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Experimental Analysis of Flat Plate Solar Water Heater using Cerium Oxide / Water Nano Fluid Under Forced Convection

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***Abstract*:- Flat plate solar water heater is commonly used for heating of water in low-temperature residential applications. In this study, Cerium Oxide/water (CeO_2/H_2O) nanofluid is prepared and its thermal performance was investigated experimentally on a 100 Liters per Day (LPD) forced type flat plate solar water heater. The volumetric fraction of 0.01% of CeO_2/water nanofluid was taken. The CeO_2/water nanofluid was prepared with the inclusion of surfactant polyvinyl pyrolidine (PVP), as it provided the best CeO_2 nanoparticle dispersion stability compared to pure water suspension. The experiment was taken on various mass flow rates for the efficient heat transfer. Significant improvement in performance was observed in forced circulation compared to conventional mode, for the low volumetric fraction considered.**

Keywords: Flat plate, solar water heater, CeO_2 nanoparticle.

I. INTRODUCTION

1.1. SOLAR RESOURCES

Enormous amount of energy from the sun falls on the earth's surface. The primary concern here is radiation in wavelength range between 0.3 to 3.0 µm, that portion of the spectrum which includes most of the energy of solar radiation. The average produced over the entire surface of the planet, twenty-four (24) hours per day in a year is approximately 4.2kW/h of energy depending on the earth's location. All the energy stored in the earth's reserve of coal, oil, and natural gas is matched by the energy from just twenty (20) days of sunshine. The energy in sunlight at noon in a cloudless day that falls on earth's surface is about 1000 kW/m2.

1.2. SOLAR RADIATION

When a dark surface is placed in sunshine, it absorbs solar energy and heats up. Solar energy collectors working on this principle consist of a sun-facing surface which transfers part of the energy it absorbs to a working fluid in contact with it. To reduce heat losses to the atmosphere and to improve its efficiency, one or two sheets of glass are usually placed over the absorber surface. This type of thermal collector suffers from heat losses due to radiation and convection. Such losses increase rapidly as the temperature of the working fluid increases.

1.3. SOLAR WATER HEATER USING NANO FLUIDS

Solar Water Heater (SWH) is a typical device that converts the solar energy into thermal energy to heat up a heat transfer fluid such as water, non-freezing liquid or air for domestic usage. Solar energy collectors are special kind of heat exchangers that transform solar radiation energy to internal energy of the transport medium. A system in which the sun's heat is gathered by a solar collector and used to increase the temperature of a heat-transfer fluid (such as water or a nonfreezing liquid) which flows through the pipes in the collector; the heat contained in this fluid then is conveyed and transferred to the water to be heated. Also see direct solar water heating system and indirect solar water heating system.

Solar water heater is being used worldwide for low temperature applications mostly in the domestic sector for washing clothes and bathing purposes. Thermo syphon flat plate solar water heater is a solar passive system, which can produce hot water in the temperature range of 60–90℃. Closed loop or heat-exchanger type or Indirect type solar water heater are used in which a primary fluid namely pure water or glycol–water mixture is added, to prevent the formation of scaling on the inner surface of the copper tubes due to passage of high saline water and to prevent damage to tubes due to water freezing in cold climates. Due to low thermal conductivity of water and the heat exchanger effectiveness, the temperature attained by the secondary fluid is reduced. In order to increase the outlet useful temperature and thermal efficiency, nanoparticles having high thermal properties are mixed with the primary fluid to form nanofluids, thereby increasing the effective thermal conductivity of the primary solution. The effect of nanofluids in several industrial and residential applications was experimentally and theoretically analyzed by several researchers all over the world. The thermal performance using nanofluids depends on several thermophysical properties ofnanoparticle such as particle diameter, shape and the pH, viscosity, thermal conductivity, volume fraction, specific heat of nanofluid

1.4 SOLAR COLLECTORS

Solar collectors are the key component of active solar-heating systems. They gather the sun's energy, transform its radiation into heat, and then transfer that heat into a fluid (usually water or air). The solar thermal energy can be used in solar water-heating systems, solar pool heaters, and solar space-heating systems. There are a large number of solar collector designs that have turned out to be functional. These designs are classified in two general types of solar collectors.

1.5 FLAT PLATE COLLECTOR

Flat plate collector (FPC) based systems are of metallic type and have longer life as compared to Evacuated tube collector (ETC) based system because ETCs are made of glass which are of fragile in nature.
Both these systems are available with and without heat exchanger. They can also work with and without pump. Systems without pump are known as thermo syphon systems and those with pump are known as forced circulation systems.

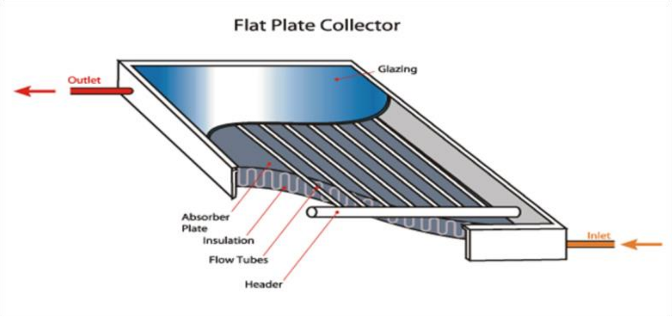

Fig No.1 Flat plate collector

1.6 Cerium Oxide [CeO_2] Nanofluid

Nanofluid is one of the novel inventions of science. Ceria nanofluid can be used for energy savings by increasing the heat transfer performance of the heat recovery systems, which are generally struggling to overcome the present challenging issues such as global warming, greenhouse effect, climate change, and fuel crisis. Specific heat capacity is necessary to analyze energy and energy performances.This paper extant different characteristic of specific heat capacity of nanofluidscontining preparation and measuring methods, effects of volume fraction, temperature, types and sizes of nanoparticles and base fluids. Additionally a compilation has been done on available theoretical results; Nano fluid specific heat falls with the enhancement of volume concentration of nano particle though there are some inconsistencies among outcomes. Moreover, specific heat of Nano fluids is generally increased after adding surfactant in mixtures. However, many contradictory results about the effects of temperatures specific heat of nanofluids found in the literatures.

HEAT EXCHANGER

A heat exchanger is a piece of equipment built for efficient heat transfer from one medium to another. The means of heat exchanger that to transfer the heat between flowing fluids. The heat exchanger is device that used for transfer of internal thermal energy between two or more fluids at different temperatures. In most heat exchangers, the fluids are separated by a heat transfer surface, and ideally they do not mix. Heat exchangers are used in the process, power, petroleum, transportation, air conditioning, refrigeration, Cryogenic, heat recovery, alternate fuels, and other industries. Common examples of heat exchangers familiar to us in day-to-day use are automobile radiators, condensers, evaporators, and oil coolers.Heat exchangers could be classified in many different ways. Heat transfer is classified into various mechanisms, such as thermal conduction, thermal convection, thermal radiation, and transfer of energy by phase changes.

2. LITERATURE SURVEY

Lazarus Godson Asirvatham, August 22, 2014 (1) an experimental study is carried out to investigate the heat transfer characteristics of silver/water nanofluid in a solar flatplate collector. The solar radiation heat flux varies between 800 W/M^2 and 1000W/ M^2, and the particle concentration varies between 0.01%, 0.03%, and 0.04%. The fluid Reynolds numbervaries from 5000 to 25000. The influence of radiation heat flux, mass flow rate of nanofluid, inlet temperature into the solar collector, and volume concentration of the particle on the convective heat transfer coefficient and the collector efficiency are studied. Both parameters increase with increase in the particle volume concentration and flow rate. The maximum percentage increase obtained in the convective heat transfer coefficient is 18.4% for the 0.04% volume concentration at a Reynolds number of 25000. An increase in the performance of Nano fluid is also witnessed when compared to the base fluid, which has a strong dependency on volume concentration and mass flow rate.
Jee Joe Michael, S. Iniyan (2) Flat plate solar water heater is widely used for heating of water in low-temperature residential applications. In this paper, Copper Oxide/water (CuO/H2O) nanofluid is prepared from Copper Acetate and itsthermal performance was investigated experimentally on a 100 Liters per Day (LPD) thermo syphon based indirect-type flat plate solar water heater. The volumetric fraction of CuO/water nanofluid chosen was 0.05%. Significant improvement in performance was observed in thermosyphon circulation comparedto forced circulation, for the low volumetric fraction considered. The CuO/water nanofluid was prepared with the inclusion of surfactant Sodium Dodecyl Benzene Sulfonate (SDBS), as it provided the best CuO nanoparticle dispersion stability compared to pure water suspension and Triton X-100 surfactant suspensions.Also, the thermophysical properties of the synthesized nanoparticle and prepared nanofluid were compared theoretically and experimentally.
Hemant Kumar Gupta Ghanshyam Das Agrawal, Jyotirmay Mathur(3) The efficiency of conventional tube in plate type solar collectors is limited due to higher heat losses for surface based solar energy absorption and indirect transfer of heat from hot absorbersurfaceto working fluidhavingpoorheattransfer properties flowing through tubes. In this paper, aprototype direct absorption solar collector having Cross area1.4 M^2 working on volumetric absorption principle is developed to investigate the effect of using Al2O3 H2O nanofluid as heattransfer fluid at different flow rates.Experimentation was carried using distilled water and 0.005% volume fractions of 20nm size Al2O3 nanoparticles at three flowrates of 1.5,2 and

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2.5lpm.A SHRAE standard 9386 was followed for calculation of instantaneous efficiency of solar collector. Use of nanofluid improves the optical and thermophysical properties that result into an increase in the efficiency of the collector in all cases of using nanofluids in place of water. Collector efficiency enhancement of 8.1% and 4.2% has been observed for1.5 and 2lpm flowrate of nanofluid respectively. Optimum flowrate of 2.5 and 2lpm towards maximum collector efficiency have alsobeen observed for water and nanofluid respectively.

3. PROBLEM IDENTIFICATION

Heat transfer enhancement in solar devices is one of the key issues of energy saving and compact designs. Most solar water heating systems have two main parts: a solar collector and a storage tank. The most common collector is called a flat plate collector but these suffer from relatively low efficiency and also corrosion and scale formation in flat plate collector tubes. There are so many methods introduced to increase the efficiency of the solar water heater. This drawback has been overcome by installing heat exchanger by passing a working medium to transfer the heat to storage tank to increase their performance level.

4. SCHEMATIC DIAGRAM

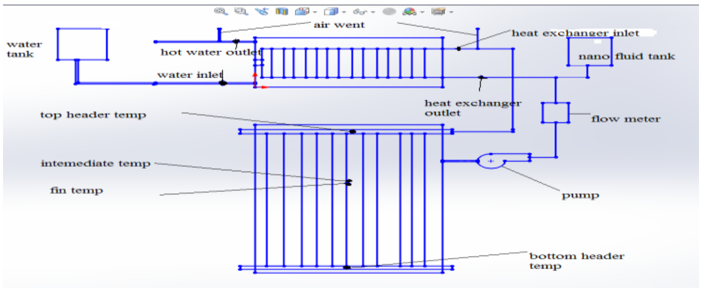

Fig No. 2. Schematic view of solar water heater

5. EXPERIMENTAL SETUP

Fig No.3. Pictorial view of the Experimental Setup

The experimental set up consists of flat plate collector, storage tank and heat exchanger. The schematic view of the experimental set up is shown in figure-1. The dimensions of the solar collector is 2 m length, 1m width and 0.15m height, the area of the absorber plate is 2 m2. A copper sheet of 0.45 mm thick is used as the absorber plate and the transparent glass of 5 mm thick is covered the collector to reduce the loss of radiation. The gap between the glass cover and absorber plate is 0.03 m.

The collector bottom and side surface are insulated to reduce the heat loss due to convection using glass wool as an insulating material with thickness of 50 mm and 25 mm respectively. The absorber cover is black painted to absorb maximum solar radiation. The storage tank mainly consists of two tanks i.e. inner tank and outer tank.

The inner tank is placed inside the outer tank. The gap is maintained between two tanks. This gap is filled by high tech insulating materials in order to reduce the heat losses from the heated water exists inside the inner tank heated by the flat plate solar water heater. Storage tank is placed at the top of frame and collectors.

The solar collector which consists of 9 parallel tubes (risers) with 10 mm diameter on the back of the absorber plate. The risers or connected at the top and bottom by headers to homogenize flow distribution and static pressure at inlet and outlet section. A capacity of the storage tank is 100 litres. A heat exchanger is made up of copper tubes with the area of 0.0839 m2 has placed inside the storage tank that transmits the heat load of the solar cycle to the consumable water.

In forced method the pump is used to pump the cerium oxide/water. This cold cerium oxide/water flows through the flat plate collector, it gets warm by sunshine. The cerium oxide/water is collected heat from the flat plate collector and transfers the heat to the cold water in the storage tank. The heat exchanger circuit is closed. The heat exchanger is to transfer the heat to the cold water.

5.1 MATERIALS SELECTION

Parts	**Material used**
Flat plate collector	
Absorber plate	Copper
Header & small pipe	Copper
Glass cover	Toughen Glass
Insulating material	Glass wool
Heat Exchanger	
Pipe	Copper
Storage Tank	
Inner Tank	Copper
Insulating material	Glass wool
Outer Tank Cover	Aluminum
Thermocouple	
Type	K-Type
Range	73k-623k
Nanoparticles	
Type	Cerium oxide
Size of one particle	15-30nm
Total quantity	25g
Thermal conductivity of cerium	206 W m-1 K-1
Thermal conductivity of cerium oxide/water	0.850 w/m k

Table 5.1.1 Material Selection

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6. RESULTS AND DISCUSSION

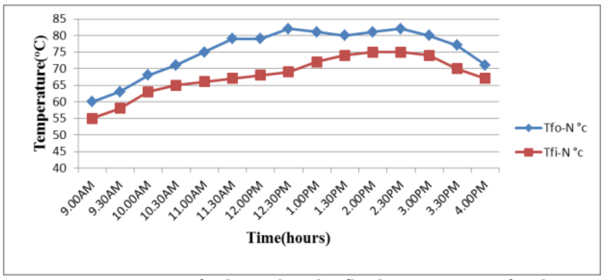

Fig No.4 Comparison of inlet and outlet fluid temperatures for the mass flow rate of 1lpm.

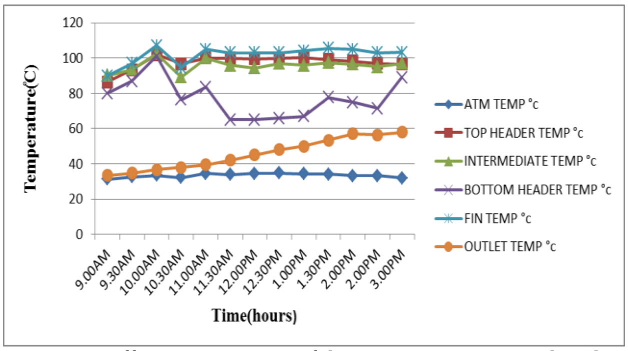

Fig No.5.Different temperatures of the system in Conventional mode

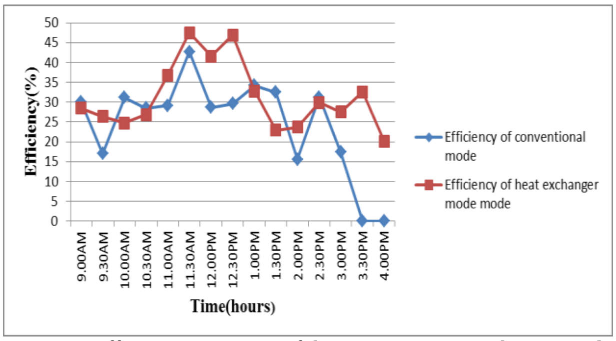

Fig No.6 Different temperatures of the system in Heat exchanger mode

It was observed that using of heat exchanger mode it produces more efficiency than the conventional mode, which produces 19.38% more than the conventional mode.

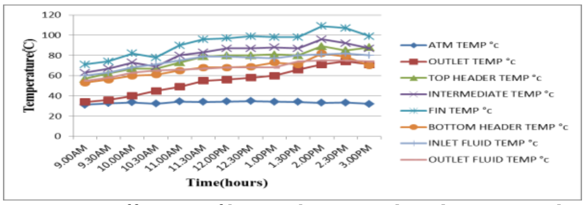

Fig No.7 Efficiency of heat exchanger mode and conventional mode

7. CONCLUSIONS

Many researchers, over the decades have increased the efficiency of solar water heater to the present level. Yet, the current efficiency of the solar water heater is less compared to other conventional technologies. Addition of nanoparticles in the heat transfer fluid contributes to a significant improvement in the thermal efficiency. Here in this study, CeO2 nanoparticles are synthesized; CeO2/water nanofluid prepared for a low volume concentration of 0.01%improved the thermal performance of the solar water heater by9.3%. Also, while comparing the mass flowrate, the highest improvement in efficiency was observed in forced circulations. However, the highest efficiency of the solar water heater was obtained at the flow rate of 1 lpm.

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