Thermal Performance of Curtain Wall Solar System Using Nanofluid

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Abstract- *A wall-integrated solar heating system refers to an architectural design approach that combines hot water generation with the building's construction system. This combination allows this system to feature a hot water generation function and become part of the building façade. Environmental control devices and/or designs in buildings that are capable of harvesting solar thermal energy can effectively capture and store this solar energy and provide energy through the use of, for instance, a hot water system or a low-power thermoelectric material. These systems used in buildings can be easily divided into three types: sensible, latent, and thermo chemical energy storage (TCES).In this study, we have attempt to combine the curtain wall structures, building construction practices, heat transfer mechanisms, and a natural circulation loop designed to develop an innovative, wall-integrated solar heater using CuO + water nanofluid on the concept of an Energy harvesting facade. This work accomplished by performing an experimental investigation using two different types working fluid, water and CuO + water nanofluid with1%, 2%, 3% of volume fraction of nano powder. For this combination of working fluid the efficiency of system is found, 42.48%, 48.26%, 55.58% and 66.63% respectively.*

Keywords- solar heating, heat transfer, copper nano particles,etc

I. INTRODUCTION

In a conventional solar collector, tubes containing water as working fluid are attached to the absorber plate. The solar energy is absorbed by the working fluid and transferred to the storage tank either by natural or forced circulation. The drawbacks associated with conventional solar collectors include the pump and its power requirement, more space to obtain the natural circulation of working fluid, night cooling due to reverse flow of cooled water, pipe corrosion and limited heat carrying capacity of working fluid. The experiments were conducted for different filling ratios of 30, 50 and 80% by evaporator length and aspect ratios of 5, 10, and 20 in vertical position. Pure water and de-ionized water mixed with silver nano fluid were used as working fluids and compared. The working temperatures were 40, 50 and 60°C. It was found that, the maximum heat transfer rate of 750.81 W, was achieved for aspect ratio of 20 (internal diameter of 25.4 mm) and working temperature of 60°C. The heat transfer rate for DI water mixed silver nano fluids is approximately 70% high when compared with pure water.

II. LITRETURE REVIEW

Chi-minget. al. [3] concluded that the wall temperature of the insulated section between the exit of the heated section and the entrance of the cooling section is affected by the low temperature of the cooling section as a result of axial heat conduction in the duct.

Mathioulakiset. al. [6] reported the results obtained through both theoretical simulation and experimental investigation of a solar collector with heat pipes. They have used ethanol as working fluid and obtained the maximum instantaneous efficiency up to 60%.

Huminicet al.[9]studied the effects of two phase closed thermo syphon for various inclination angles, operating temperature and nanoparticles concentration levels on the heat transfer characteristics of two phase closed thermo syphon.

Enaburekhanet. Al.[8] reported that the maximum collection efficiencies of solar collector throughout the day were found to be 50.84%, 49.43% and 48.72% for R410A, R407C and R-134a, respectively. The thermal performance of solar collector by using various refrigerants such as: R-134a, R12, and ethanol. The heat pipe that utilizes R-134a as working fluid exhibits maximum collection efficiency compared to other working fluids. Since thermosyphon utilizes phase change of the working fluid to transfer heat, selection of a working fluid is essential to achieve the maximum heat transfer capacity.

Hokai et.al.[7] concluded that the heat transfer performance of an innovative, wall-integrated solar heater was investigated experimentally. Under isothermal boundary conditions for the heat sink, it was determined that the exterior wall surface temperature of the proposed test cell increases with increases in the solar heating power, which causes steeper slopes in the temperature variations. The wall temperature of the insulated section between the exit of the heated section and the entrance of the cooling section is affected by the low temperature of the cooling section as a result of axial heat conduction in the duct.

Rong-Horng et.al.[3] concluded that an increase in the heating power or aspect ratio or a decrease in the length of the cooling section resulted in an increase in the average fluid velocity. The wall temperature at the end of the heating section was the highest temperature observed in the loop. Due to the axial heat conduction along the wall, this was caused by the cooling end temperature, the wall temperature of the section following the adiabatic section decreases slightly. At the exit of the cooling section, due to the axial wall heat conduction, the wall temperature of the following adiabatic section increases slightly.

Singh et.al.[10] stated most systems/processes whose performance is affected by heat generation could benefit from Nano fluid coolants. Nano fluids have great potential for thermal management and control involved in a variety of applications such as electronic cooling, micro electro mechanical systems and spacecraft thermal management. The miniaturization of mechanical and electrical components creates a need for heat transfer fluids with improved thermal characteristics over those of conventional coolants. The significant growth in performance and functionality of microelectronics combined with a miniaturization trend in MEMS has resulted in an unprecedented increase in heat loads that presents a great challenge to thermal engineers.

Chougule et.al.[5]experimentally studied that the thermal performance of solar heat pipe collector is higher by using water/2-ethyl-hexanol followed by CNT/water nano fluid, water as a working fluid for the heat pipe solar heat pipe collector that uses nanofluid as working fluid provides better performance at higher tilt angles. The collector will provide improvement in the thermal performance by locating solar heat pipe collector at the place where the angle of getting maximum total solar radiation matches with higher performance tilt angle of solar heat pipe collector The heat transfer rate is found to increase by increasing the tilt angle from 200 to 500 for both cases, namely, pure water and water/2-ethyl-hexanol.

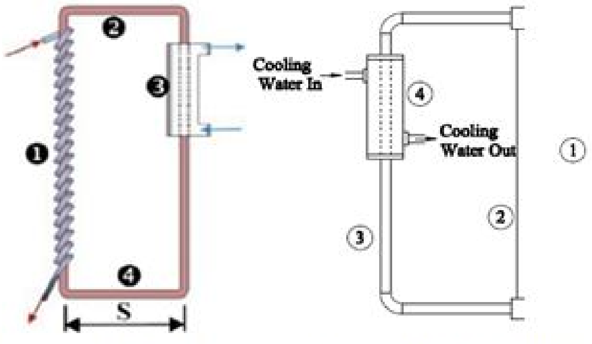
Shanthi et.al.[9] experimentally studied that the decrease in fill ratio increases the evaporator temperature due to reduction in contact surface between the working fluid and heat transfer surface where heat transfer coefficient is high. The lower efficiency in the case of higher fill ratio shows that the rate of condensation is lower when the fill ratio is higher. This could be due to the heat transfer mechanism in the condenser section that changes from film condensation to a two phase mixture convection which causes the decrease of thermosyphon performance. However at higher heat flux, there is no difference in efficiency with respect to fill ratio. This is due to the higher heat flux which decreases the fluid level in the evaporator section which reduces the evaporator performance particularly at lower fill ratio. Hence the advantage received in the condenser section at lower fill ratio is compensated by the reduction in performance in the evaporator section due to more dry out at lower fill ratio.

Santos et.al.[11]presents a methodology based on experimental tests and on a mathematical modeling for developing thermosyphons that could be applied in thermosyphon solar compact collectors. The methodology here presented is focused on only one thermosyphon, but it can be extended to a set of thermosyphons. The mathematical modeling was based on operating limits of thermosyphons. The geometric parameters of thermosyphon analyzed were: outer diameter of thermosyphon, lengths of the evaporator and condenser. With length of evaporator smaller than 17.5 cm, the thermosyphon can be failed due to the boiling limit achievement. The sonic limit, drag limit and viscous limit are not critical in the developing this type of thermosyphon. Based on the theoretical results obtained with the mathematical model, a thermosyphon was manufactured of copper and using water as working fluid and with evaporator length of 16 mm. Experimental tests were runned out for increasing heat load (from 40 up to 80 W) at a slope of 90o with the condenser above the evaporator. Therefore, it could be conclude that this model could predict the theoretical limit for success operation of the thermosyphon, showing that the mathematical model should be used in the design of kind of thermosyphon.

Arekete et.al.[4] studied that solar water heater was designed, constructed and tested in Akure, Nigeria. Hourly readings of the ambient, inlet and outlet temperatures and radiation intensity were recorded between 9.00 hrs and 16.00 hrs. Between the hours of 12.00 and 4.00 pm, hot water temperatures of above 50^{o}C were achieved. The maximum hot water temperature recorded was 73^{o}C and the mean peak hot water temperature was 70^{o}C. Collector’s mean hourly efficiency rose slight until 2.00 pm after which a sharp rise was obtained. The performance of solar water heater in Akure, South West, and Nigeria shows that solar water heating is technically feasible in Nigeria and most parts of tropical Africa since insolation is similar in these regions. Since most of the hot water requirements in our society are largely below 60^{o}C, we have established in this paper that most of these needs can be met through solar water heating.

III. EXPERIMENTATION

A) Experimental Setup



Prototype developed by researcher Proposed develop protototype

Fig No. 1

The experimental test cell consisted of an exterior wall plate (1), a vertical flow duct with a square cross section (2), a circulation loop (3), and a cooling sleeve (4). The exterior wall (1) width was 40 cm and the height was 80 cm, which is a commonly used curtain wall height. On one side of the wall, incident solar radiation used to heat the wall surface, simulating the solar radiation received by the exterior wall plate ,on the other side (inside the curtain wall), the vertical flow duct measured 30 mm wide by 20 mm high and can be welded specifically to form a heat exchanger.

B) Design Of Setup

The proposed work concentrates on design, development and performance evaluation of curtain wall integrated solar heater prototype using nanofluid as absorbing medium consists of the following components and measuring instruments.

i) Nano fluid preparation
ii) Circulation tubes
iii) Cooling sleeve insulating over cooling sleeve
iv) Temperature sensors and indicator
v) Pyranometer
vi) Calibrated measuring flasks/Rotameter
vii) Flow Control valve

C) Nanofluid Preparation

The selected nanopowder for the proposed study is CuO+ Graphene (5 ml)/H_20 nanofluid 50nm size with water as base fluid. This selection of nanoparticle material is done on the basis of enhancement of thermal conductivity obtained with addition of nanoparticle material. As the thermal conductivity of CuO is high hence it is expected that addition of nanoparticle material with higher thermal conductivity leads to enhancement in thermal conductivity and higher heat transfer coefficient .Purposely the addition of graphene is to be added in the nanofluid in small quantity because graphene is having very high thermal conductivity and it can give high rise in thermal conductivity compared to addition of CuO nanoparticle.The amount of nanopowder required for the same can be calculated as below.

The total volume of nanofluid to be prepared:-

Vnf =Volume of circulating pipes x No. of loops

The amount of nanopowder required is calculated by,

Vol. fraction of nanofluid (%) = Vol. of Nanoparticle/Vol. of Nanofluid but, Vol. of nanoparticle = Mass of nanoparticle / Density of nanoparticle

Hence Volume fraction of nanofluid is =

$$\frac{\text{(Mass of nanoparticle/Density of nanoparticle)}}{\text{Volume of nanofluid}}$$

Thus for given volume fraction of nanofluid and decided amount of nanofluid to be prepared the mass of nanoparticle to be added in the base fluid can be calculated. As the quantity of required for the same for volume fraction basis is large and considering the cost of same it will be later decided the weather to conduct the experiment with preparation of nanofluid on volume basis or weight basis.

Nanofluids Thermal and Flow Properties:

The thermal and flow properties of nanofluid are calculated using different available correlations as below:
Thermal conductivity using Timofeeva correlations as below:

$$K_{nf} = [1 + 3\phi]K_w \quad (1)$$

Viscosity of nanofluid using Drew and Passman correlations as below:

$$\mu_{nf} = [1 + 2.5\phi]\mu_w \quad (2)$$

The density and specific heat using Pak and Cho correlations as below

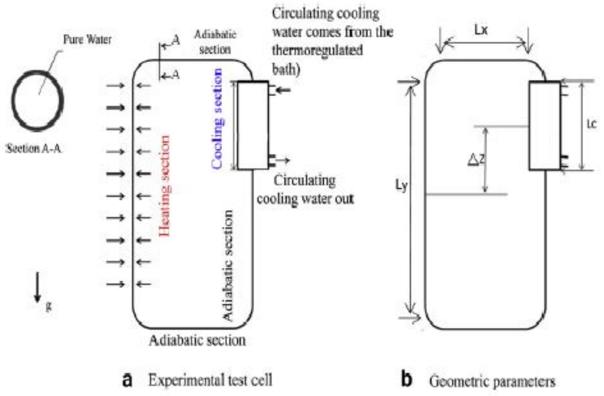
$$\rho_{nf} = \phi\rho_{np} + (1-\phi)\rho_w \quad (3)$$

$$Cp_{nf} = \phi Cp_{np} + (1-\phi)Cp_w \quad (4)$$

D) Circulation Tubes

The circulation tubes were also used as structural support for the curtain wall; therefore, the tube material used in this study is copper. The joints between the circulation tube and square duct were constructed with filet material, and the tubes were shaped to maintain a constant cross-sectional area throughout the circulation loop. The outer radius of the tube was 12.7 mm. The inner radius was 11 mm, and the wall thickness was 1.7 mm. To align the loop with the exterior wall, we fixed the horizontal distance S to be approximately 200 mm to match the typical wall thickness. Therefore, the overall exterior size of the test cell was 40 cm wide, 20 cm deep, and 80 cm high, which matches the dimensions of typical metal curtain walls. In addition, valves were installed at the top and bottom of the loop to allow for the removal and addition of fluid .The cooling section (4) is opposite the heated section.

IV. EQUIPMENT WORKING



a Experimental test cell **b** Geometric parameters

Fig.No.2

Copper tubes (85% Cu, 9% Sn, 6% Zn) were fabricated and assembled to construct the rectangular loop, and the flow cross sectional areas were the same in the entire loop. The copper tubes used had an outer diameter of 12.7 mm and an inner diameter (Di) of 11 mm. To conform to the exterior wall construction practices, the two upper and lower adiabatic section lengths in the experimental models were both fixed at 200 mm (Lx) to coincide with the common household wall thickness in Taiwan. Distilled water was used as the working fluid. Furthermore, the length of the heating section (Ly) in this experimental model was also changed to reasonably match the scale of the exterior wall structure and to explore the geometric parameters that affected the heat transfer capability, the geometric parameters in this study could be divided into 4 aspect ratio groups and 10 potential difference groups.

Heatingsections

The loop is heated uniformly by a constant heat flux over the left vertical leg (heating section) using an electric heating wire and a DC power supply. The heating sections are 40, 70, 90, and 120 cm. To heat uniformly, the heating section was equipped with an electric heating wire, mica paper and insulation materials. The experimental rectangular loop uses copper as the primary material because of its high thermal and electrical conductivity. To wrap the electric heating wire around the heating section, the copper tube must first be electrically insulated. The soft mica paper, which has proper insulation and can be heated to 500^0C to 550^0C, was used by wrapping it around the heating section. A 2.5 m electric heating wire with a diameter of 0.25 mm and a resistivity of 25.8 Ω/m was used.

Cooling Section

The cooling system mimicked the isothermal boundary at the cooling section and was composed of a cooling sleeve with an outer diameter of 61 mm, an inner diameter of 40 mm and a cooling water flow length of 300mm, 600mm, and 900 mm. Both ends of the water sleeve came with caps that have 11 mm diameter holes for the loop tube to pass through. O-rings were used to keep the tubes watertight. Additionally, rubber gaskets were inserted between the cooling water sleeve and the caps to keep the system watertight.

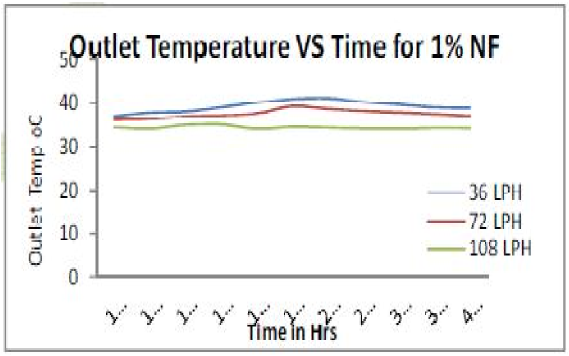


Fig. No. 3 Hourly variation at Output Temperature for 1% nanofluid

V. CONCLUSION

- The efficiency thermal performance of solar collector will increase by using 3% nano fluid followed by pure water.
- The outlet temperature will be increase low mass flow rate for both fluid as pure water and nano fluid.
- For same working fluid efficiency slightly increases as mass flow rate increases.
- An increase in the heating power or aspect ratio or a decrease in the length of the cooling section resulted in an increase in the average fluid velocity.

- The wall temperature at the end of the heating section is the highest temperature observes in the loop due to the axial heat conduction along the wall.

VI. FUTURE SCOPE

- Thermal performance of wall curtain solar water heater will be increase by using different nanofluid i.e. Carbon multi-wall nano tubes, Carbon nano tubes, CuO, Titanium etc.
- The intelligent use of an integrated approach makes for more functional. Attractive and energy efficient spaces.
- Adding to a buildings value though renovation is an increasingly important factor in a building's design in the future.

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