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PERFORMANCE ANALYSIS OF SOLAR THERMAL EVACUATED TUBE COLLECTOR USING DIFFERENT NANOFLUIDS

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ABSTRACT

Energy use and energy security are greatly interrelated and corresponds to a major concern in the Indian energy sector. Renewable energy sector occupies an inevitable role in the sustainable development technologies in which the needs of the present generation are met without compromising the ability of the future generation to meet their own needs. Drastically increasing energy demand and environmental issues have motivated many international researchers for searching an alternative option to fulfill the future energy demand. In such a case, solar energy appears as the most attractive option due to its abundance and clean feature. Nowadays, solar thermal technologies are the most popular due to ease of application, high conversion factors and economic viability. The performance of solar thermal technology is dependent on certain factors such as nanofluids, solar radiation, collector tilt etc. The system efficiency depends on temperature of the different nanofluids used. Hence their performance analysis also holds greater importance in this context. In this paper, a performance analysis on the evacuated tube solar collector system with different nanofluids is being illustrated. The simulation of the same system is done with software named TRNSYS.

KEYWORDS: Solar thermal system, Thermal energy storage, nanofluid, evacuated tube collector, thermal efficiency.

INTRODUCTION

Situation in energetic becomes more acute with each year. With an increase of producing, will increase both need for heat as well as for electrical energy. Its standard that large amount of total consumed energy is created in manner of combustion of many fossil fuels: solid, liquid and gaseous. As better-known fossil fuels are expensive, need for a storage room, combustion of them makes pollution of the atmosphere and resources of fossil fuels within the near future can run away. These are reasons why an alternate energy sources have become additional and a lot of attraction. Solar power is one among the richest renewable energy supply. It's one among the cleaner kinds of renewable energy resources. At the guts of a solar thermal system is that the solar collector. It absorbs solar radiation, converts it into heat, and transfers useful heat to the system. The traditional solar collector could be a well-established technology that has numerous applications like water heating, space heating and cooling.

Water heating accounts for a substantial portion of energy use at many residential, commercial, institutional, and Federal facilities. Nationwide, approximately 18% of energy use in residential buildings and 4% in commercial buildings is for water heating. Solar water heating systems, which use the sun's energy rather than electricity or gas to heat water, can efficiently serve up to 80% of hot water needs with no fuel cost or pollution and with minimal operation and maintenance expense. Solar water heating currently represents less than 1% of the potential water heating market (about 1% of residential buildings have solar water heating, fulfilling about two-thirds of each building's water heating requirements).

S. P. Sukhatme *et al.*[1] expains different solar thermal collectors and principles of thermal collection. S. A. Kalogirou[2] explains the different solar thermal collectors and its applications. G. N. Tiwari [3] discuss solar energy fundamentals,its design, modelling and applicatons. A. Subiantoro *et al.* [4] explains analytical models for the computation and optimization of single and double glazing flat plate solar collectors with normal and small air gap spacing. S. Arora *et al.* [5] explains thermal analysis of evacuated tube solar collectors. S. Z. Heris *et al.* [7] discuss the experimental investigation of oxide nanofluids laminar flow convective heat transfer. B. G. Vishalkumar*et al.* [8] discusses Nanofluid: Atool to increase the efficiency of solar collector. M. N. Mohammed *et al.* [10] studied about TRNSYS simulation of solar water heating in Iraq.

Conventional flat plate collectors are suited for warmer climates and for the times when the intensity of the solar radiation is substantially high. Their benefits are however reduced when they are exposed to cold, cloudy and windy days. Furthermore, when exposed to weathering conditions, the tubes and the insulation has a tendency to deteriorate thereby causing loss of performance. Each evacuated tube consists of two glass tubes made from extremely strong borosilicate glass. The outer tube has very low reflectivity and very high transmisivity that radiation can pass through. The inner tube has a layer of selective coating that maximizes absorption of solar energy and minimizes the reflection, thereby locking the heat. The ends of the tubes connected to the copper header are fused together and a vacuum is created between them. This process is called as evacuation, as by definition, it means that the air is pumped out from the cavity. The vacuum is created to recreate the thermos flask effect as vacuum acts as an insulator and does not allow short wave radiation to escape through the glass tube. This traps the solar radiation much more effectively and hence higher temperatures can be a c h i e v e d .

This paper describes the relevance of solar water heating system using evacuated tube collector with different nanofluids in the renewable energy sector.

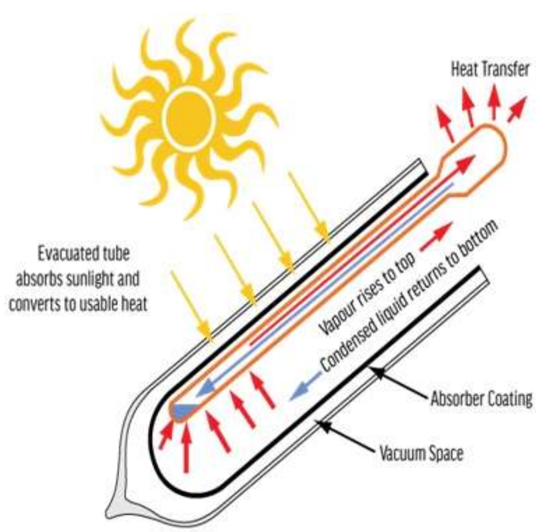
CURRENT TOPOLOGY

One way of improving the performance of a liquid flat-plate collector is to reduce or suppress the heat lost by convection from the top. This is done by having a vacuum above the absorber plate. As consequence, it becomes essential to use a glass tube as the cover because only a tubular surface is able to withstand the stresses introduced by pressure difference.

A. Evacuated Tube Collector

In evacuated tube collector solar energy is captured in the vacuum sealed glass tube, quickly heating a special non-toxic heat transfer fluid in the copper heat pipe. The heated fluid rises to the top of the pipe where it heats water that is being circulated through the copper manifold in the insulated aluminum header. When the heat transfer fluid cools, it falls to the bottom of the heat pipe to be reheated. Figure 1 indicates that the working of ETC.

Figure:1



Schematic representation of evacuated tube collector collecting solar radiation [3]

NANOFLUID

Nanofluid is the fluid with Nano sized solid particles. The metallic or nonmetallic nanoparticles change the transport properties and heat transfer characteristics of the base fluid. Nano fluids are the new generation heat transfer fluids for various industrial and automotive applications because of their excellent thermal performance. There are so many methods introduced to increase the efficiency of the solar water heater. But the novel approach is to introduce the Nano fluids in solar collector instead of conventional heat transferfluid[6].

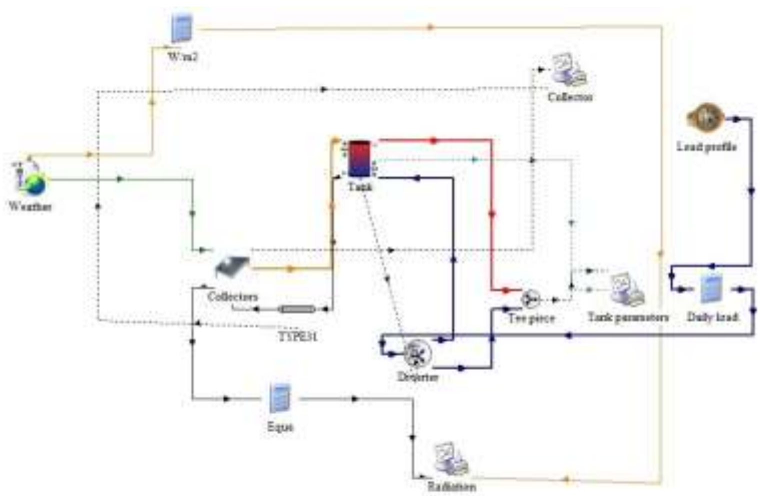
Thermal properties of liquids play a decisive role in heating as well as cooling applications in industrial processes. Thermal conductivity of a liquid is an important physical property that decides its heat transfer performance. Conventional heat transfer fluids have inherently poor thermal conductivity which makes them inadequate for ultra-high cooling applications. Scientists have tried to enhance the inherently poor thermal conductivity of these conventional heat transfer fluids using solid additives following the classical effective medium theory for effective properties of mixtures.

Downscaling of particle sizes continued in the search for new types of fluid suspensions having enhanced thermal properties as well as heat transfer performance. Well-dispersed and stable nanofluids are formed after properly dispersing nanoparticles into base fluids and the resulting nanofluids are expected to exhibit several beneficial features. Nano fluids demonstrate higher thermal conductivities than the base fluid due to several factors. The large surface area of nanoparticles per unit volume allows for more heat transfer between solids particles and base fluids. Another advantage is that the high mobility of the nanoparticles due to the tininess, which may introduce micro-convection of fluids to further stimulate heat transfer.

SIMULATION STUDY AND RESULTS

TRNSYS (Transient System Analysis Simulation) program is a complete and extensible simulation environment for the transient simulation of systems, including multizone buildings. It is used by engineers and researchers around the world to validate new energy concepts, from simple domestic hot water systems to the design and simulation of buildings and their equipment, including control strategies, occupant behaviour, alternative energy systems (wind, solar, photovoltaic, hydrogen systems), etc. One of the key factors in TRNSYS's success over the last 25 years is its open, modular structure. The source code of the kernel as well as the component models is delivered to the end users [9]. This simplifies extending existing models to make them fit the user's specific needs.

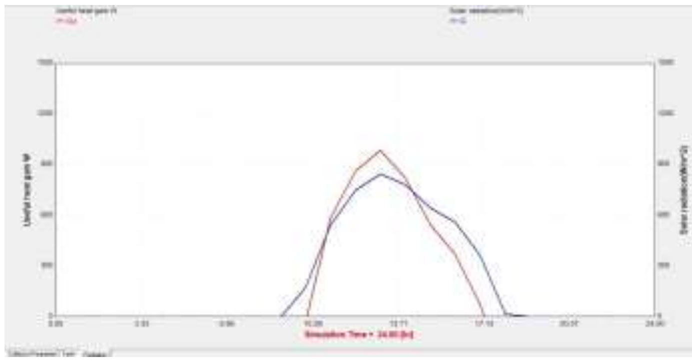
Figure:2



TRNSYS model diagram for solar water heating with water as HTF

Figure 3 shows the variation of solar radiation with time for the simulated model with water as heat transfer fluid. From the graph, it is clear that the maximum values for solar radiation (watts per square meters) and useful heat gain (watts) are being obtained during the peak hours i.e. at the noon time.

Figure:3



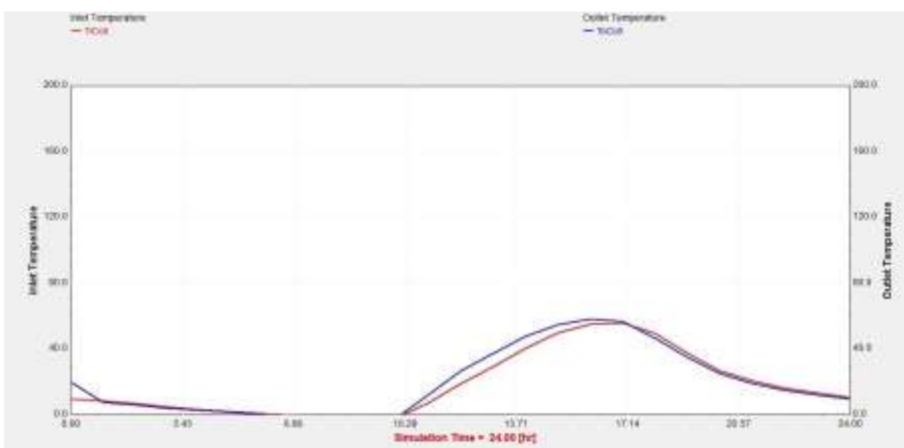
Variation of solar radiation and useful heat gain with respect to time

Figure 4 shows the variation of collector temperature with time for the simulated model with water as heat transfer fluid. From the graph, it is clear that the maximum collector temperature at the outlet is about 60 to 80 ˚C and that of inlet is 20˚C.

A. Water as heat transfer fluid

Figure:4

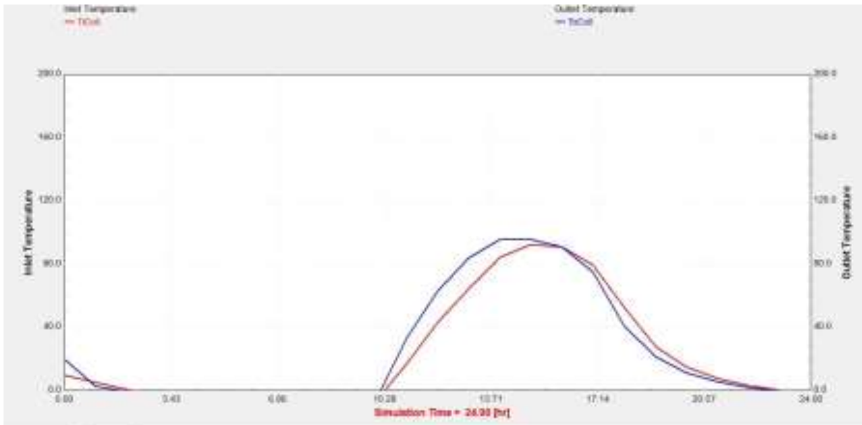
Variation of collector temperature with respect to time



B. Aluminium as nanofluid

The variation of temperature within the collector using aluminium nanofluid is shown below. From the graph 5, it is clear that there is a gradual and sharp increase in the value of outlet temperature from 93˚C to about 96˚C.

Figure:5

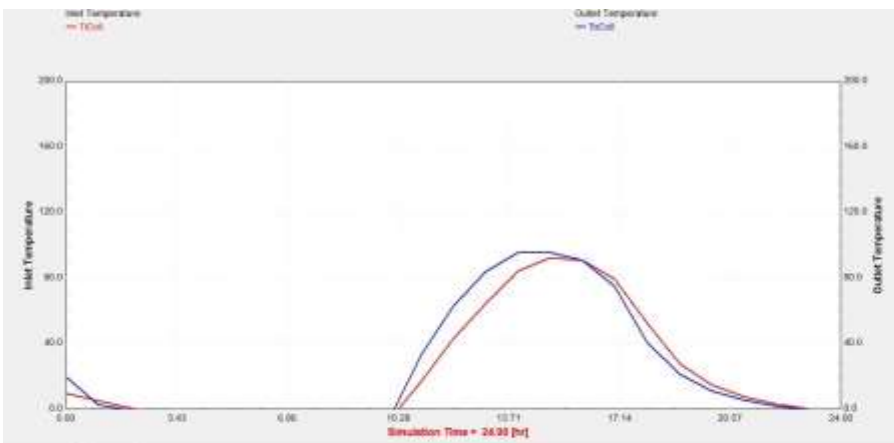


Variation of collector temperature with respect to time

C. Silica as nanofluid

The variation of temperature within the collector using silicon nanofluid is shown below. From the graph 6, it is clear that there is a gradual and sharp increase in the value of outlet temperature from 97˚C to about 104˚C.

Figure:6



Variation of collector temperature with respect to time

D. Copper as nanofluid

The variation of temperature within the collector using copper nanofluid is shown below. From the graph 7, it is clear that there is a gradual and sharp increase in the value of outlet temperature from 100˚C to about 114˚C.

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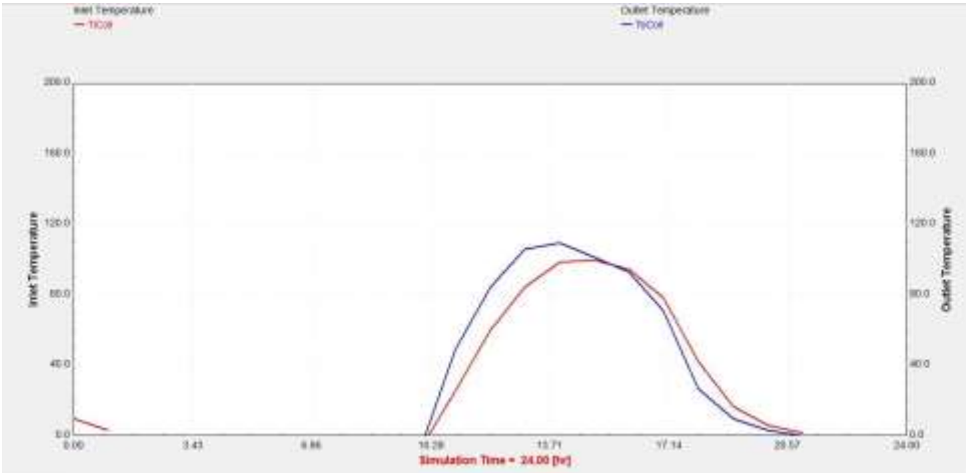
Figure:7

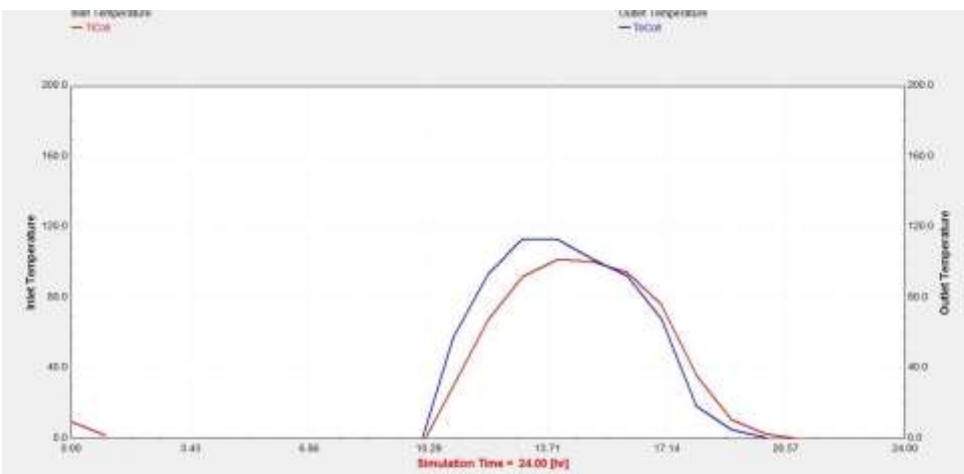


Variation of collector temperature with respect to time

E. Alumina as nanofluid

The variation of temperature within the collector using alumina nanofluid is shown below. From the graph 8, it is clear that there is a gradual and sharp increase in the value of outlet temperature from 105˚C to about 115˚C.

Figure:8

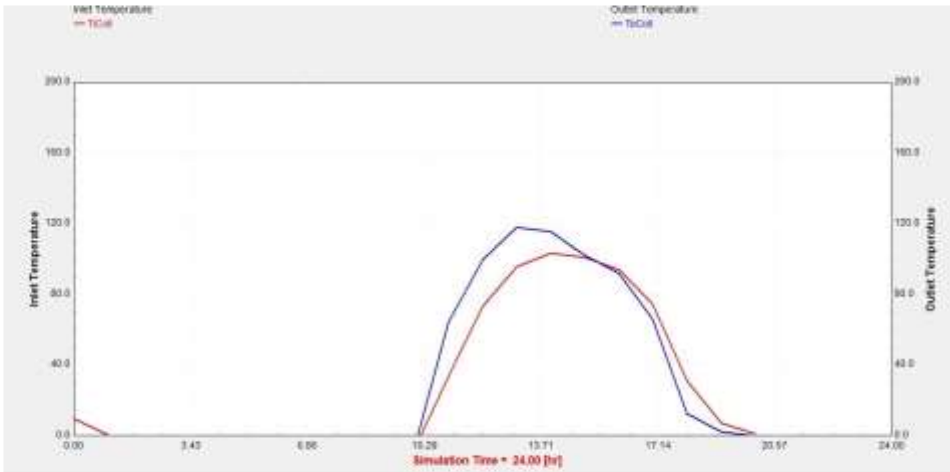


Variation of collector temperature with respect to time

F. Carbon Nanotube Nanofluid

The variation of temperature within the collector using carbon nanotube nanofluid is shown. From the graph 9, it is clear that there is a gradual and sharp increase in the value of outlet temperature from 105˚C to about 120˚C.

Figure:9



Variation of collector temperature with respect to time

CONCLUSION

The maximum possible utilization of solar energy is ensured through the performance improvement of the proposed thermal system. For improving performance reflector perfection, receiving system perfection and especially high quality thermal fluid should be ensured. Basically higher fluid temperature ensures higher efficiency of the system. So such type of fluid is necessary, which can sustain at elevated temperature and hence can transfer more heat.

Based on the simulation study, it was concluded that the thermal conductivity of carbon nanotube nanofluid holds good in the area of solar water heating systems. The outlet tem- peratures show a tremendous increase with the use of carbon nanotube as the nanofluid. The maximum outlet temperature using a carbon nanotube was obtained to be more compared to that of silicon, aluminiun, alumina and copper nanofluids.

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