Performance evaluation of energy storage system coupled with flat plate solar collector using hybrid nanofluid of CuO+Al$_2$O$_3$/water

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Abstract. Charging of energy storage system using flat plate solar collector (FPSC) is very popular in recent years. FPSC for the thermal energy storage system (TESS) using hybrid nanofluid was discussed in this manuscript. Hybrid nanofluid of CuO+ Al$_2$O$_3$/water was used as heat transfer fluid (HTF) for solar collector which is coupled with thermal storage and analysis carried out. To predict the thermal performance of solar energy storage system using hybrid nanofluid, a stainless steel container was used for thermal storage. CuO+Al$_2$O$_3$/water hybrid nanofluid were used to investigate the thermal performance of the solar collector and energy storage system. The FPSC is used for experimental investigation on the stainless steel container TESS. The flat plate solar collector is found more efficient than the other conventional type solar collector using hybrid nanofluid. The temperature of stainless steel container thermal energy storage system was reached to 87°C by using hybrid nanofluid in FPSC.

Keywords. Hybrid nanofluid, flat plate solar collector, thermal storage, solar collector

1. Introduction
Solar energy is every good alternative to fossil fuels it is one of best renewable energy source. There are various types of non-conventional energy sources among them solar energy is most promising and cleanest as it does not add to global warming. Sun emits more energy every second, this energy is more than energy used by mankind till date. The basic problem associated with solar radiation is that it varies with time and seasons, the impact by atmospheric condition is greatest on solar energy [1]. Solar energy can be store in thermal energy storage using solar collector and also performance of solar collector may be improve by using nanofluid in it [2]. Yousefi et al. [3] experimentally tested the Al$_2$O$_3$/water nanofluid effects on flat plate collector for thermal performance. The Al$_2$O$_3$ nanofluid with 0.2 wt% increases collector efficiency upto 28%.

Faizal et al. [4] has been performed experimental study on FPSC by using metal oxide types nanofluids. The metals oxides are Al$_2$O$_3$, CuO, TiO$_2$ and SiO$_2$ nanoparticles was dispersed in water.
with volume fraction of 3%. It is found that the CuO nanofluid had a highest properties value as compare to Al₂O₃, TiO₂ and SiO₂ nanofluids. Also area reduction of 21.5%, 25.6%, 22.1% and 21.6% of flat plate collector was achieved for Al₂O₃, CuO, TiO₂ and SiO₂ nanofluid respectively. Dasaian et al. [5] has been discussed the performance of thermo-syphon based flat plate solar water heater with nanofluid of CuO and water. The 40-50 nm size of the nanoparticles was dispersed at 0.1 to 0.5 wt% concentration in base fluid. The efficiency enhancement upto 5.7% achieved at 0.2 wt% nanoparticles concentration in base fluid. From the experimental and computational investigation it was found that the CuO nanoparticles enhances the efficiency of thermo-syphon based solar collector.

The enhancement of heat transfer in pipe with twisted tape for the solar thermal applications using alumina based nanofluid was studied. The 8 to 12% of heat transfer coefficient enhancement was found using nanofluid in comparison with water in plain tube. It is found that the 0.5% concentration value of nanoparticles having higher friction factor [6]. The effect of nanoparticles size, volume fraction and shape on thermal and heat transfer systems was studied by researchers. The effect of dimensional and physical parameters of nanoparticles on thermal conductivity and viscosity was also discussed through the experimental and numerical analysis [4,7,16–23,8–15].

A numerical study was carried out on FPSC using water+ Al₂O₃ nanofluid to predict the thermal performance of system. The volume fraction of 0.1 to 3% was taken in studied for the flat plate collector. Thermal efficiency of the system was increased upto the range of 0.5% of nanoparticles volume concentration and thermal efficiency decrease as nanoparticles concentration was increased [24]. Performance of aluminum and oil type heat storage using flat plate solar collector with soybean oil has been investigated and found that oil based heat storage was efficient than metal based heat storage [25]. Also aluminum type heat storage investigated using parabolic trough collector with soybean oil/Al₂O₃ nanofluid and solar collector temperature reached upto 178°C [26]. Kasaeian et al. [27] experimentally studied the effect mineral oil+MWCNT nanofluid on parabolic trough solar collector. The weight concentration of MWCNT nanoparticle was 0.2% and 0.3% was taken for experimentation. From the results it is found that the 4 to 5% and 5 to 7% of efficiency was enhanced by using nanoparticle concentration of 0.2% and 0.3% respectively. Khullar et al. [28] studied the thermal effect of therminol VP-1 and aluminium nanofluid with 0.05% of volume concentration on performance of parabolic trough solar collector. It is found that the collector efficiency is enhanced by 5 to 10% as compared to conventional based parabolic trough collector (PTC).

Authors studied the various solar concentrator such as flat plate collector and parabolic concentrator using nanofluid as HTF. Researchers are missing significant data and conclusion for the FPSC which is coupled with thermal energy storage by using hybrid nanofluid of CuO+Al₂O₃/water. Authors not experimentally compared the hybrid nanofluid for FPSC which is coupled to container based thermal energy storage. The theoretical studies from the most of the researcher, says that the FPSC is more prominent for the conventional heat transfer fluid or mono nanofluid. From the above literature gap, it is necessary to investigate the performance FPSC coupled with container based thermal energy storage system using hybrid nanofluid.

2. Experimental setup
The experimental performance of TESS was tested using FPSC and both are connected to each other and it is shown in figure 1. The self-circulation loop which is connected between flat plate solar collector and thermal energy storage contains Al₂O₃+CuO/water hybrid nanofluid. The heat transfer fluid (hybrid nanofluid) flows in solar collector to absorbed heat from sun and this heat released to the thermal energy storage. The container of stainless steel type used as thermal energy storage system contains Cu+Al₂O₃/water hybrid nanofluid. Al₂O₃+CuO/water hybrid nanofluid used during experimentation as a heat transfer fluid. The heat transfer fluid (hybrid nanofluid) loss its heat during flow through the stainless steel type heat storage container. Water based hybrid nanofluid absorbed the heat which comes from the sun and send this heat in stainless steel type thermal storage container. To estimating temperature, a thermocouple was set at channel and source of sun flat plate collector. Also at inlet and outlet of stainless steel container another thermocouple was set. All the different
places temperature is shown in the digital temperature indicator.

Figure 1. Schematic of FPSC with thermal storage for experimentation.

During the sunny days the experimentation was conducted for measurement of reading. The experimental results are shown in next section i.e. in results and discussion.

3. Results and discussion

The experimental performance was conducted during sunny days and when the sky with no cloud, the temperature measurement was taken by the help of pyranometer and temperature indicators. The recorded temperature from the temperature indicator was taken for the readings. The temperature of solar collector and thermal storage both was measure with respect to time. The graph of the temperature for the flat plate collector and thermal storage is shown in Fig. 2. The average atmospheric temperature was 35°C.

Figure 2. Temperature vs time graph of inlet and outlet of flat plate collector and thermal energy storage.

Total 2 hours and 20 minutes experimentation was conducted on flat plate collector and reading
4. Conclusion
Experimental performance was conducted on the FPSC for the TESS using CuO+Al₂O₃/water hybrid nanofluid. The results shows that the FPSC is a good option for the t TESS. The heating of working fluid is faster using hybrid nanofluid in flat solar collector. From the results and discussion, it can be concluded that the using hybrid nanofluid in thermal energy storage coupled with flat plate collector, the thermal energy storage temperature is reached up to 87°C in 2 hours and 20 minutes. So the hybrid nanofluid is the better option for the FPSC and it increases the heating capacity of the TESS.

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