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Recovery Using Heat Pipe Heat Exchanger with Hybrid Nanofluid

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ABSTRACT

Research has been carried out on the theory, design & construction of waste heat recovery using heat pipe heat exchanger with hybrid nanofluid, especially their use in waste heat recovery for energy recovery, reduction of air pollution & environmental conservation. In this research, the characteristic design & heat transfer limitation of single heat pipe without wick & working with hybrid nanofluids have been investigated. There has been increasing interest in nanofluid & its use in heat transfer enhancement. A significant amount of waste heat exhausted through the exhaust ducts of commercials & industrials exhausts, capturing the energy in that waste heat represents rich potentials for energy savings. The heat pipe heat exchanger heat recovery system is cost effective to install and operate could potentially recover wasted heat economically and be an effective addition to utility CIPs. The limiting factor against increasing the heat transfer performance of heat pipe depends on the properties of the working fluid. The enhancement of liquid thermal conductivity is achieved by adding highly conductive solid nanoparticles within the base fluid. The special characteristics of the nanofluid substantially increase the heat transfer coefficient, thermal conductivity and liquid viscosity. Two types of nanoparticles added in base fluid are aluminum oxide and copper oxide.

***Keywords*— Waste heat Recovery, Heat Pipe Heat Exchanger, Hybrid Nanofluid, Thermosyphon.**

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I. INTRODUCTION

With increasing trend of energy demand, there are a lot of concerns over energy supply and it is a major issue for the policy makers. Globally, buildings consume about 40% of the total world annual energy consumption and most of this energy is used for the purpose of heating, ventilation & air conditioning (HVAC) system. Therefore, Engineers and researches try to find new energy recovery technologies to enhance the performance in terms of air quality and energy consumption level. Furthermore, increasing awareness of the environmental impact of CFC refrigerants, make the engineers to implement environmentally friendly energy recovery technologies. Most of heat is wasted in many of the outputs like industrial, automobiles etc. There are many types of energy recovery system, but most commonly used are rotating wheels, plates, heat pipes & run around loops. This experiment considers the thermal design & the experimental testing of a heat pipe (thermosyphon) heat exchanger for a relatively small commercially available waste heat. The purpose of the heat exchanger is to recover maximum heat from moist waste air stream to preheat the fresh incoming air. A significant amount of waste heat exhausted through the exhaust ducts of commercials & industrials exhausts. Capturing the energy in that waste heat represents rich potentials for energy savings. The heat pipe heat exchanger heat recovery system is cost effective to install and operate could potentially recover wasted heat economically and be an effective addition to utility CIPs. This pilot project was undertaken to design, develop, install and measure the effectiveness of a heat recovery system at a small temperature range. The design concept was to capture waste heat from exhaust duct and use that heat for the fresh air supply. The limiting factor against increasing the heat transfer performance of heat pipe depends on the properties of the working fluid. The enhancement of liquid thermal conductivity is achieved by adding highly conductive solid nanoparticles within the base fluid. The special characteristics of the nanofluid substantially increase the heat transfer coefficient, thermal conductivity and liquid viscosity. Two types of nanoparticles used in heat pipes are aluminum oxide and copper oxide.

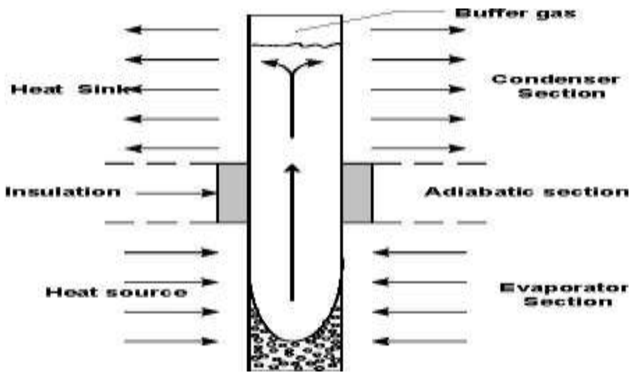


Fig. 1 The construction & the principle of operation for Thermosyphon [5]

II. LITERATURE SURVEY

In energy recovery ventilation, the technology that recovers the waste energy is studied. Application of air-to-air energy recovery equipment continues to grow in acceptance and use in HVAC systems.

In Research & Energy saving Potential for ventilation system suggests decoupling dehumidification from cooling to reduce energy consumption. The feasible usage and the energy saving potential of heat pipe heat exchanger at the air handler dedicated in accomplishing this objective is investigated.

A case study on energy savings in air conditioning system by heat recovery using heat pipe heat exchanger shows that, In air conditioning facilities with high outside air requirements such as clean room air conditioning systems, considerable energy savings is possible by heat recovery using heat pipe heat exchanger (HPHX).

In Heat Pipes for Steam Condensation, paper explores the feasibility of using the heat pipe for steam condensation. In this paper an attempt is made to replace thousands of condenser tubes by hundreds of “Heat Pipes”.Heat Transfer Characteristics Study on Water – To – Water Heat Pipe Heat Exchanger using Effectiveness – NTU Method presents the heat transfer characteristics of a water-to-water heat-pipe heat exchanger (W-W HPHE) experimentally.

A nanofluid is a mixture of nano sized particles of size up to 100 nm and a base fluid. Typical nanoparticles are made of metals, oxides or carbides, while base fluids may be water, ethylene glycol or oil.

A Nanoparticles application is studied in enhancing thermal conductivity of fluids with nanoparticles. Low thermal conductivity is a primary limitation in the development of energy-efficient heat transfer fluids that are required in many industrial applications.

Nanofluids (NFs) are nanotechnology-based colloidal dispersion prepared by dispersing nanoparticles (NPs) in conventional liquids, as the base liquid.

Heat Transfer Enhancement Using Nano Fluids- An Overview has been increasing interest in nanofluid and its use in heat transfer enhancement. Nanofluids are suspensions of nanoparticles in fluids that show significant enhancement of their properties at modest nanoparticle concentrations.

Woo-Sung HAN and Seok-Ho RHI studied the specially designed grooved heat pipe charged with nanofluids was investigated in terms of various parameters

III. DESIGN & EXPERIMENTAL SETUP

As described earlier proposed work aims to investigate the experimental performance of heat pipe heat exchanger charged with (CuO+Al2O3)/$H_2$0 Hybrid Nanofluid under variable source temperatures and mass flow rate. With broad perspective this study aims to investigate the feasibility of TPCT HPHX from low temperature waste heat source. In order to achieve the objectives stated above it has been decided to design and develop the experimental system as shown in following figure 3.1. Heat pipe heat exchangers are devices that made the exchange of energy (waste heat) from a waste heat source to a colder source. Fig. 3.1 shows the schematic diagram of the experimental system. The system is composed of three major parts: air heater (for waste hot air preparation), heat pipe heat exchanger (with hybrid nanofluid) and devices for measurement and control of parameters. In the installation there are two circulating fluids: the hot agent (waste air) in the lower chamber of the heat exchanger and the cold agent (cold air) in the upper chamber of the heat exchanger. The heat pipe heat exchanger was equipped with ten heat pipes arranged vertically at an angle of 90 ° (Fig. 2). The working fluid used in heat pipe is hybrid (CuO & Al2O3) nanofluid.

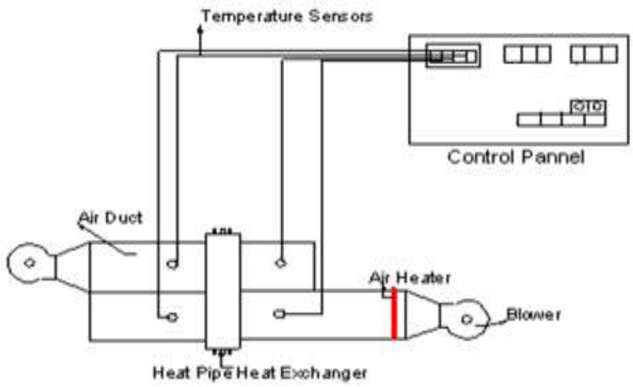


Fig. 2 Schematic diagram of the experimental set up [7]

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 ^{0}C and corresponding ambient temperature 25^{0}C with maximum mass flow rate of air as 0.05762 kg/sec. The heat load on heat exchanger can be calculated as follows,

Heat Load (Q) = m.C_p.ΔT

= 0.05762 * 1.005 * 35

= 2.02 kW.

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

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

$$= \frac{2.02}{10}$$

= 0.202 kW

B. Design Procedure for Proposed Heat Pipe

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. The viscous limit is sometimes called the vapor pressure limit,

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

Calculated viscous limit for selected heat pipe parameters under operating temperature are shown in figure 3.

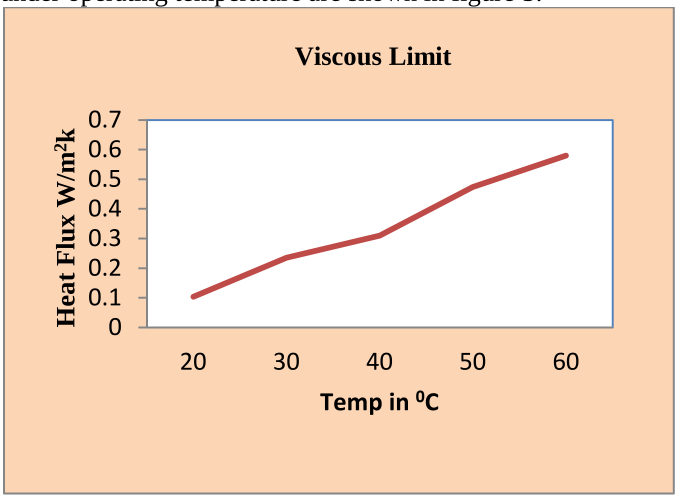


Fig. 3 Heat pipes Viscous Limits for various operating temperatures

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.

$$Qs = 0.474 A_v . h_{fg} . (\rho_v . P_v)^{0,5}$$

Calculate sonic limit for proposed heat pipe are shown in figure 4,

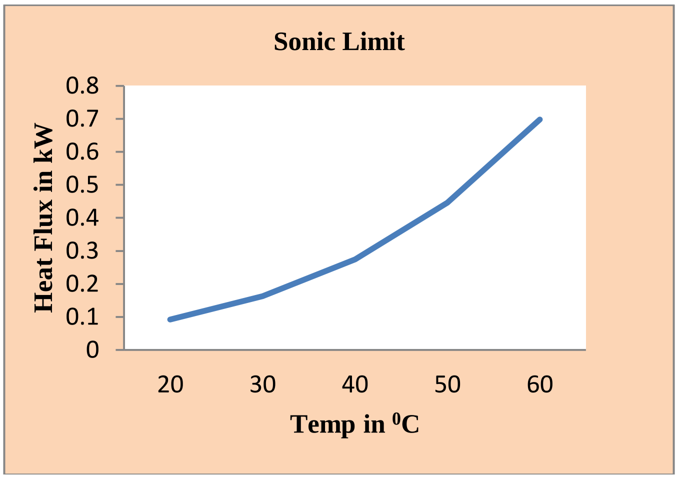


Fig. 4 Heat pipes Sonic Limit for various operating temperatures

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.

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

Entrainment limit is calculated using above equation and results are plotted on graph which is shown in figure 5,

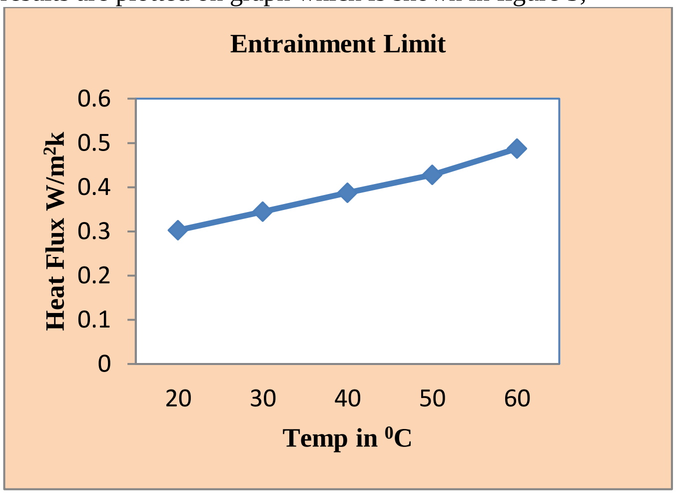


Fig. 5 Heat pipes Entrainment Limit for various operating temperatures

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.

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

Boiling limit is calculated using above equation and results are plotted on graph which is shown in figure 6.

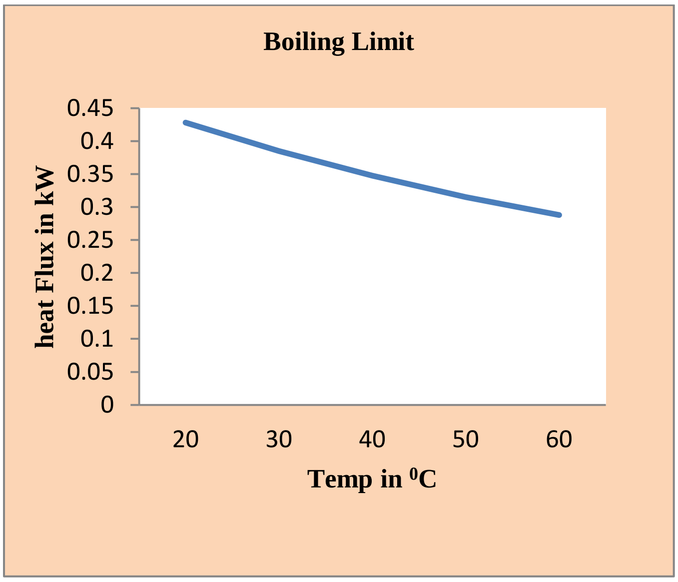


Fig.6 Heat pipes Boiling Limit for various operating temperatures

5) *Various heat pipe limits-*

The various heat pipe limits calculated considering the operating temperature and parameters related to heat pipe are shown in figure 7. For heat pipe parameters mentioned above the axial heat flux under variable operating temperatures are calculated for different mentioned above i.e. viscous limit, boiling limit, entrainment limit and sonic limit.

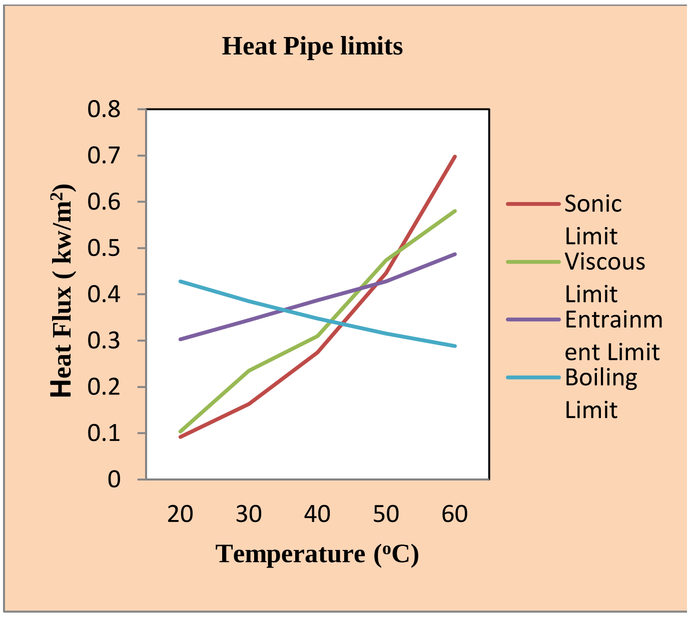


Fig. 7 Heat pipes Limits for various operating temperatures

TABLE I

The various limits for heat pipe

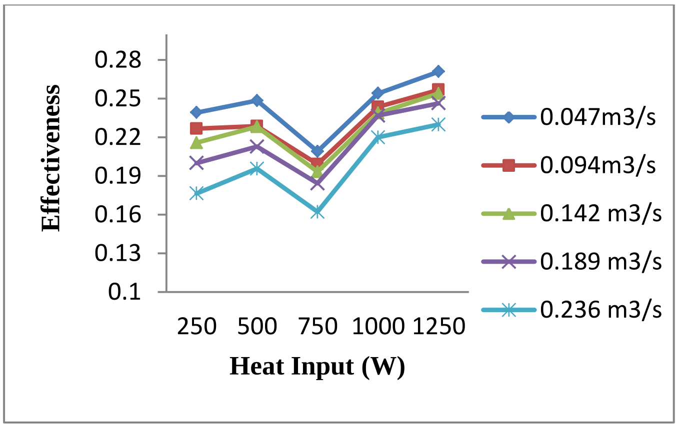
Temp ° C	Sonic Limit (kW)	Viscous limit (kW)	Entrainment Limit (kW)	Boiling Limit (kW)
20	0.21201	0.20357	0.30247981	0.42804
30	0.26274	0.23483	0.34451077	0.384978
40	0.37467	0.30973	0.38709841	0.347509
50	0.44576	0.47349	0.42776495	0.31518
60	0.69752	0.58002	0.48703859	0.287965

IV. RESULT & DISCUSSION

The variation of effectiveness of heat exchanger with heat input i.e. source temperature and mass flow rate of air streams are represented graphically.

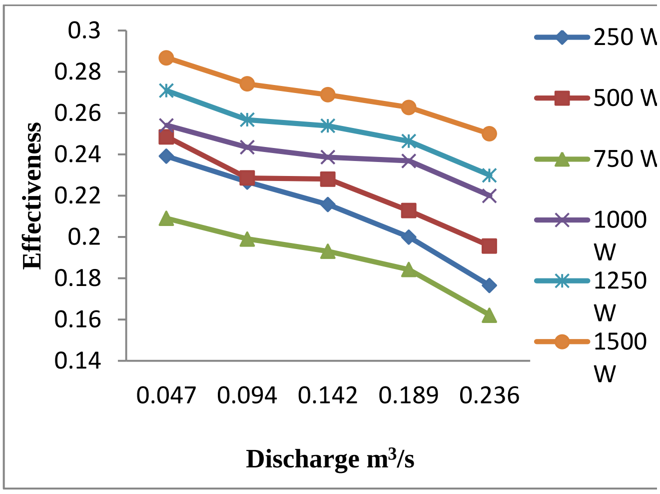
a. Effect of Heat Input on Effectiveness of TPCT Heat Exchanger

The effect of heat input on the performance of TPCT heat exchanger is studied by varying the heat input from 250 W to 1250 W and maintaining the flow rate of air stream from 0.047 m^3/s to 0.236 m^3/s. The effectiveness of heat exchanger was calculated under conditions mentioned above and results are as shown graphically below,



b. Effect of Air Stream Flow Rate on Effectiveness of TPCT Heat Exchanger

Figure shows the variation in effectiveness with air stream flow rate under different heat input. It has been observed that effectiveness of heat exchanger decreases with increase in air stream flow rate of hot side and cold side as shown graphically below,



V. CONCLUSION

The performance of heat pipe heat exchanger charged with (CuO+Al2O3)/H_20 hybrid nanofluid increases with increase in source temperature.

Maximum effectiveness observed for proposed heat pipe heat exchanger is up to 0.25.

The results obtained for TPCT heat exchanger charged (CuO+Al2O3)/H_20 hybrid nanofluid are superior with that of TPCT charged with conventional fluid

Improvement in effectiveness of heat pipe heat exchanger charged with hybrid nanofluid is due to thermal conductivity enhancement of nanofluid.

TPCT heat recovery heat pipe heat exchanger can be suitably employed for heat recovery from low source temperature.

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