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An Experimental and CFD Analysis of CuO-H_2O (DI) Nanofluid Based Parabolic Solar Collector

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Abstract : *Parabolic solar collectors have been used for producing power in solar thermal power plants. Nanofluids in solar energy, when used as a working fluid in parabolic collector enhances its efficiency due to its improved thermo-physical properties like thermal conductivity, heat capacity , density and viscosity. Nnaofluids is a suspension of nanoparticles in a base fluid like water, ethylene glycol. In this paper both experimental and computational fluid dynamics study has been presented. Nanofluid used is 0.01% CuO- H_2O (DI). System performance is conducted under mass flow rate of 20 Litres/hr In ANSYS FLUENT 14.5 based computational fluid dynamics tool, the absorber tube is modeled as metallic copper tube with working fluid flowing in it. Solar load model has been used for modeling solar fluxes. S2S radiation model has been used for modeling heat transfer comprising of conduction, convection and radiation. It has been reported from both experimental and CFD analysis that system performance is enhanced by using nanofluid as working fluid as compared with conventional fluid like water. Also both experimental and CFD simulated results are in good agreement.*

Keywords:– *Computational fluid dynamics, efficiency, nanofluid, parabolic solar collector, performance.*

I. SOLAR ENERGY

The Sun is a sphere, comprising of intensely hot gaseous matter having a diameter of 1.39×10^6 Km .In fact sun is a fusion reactor in which hydrogen is converted into helium. About 1.8×10^{11} MW sun's energy is intercepted by the earth, even this energy is very immense and it has been reported that solar radiation for 30 min. is capable enough to fulfill worlds annual demand [1]. Various devices has been made to receive this source of energy. Parabolic solar collector is one of them. Parabolic solar collector consists of parabolic shaped reflector, absorber tube. Main purpose of parabolic shaped reflector is to reflect and concentrate all the sun radiations towards absorber tube, where a working fluid is flowing [2]. Glass enclosure is provided over the absorber tube to minimize the re-radiation losses. Main utility of parabolic solar collector is for power production in solar thermal power plants. The efficiency of parabolic shaped collector depends upon various factors like solar intensity, collector design, working fluid, and absorber material.

II. NANOFLUID IN SOLAR ENERGY

In this era of increasing demand of energy various alternatives has been suggested from time to time. Use of nanofluid as working fluid in solar collector has been adopted widely, because it enhances the system performance due to its improved thermo-physical properties like: thermal conductivity, viscosity, heat capacity and density. Nanofluid is basically a suspension of nanoparticles in a conventional base fluid like water [3]. Various different types of nanoparticles are used such as gold, copper, aluminium, aluminium oxide, copper oxide, etc[4]. Nanofluid provides following benefits when used as a working fluid in solar collector: (1) Nanofluid absorbs solar energy directly without avoiding intermediate heat transfer steps[5]. (2) Nanofluids has high absorptivity in solar range and low emissivity in infrared range[6]. (3) More uniform temperature is obtained inside the absorber tube. (4) Enhances the system efficiency due to its improved thermophysical properties [7]. Recently many researchers have investigated the effect of nanofluid in improving the heat transfer both experimentally and theoretically. Yousefi et al. [8] examined experimentally the performance of flat plate solar collector where working fluid was Al_2O_3 water based nanofluid. Then its performance is compared with traditional flat plate solar collector where water was used as working fluid. Parameters used were mass flow rate, volumetric concentration of nanomaterials in water. It was found out that efficiency of flat plate solar collector enhanced by 28.3% by using 0.2 wt% Al_2O_3 in water for making nanofluid as compared to water. Khullar et al.[9] theoretically examined the performance of concentrated parabolic solar collector using Al-therminol VP-1 based nanofluid. Finite difference technique was used for this. It was evaluated that nanofluid based concentrated parabolic solar collector was 5-10% more efficient as compared to the conventional one in terms of efficiency.

III. EXPERIMENTAL METHODOLOGY

The experimental set up conducting experiment on CuO- H_2O (DI) consists of parabolic shaped reflector, absorber tube (copper tube) with glass cover, ball valve, and storage device.

Table 1 different parameters of parabolic solar collector

Collector length	1.20 m
Collector breadth	0.915 m
End plate thickness	2 mm
Focal length	0.30 m
Receiver inside diameter	0.027 m
Receiver outside diameter	0.028m
Receiver length	1000 nm
Glass envelope inside diameter	0064 nm
Glass envelope outside diameter	0.066 nm
Concentration ratio	11:30

The working fluid from the storage tank is made to circulate with the help of pump in the absorber tube, which is centrally placed in order to have maximum solar radiations falling upon it directly and also reflected rays from the parabolic shaped reflector. The working fluid taken is H_2O (DI) and 0.01% CuO-H_2O (DI). Flow rate of 20 litres/hr. The working fluid after been traversing through the absorber tube is made to flow into the storage tank, from where again working fluid is circulated into the system. While inlet and outlet temperatures are recorded using thermometer.

Fig. 1 Parabolic solar collector

Sonication is the technique of dispersing the agglomerated nanoparticle. CuO-H_2O nanofluid is prepared by two step method. CuO nanoparticles are mixed with double distilled water. Volume concentration of 0.01% is obtained and mixture is stirred for around 30 min. in a device called magneto stirrer hot plate as shown in fig 2. In order to make nanoparticle more stable and dispersed in water, ultra bath sonicator is used. After sonicating the nanofluid so obtained is ready for use.

Fig. 2 magnetic stirrer with plate

IV. COMPUTATIONAL FLUID DYNAMICS METHODOLOGY

1 Geometric Modeling

The geometry consists of two concentric cylinders (glass and HCE pipe) with two fluid regions for the working fluid (inner cylinder) and the vacuum region (annulus). In the present analysis, the geometry is considered to be oriented along the z-axis, with positive Z denoting the south direction while the positive X denotes the east direction.

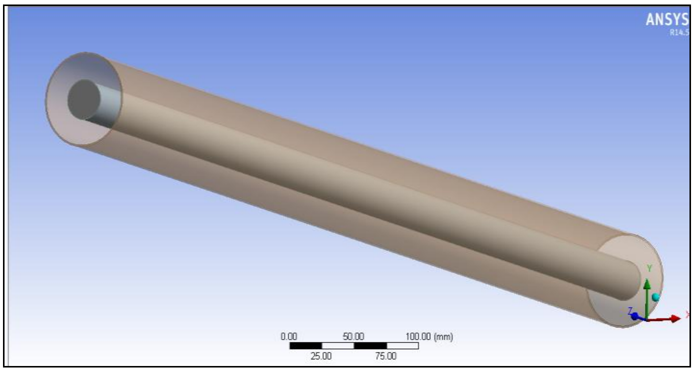

Figure 3 HCE (absorber tube)

2 Material Model

Material model is applied for carrying out CFD simulation of CuO – H_2O (DI) nanofluid based collector. Table 2 depicts the material used along with their thermo-physical properties.

Table 2 Thermo-physical properties

Thermo-physical properties	Water	CuO- water based nanofluid (0.01% conc.)	Glass
Density(kg/m^3)	1000	1054	2200
Specific heat (J/kg/K)	4187	3965.05	910
.Thermal conductivity (W/mK)	0.667	0.68701	1.75
Viscosity (m^2/s)	0.415e-6	0.396e-6	-

3 Solar Load Model

ANSYS FLUENT provides a model that can be used to calculate radiation effects from the sun's rays that enter a computational domain. It includes a solar calculator utility that can be used to construct the sun's location in the sky for a given time-of-day, date, and position and can be used to model steady and unsteady flows. It allows simulating solar loading effects and determining the solar transmission through all glazed surfaces over the course of a day.

4 Boundary Condition

The flow at the inlet was maintained as uniform mass flow at ambient temperature conditions. A low Re is typical for HCE applications for Parabolic Trough Collectors .This variation is due to highly temperature dependent viscosity. The vacuum region is modeled by assuming it to be a fluid with very high viscosity and the velocity components have been fixed at zero value. The outlet is maintained to be at ambient pressure.

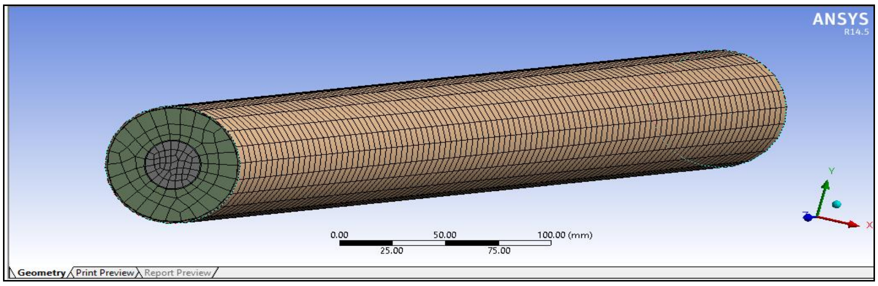

Fig. 4 Meshed Geometry of a absorber tube

V. RESULTS

For water as a working fluid having flow rate of 20 litres/hr CFD results is depicted in figure. 5, which shows the temperature growth within the absorber tube (HCE). Temperature gain of around 6 degrees is obtained.

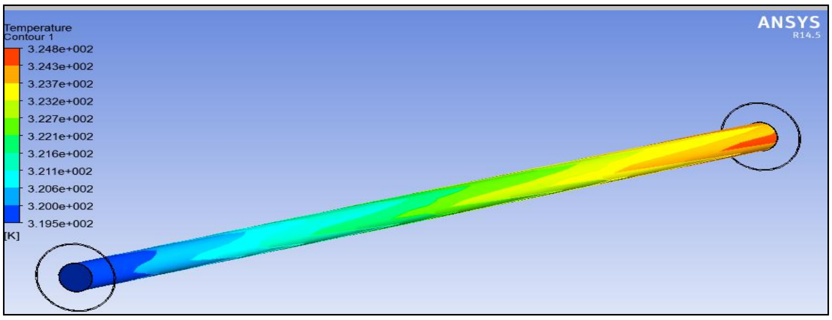

Fig .5 Temperature contours with water at flow rate of 20 litres/hr

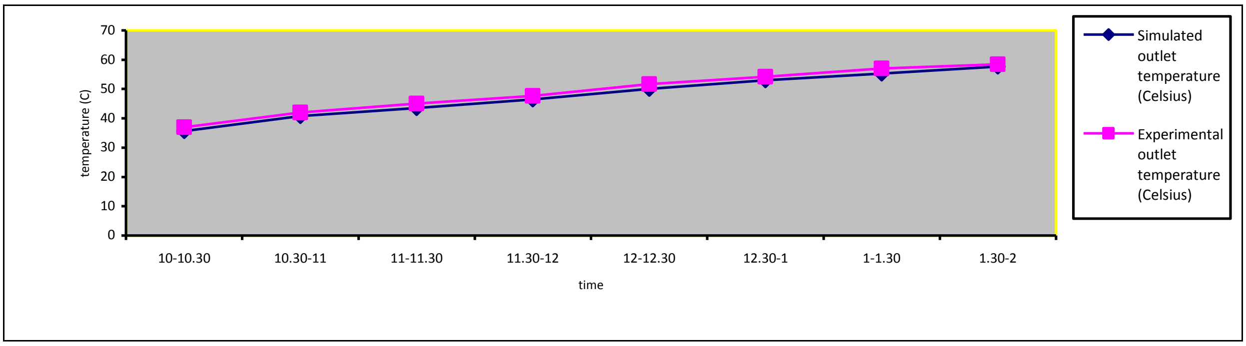

Fig 6 . simulated vs experimental outlet temperature with water at flow rate of 20 litres/hr

Figure 7 depicts the temperature contour with 0.01% CuO-H_2O nanofluid as a working fluid with a flow a flow rate of 20 litres/hr. where high outlet temperature is obtained as compared with conventional water as working fluid.

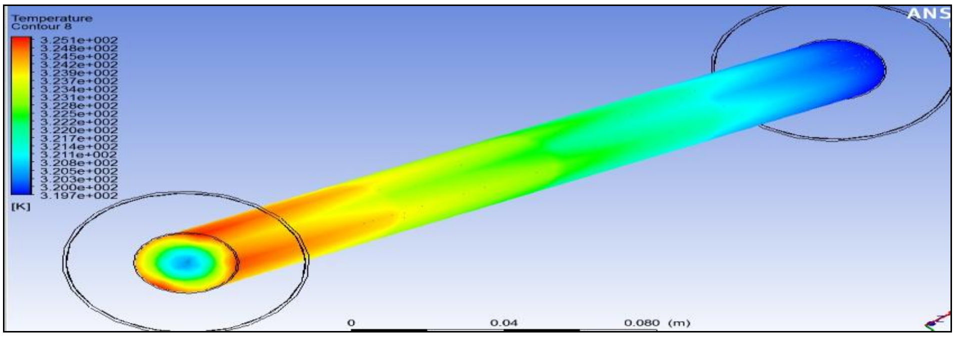

Fig.7 Temperature contour with 0.01% CuO-H_2O (DI)

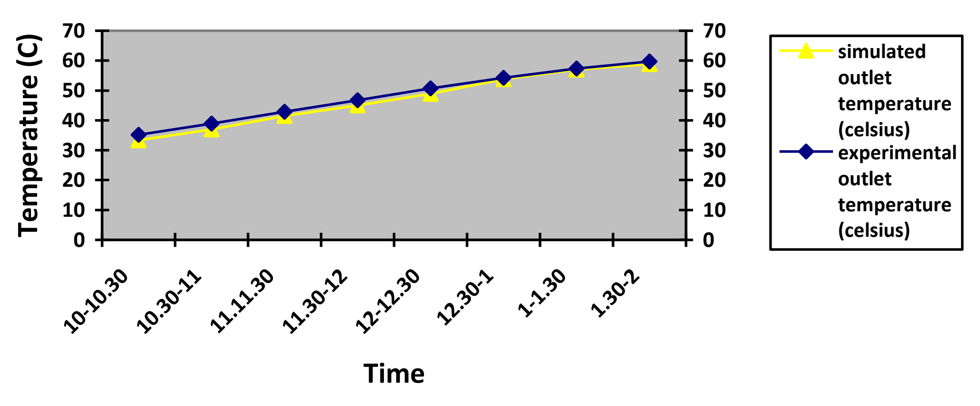

Fig. 8 simulated vs experimental outlet temperature with 0.01% CuO –H_2O (DI) as a working fluid

VI. CONCLUSION

Nanofluid when used as a working fluid improves the parabolic solar collector efficiency due to its improved thermo-physical properties like specific heat, thermal conductivity and others. From both the experimental and CFD analysis it is found out that the thermal efficiency improved by and 7.4% when 0.01% CuO-H_2O nanonofluid is used, as compared with conventional working fluid like water at flow rate of 20 litres/hr. Both experimental and CFD outlet temperature are found out to be in close agreement for 0.01% CuO-H_2O nanofluid with a difference of and 8.12% at flow rate of 20 litres/hr..

REFERENCES

[1] Sani E., Mercatelli L., Barison S, Pagura C., Agresti Colla L., Sansoni P., Potential of carbon nanohorn-based suspensionf for solar thermal collectors, Solar Energy Materilas & Solar Cells vol, 95,issue11, pp. 2994-3000.

[2] Roman A., simulation analysis of thermal storage for concentrating solar power, Applied Thermal Engineering, vol, 31, 2011, pp. 3588- 3594.

[3] Reddy S., Vankataramaniah P., Sairam P., Optimization of process parametrs of solar parabolic trough in winter using Grey-Taguchi approach, International ournal of Enineering Research and Applications, vol. 2 Issue 1, 2012, pp. 816-821.

[4] Chang M., Liu S., Tai C., application of nanoluids , nanotechnology. Vol. 207, 2011, pp. 378-386.

[5] Chow T.T., A review on photovoltaic/ thermal hybrid solar technology, Applied Energy", vol. 87, issue 2, 2009, pp.365-379

[6] Chai H., Ajabshirchi Y., Esmaeilzadeh E.,. Experimental study on thermal efficiency of flat plate solar collectorusing TiO_2 / water nanofluid, "Modern Applied Science", published by Canadian Centre of Science and Education, vol.7, issue 10, 2013 pp.60-69

[7] Tyagi H., Phelan P., Prasher R., Predicted eficiency of a low temperature nanofluid-based direct absorption solar collector, International Journal of Solar Energy Enfineering, vol. 131, 2009. pp-7-15.

[8] Yosefi T., Shojaeizadeh E., Zinadini S., An experimental investion on the effect of MWCNT-H_2O nanofluid on the efficiency of flat plate solar collector, Solar Energy, vol 86, 2012, pp. 771-779.

[9] Khullar V., Tyagi H., Phelan P.E., Otanicar T.P., Singh H., Taylor R.A., Solar Energy harvesting using nanofluids based oncentrating solar collector , Journal of Nanotechnology in Engineering and Medicine", vol.3, 2012, pp. 031003-1-9.