of air as 0.2361 kg/sec. The heat load on heat exchanger can be calculated as follows,

$$\text{Heat Load (Q)} = m \cdot C_p \cdot \Delta T$$

Heat Load on Single Heat Pipe (Q_{Heat Pipe})

$$= \frac{\text{Total Heat Load On Heat Exchanger}}{\text{No.of Heat Pipe}}$$

B. Heat Pipe Limit Calculation

Heat pipes undergo various heat transfer limitations depending on the working fluid, the dimensions of the heat pipe, and the heat pipe operational temperature.

1. Viscous limitation

Viscous limit depends on the viscous pressure losses in vapor phase and the vapor pressure of the working fluid

$$Q_{vp} = \frac{\pi \cdot r_v^4 \cdot h_{fg} \cdot \rho_{v,e} \cdot P_{v,e}}{12 \cdot \mu_{v,e} \cdot l_{eff}}$$

2. Sonic limitation

The sonic limit is due to the fact that at low vapor densities, the corresponding mass flow rate in the heat pipe may result in very high vapor velocities, and the occurrence of choked flow in the vapor passage may be possible.

$$Q_s = 0.474 A_v \cdot h_{fg} \cdot (\rho_v \cdot P_v)^{0.5}$$

3. Entrainment limitation

The entrainment limit refers to the case of high shear forces developed as the vapor passes in the counter flow direction over the liquid saturated wick, where the liquid may be entrained by the vapor and returned to the condenser. This results in insufficient liquid flow of the wick structure.

$$Q_e = A_v \cdot h_{fg} \cdot \left(\frac{\rho_v \cdot \delta_1}{2 \cdot r_{c,ave}} \right)^{0.5}$$

4. Boiling limitation

The boiling limit occurs when the applied evaporator heat flux is sufficient to cause nucleate boiling in the evaporator wick. This creates vapor bubbles that partially block the liquid return and can lead to evaporator wick dry out. The boiling limit is sometimes referred to as the heat flux limit.

$$Q_b = \frac{4\pi \cdot l_{eff} \cdot \gamma_{ef} \cdot T_v \sigma_v}{h_{fg} \cdot \rho_v \cdot \ln \frac{r_i}{r_e}} \left(\frac{1}{r_n} - \frac{1}{r_{c,e}} \right)$$

8. CONCLUSION

We studied the working principle of the heat pipe. And replace the working fluid by nanofluid ZnO/H₂O.

- The performance of heat pipe heat exchanger charged with ZnO/H₂O nanofluid increases with increase in source temperature.
- The results obtained for TPCT heat exchanger charged ZnO/H₂O nanofluid are superior with that of TPCT charged with conventional fluid
- Enhancement in effectiveness of heat exchanger for current study is about 35% compared with the available literature.

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