ISSN: 2321-2152

IJMECE

International Journal of modern electronics and communication engineering

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IJMECE
ISSN2321-2152www.ijmece .com
Vol 7, Issue.2 May 2019

CFD ANALYSIS OF A PARABOLIC-TROUGH COLLECTOR USING NANO-FLUIDS

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Abstract
The performance of a parabolic trough collector (PTC) using nanofluids as the working fluid has not been fully investigated. Therefore, the objective of this study is to analyse the fluid flow and heat transfer characteristics of a PTC using water-based Al2O3 and CuO nanofluids with different volumetric concentrations. Specifically, the study aims to determine the optimal concentration of nanofluids that maximizes the heat transfer rate and outlet temperature of the working fluid, and compare the performance of the PTC using nanofluids with that of a PTC using a conventional working fluid. The findings of this study could provide insights into the potential of nanofluids for improving the thermal performance of PTCs, and inform the design and optimization of PTC systems.

Keywords: Fluent, PTC, Nano fluids, optimization of PTC, Computational Fluid Dynamics.

Introduction

In today's world the fastest growing thing is the energy requirement by world, with the reduction in the conventional resource. The most challenging thing in front of the world is how the to fulfil the requirement of energy. Increasing in fuel prices and carbon emissions from the conventional energy resources like thermal energy and fossil fuels usage leads to global warming and air pollution. Due to overuse and depletion of conventional energy resources, the world has to think about the alternative sources of energy. Nowadays, renewable power generation or hybrid renewable power generation systems are attracting the interest of the whole world due to advanced technologies capable of efficient use of renewable resources including reduction of greenhouse gas emissions (Paperman's, 2005; Xi, 2012). Renewable energy resources are used generally for three main purposes: electricity generation, bio products and heating/cooling systems. Concentrating solar power generation system, geothermal power generation and hydropower generation systems are well-disposed technologies, while solar thermal heating, geothermal district heating and pellet-based heating can provide significant benefits in case of heat supply (Dombi, 2014). In many countries, various schemes like development of technologies, increased economies of scale, and strong policy support have contributed.

However, out of the renewable energy resources, the amplest resource is solar which has immense potentiality (Şen, 2004).

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Technologies are available to harness solar energy to a useful state. Solar has the potency to meet all residential and industrial energy needs. Already the world is moving toward sustainable technologies especially solar energy technologies. Solar PV system is growing so fast of all renewable technologies with an impressive rate (Hosenuzzaman et al., 2015). Recently solar concentrating system attracts the attention of many countries. Some countries have established such type of system, and in some region of the world, this system is under development. Today the world stands at an exciting transition moment when renewable energy is competing head- to-head with fossil fuel and nuclear energy. Due to increased energy consumption, dependence on fossil fuels, solar power generation can be the main and important factor for the world now.

Statement of the Problem

The performance of a parabolic trough collector (PTC) using nanofluids as the working fluid has not been fully investigated. Therefore, the objective of this study is to analyse the fluid flow and heat transfer characteristics of a PTC using water-based Al2O3 and CuO nanofluids with different volumetric concentrations. Specifically, the study aims to determine the optimal concentration of nanofluids that maximizes the heat transfer rate and outlet temperature of the working fluid, and compare the performance of the PTC using nanofluids with that of a PTC using a conventional working fluid. The findings of this study could provide insights into the potential of nanofluids for improving the thermal performance of PTCs, and inform the design and optimization of PTCsystems.

Objectives of the study

- To analyse the fluid flow and heat transfer characteristics of a parabolic trough collector (PTC) using water-based Al2O3 and CuO nanofluids with different volumetric concentrations.
- To determine the optimal concentration of nanofluids that maximizes the heat transfer rate and outlet temperature of the working fluid.
- To compare the performance of the PTC using nanofluids with that of a PTC using a conventional working fluid.
- To provide insights into the potential of nanofluids for improving the thermal performance of PTCs, and inform the design and optimization of PTC systems.

Review of Literature

Many studies have been carried out on the performances of PTCs using synthetic oils and nanofluids as heat transfer fluid. The latter are formed by suspending nanoparticles (1nm100nm) in a traditional heat transfer fluid. These so-called nanofluids display good thermal properties compared with fluids conventionally used. S. Kakaç [1] is the first who used the nanofluid term at the 1995 annual winter meeting of the American Society of Mechanical Engineers as he presented the possibility of doubling the convection heat transfer coefficients using nano-fluids. In addition to this work, researchers in Japan and Germany have published articles concerning similar fluids. K. Das et al. [2] conducted experiments with the Al2O3 and CuO nanoparticles suspended in water under laminar flow. They found that the heat transfers could increase of about 40% while the improvement of thermal conductivity doesn't exceed 15%. S. Z. Haris et al. [3] studied theoretically the efficiency of a low-temperature nanofluid-based direct absorption solar collector using a mixture of water and aluminium, where the nanoparticle volume fraction varies from 0.1 % to 5%. They found that the efficiency increases significantly for low volume fractions of nanoparticles, whereas for values higher than 2% the efficiency levels off. H. Tyagi, [4] carried out both experimental and the CFD investigations with different types of nanofluids like carbon nanotubes, graphite and silver, in order to study their effect on the system performance. Otanicar T.P et al. [5] investigated theoretically in 2012 thermal efficiency of a nanofluid-based direct absorption solar parabolic trough collector. They used aluminium nanoparticles at the volume fraction of 0.05% suspended in the base fluid Therminol-VP1. V. Khullar et al. [6] have used Al2O3 nanoparticles for the preparation Al2O3-H2O nanofluid. This prepared sample was used as a working fluid in flat plate solar collector, and it was found that efficiency of collector got improved by 28.3% at 0.2 wt% of nanofluid as compared with water. Yousefi T et al. [7] carried out comparative analysis on the efficiency of tubular solar collector with three different nanofluids consisting of Al2O3, ZnO and MgO in water based and it was found out that that the nanofluid of ZnO-water at 0.2% volume concentration was a better selection as working fluid in the solar collector than other tested nanofluids. Han D et al. [8] carried out an experiment with nanofluid of single wall carbon nanohorns (SWCNH) dispersed in water to investigate their thermal and optical characteristics in view of their use as working fluid in solar collector device. It was reported that their thermal conductivity was higher as compared with conventional water. Saini E. et al. [9] carried out both experimental and theoretical investigation in order to evaluate the performance of nanofluid as working fluid in high flux solar collectors. The result showed that when graphite therminol VP-1 nanofluid with a volume concentration of 0.01%

nanofluid was used as a working fluid in solar collector, an improvement in efficiency of about 10% was seen as compared to water. Taylor R.A. et al. [10] performed experimental investigation in order to study both absorption and the scattering properties of carbon nanohorns nanoparticles dispersed in an aqueous solution of water for the usage as a working fluid in solar collector.

Research Methodology:

PARABOLIC-TROUGH COLLECTOR:

The collector, the parabolic trough, is a trough the cross-section of which has the shape of a part of a parabola. More exactly, it is a symmetrical section of a parabola around its vertex.

Parabolic troughs have a focal line, which consists of the focal points of the parabolic cross- sections. Radiation that enters in a plane parallel to the optical plane is reflected in such a way that itpasses through the focal line. A proof of the existence of a focal point is presented in the annex. An appropriate analytic representation of a parabola is

$$y = \frac{1}{4f}x^2$$

Where f is the focal length, i.e., the distance between the vertex of the parabola and the focal point. NANO FLUIDS:

The average size of the Nano particles is 20-60 nm. To calculate the thermo physical properties of both Nano particles and base fluid. The base fluid is water. The properties of the Nano particles Al2O3 and CUO are shown in the table below 1.

Table 1: Thermo physical properties of nano particles and water

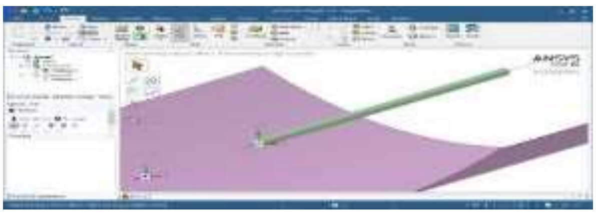
Property	CUO	Al_2O_3	Water
Density[kg/m3]	6500	3970	997.1
Specific heat[J/kg-K]	535.6	765	4178
Thermal conductivity [W/m-K]	20	40	0.61
Dynamic viscosity [kg/m-s]	-	-	0.000853

ANALYSIS PROCEDURE IN ANSYS FLUENT:

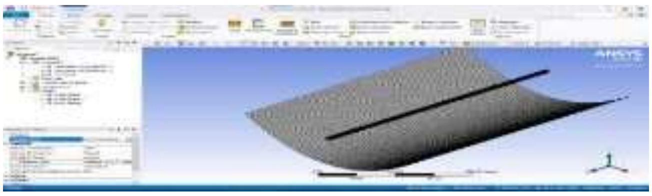
The procedure of solving a problem in ANSYS fluent is a step-by-step procedure which includes importing or designing geometry, generating mesh, setting up the physics and solver conditions, solving the problem for solution and observing the results.

Figure 1-3 represents pre-processing elements Geometry, Meshing and Model Setup.

Figure 4 represents parameters given to solar collector and Fig 5-6 represents boundary conditions.



1. Fluid domain model designed in space claim



2. Meshed domain

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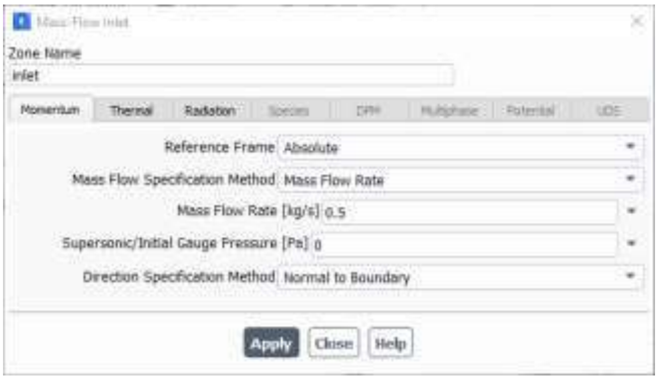
3. radiation model set up for analysis

4: Parameters given to solar calculator

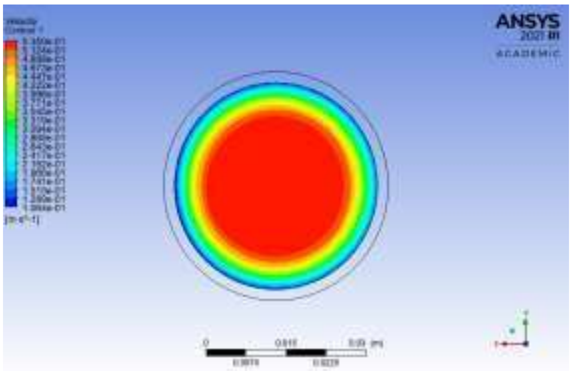


5. Inlet Boundary conditions

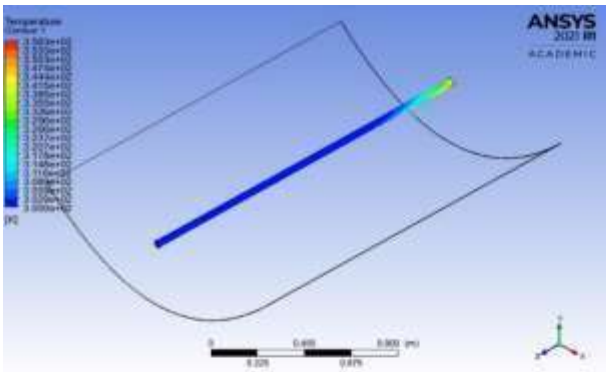
6. Boundary condition for absorbing surface wall

Results and Discussion

Fluent analysis of parabolic trough collector with different volumetric concentration of water based Al2O3 and water based CUO nanofluids was done using ANSYS software and results are discussed here. Fig 7-8 shows computational fluid dynamics counters. Fig 9-13shows Temperature counters of Al_2O_3 nanofluid at different concentrations. Fig 14-18 shows Temperature counters of CuO nanofluid at different concentrations.

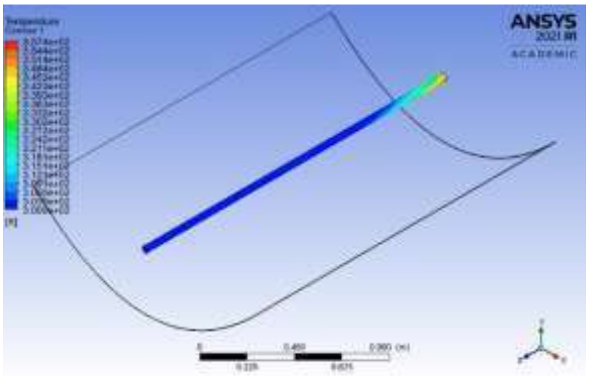


7.Temperature counter with water as Working fluid

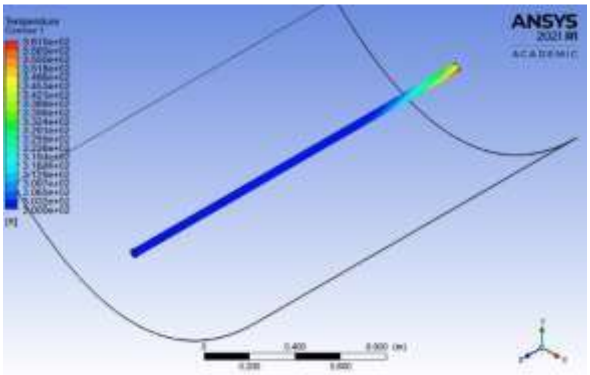


8.Velocity counter with water as working working fluid

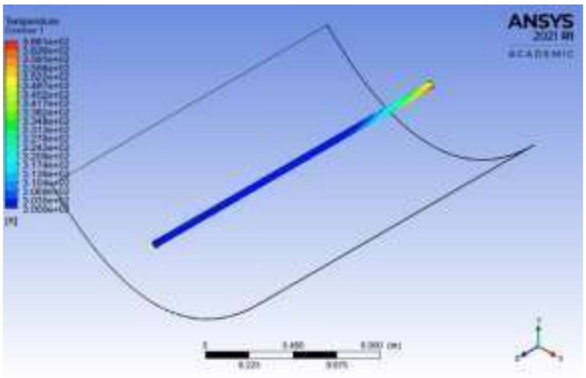
TEMPERATURE COUNTERS OF NANOFLUIDS:



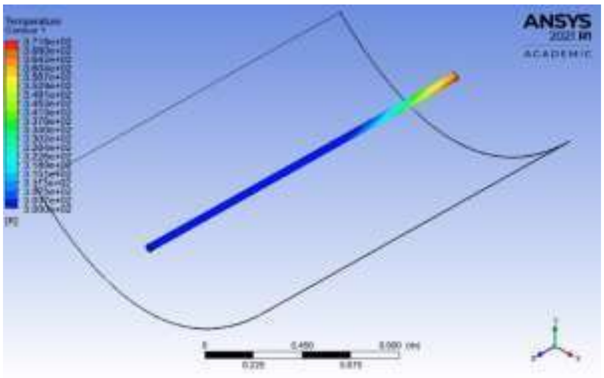
9.Temperature contour with 0.01% volumetric



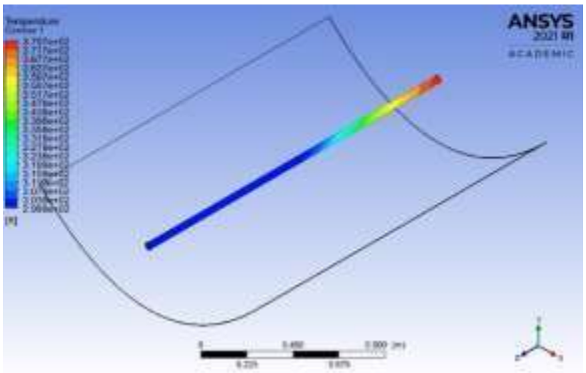
10.Temperature contour with 0.05% volumetric



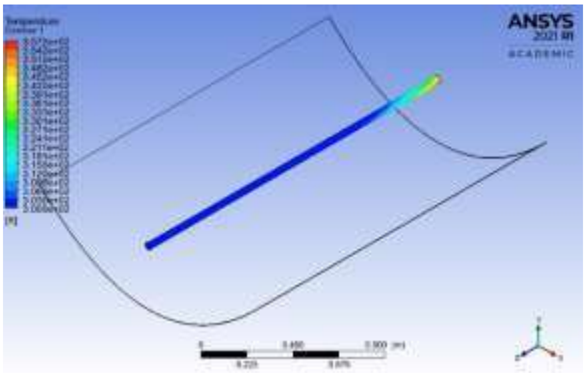
11.Temperature contour with 0.1% volumetric



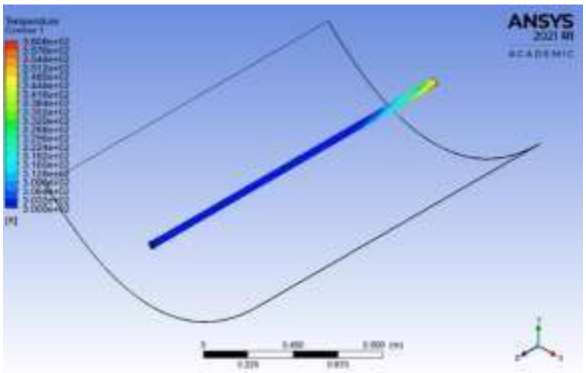
12. Temperature contour with 0.2% volumetric



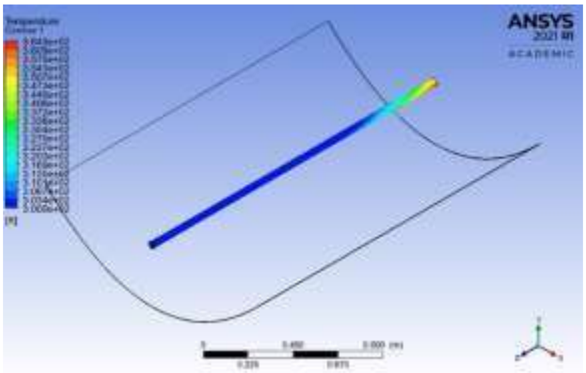
13.Temperature contour with 0.4% volumetric



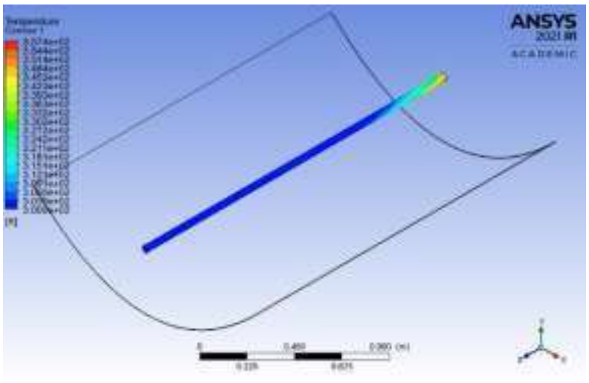
14. Temperature contour with 0.01% volumetric

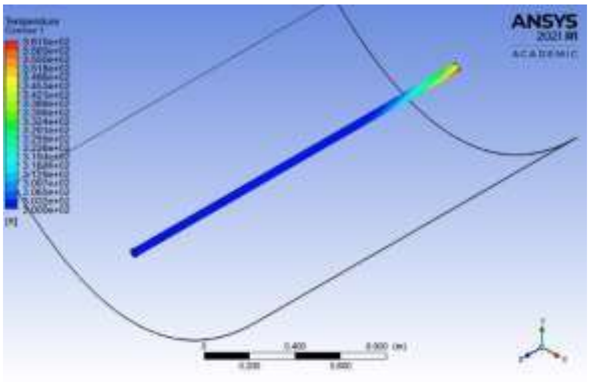


15.Temperature contour with 0.05% volumetric



16. Temperature contour with 0.1% volumetric





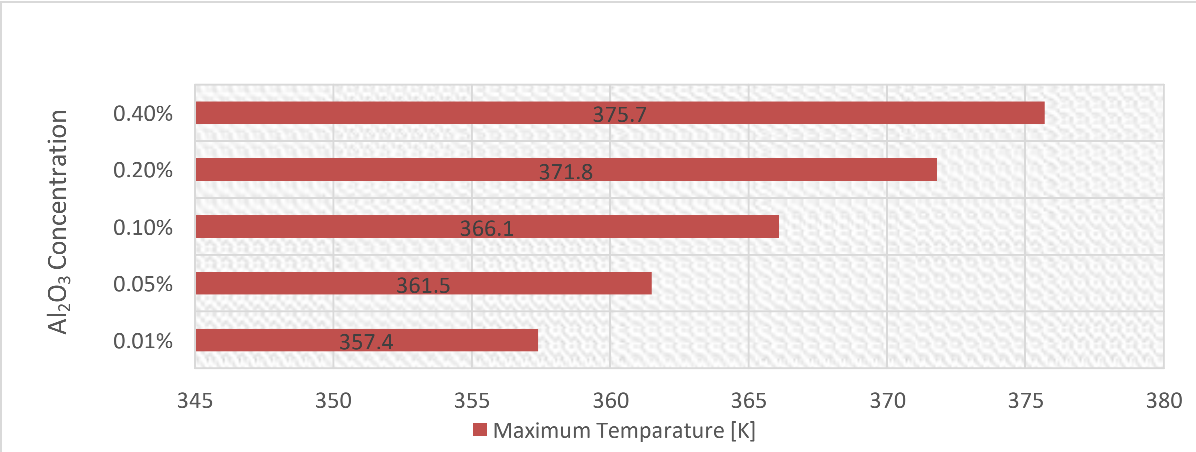
17.Temperature contour with 0.2% volumetric Concentration CuO-water nanofluid

18.Temperature contour with 0.4% volumetric Concentration CuO-water nanofluid

RESULTS:

Table 2 &graph 1 indicates the maximum temperature distribution in Al2O3-water nanofluid.
Table 3 &graph 2 indicates the maximum temperature distribution in CuO-water nanofluid. The maximum outlet temperature of Al_2O_3 - water nanofluid is shown in the table below.
Table 2: Maximum outlet temperature of Al_2O_3 - water nanofluid

Al_2O_3 Concentration [%]	**Maximum temperature [k]**
0.01	357.4
0.05	361.5
0.1	366.1
0.2	371.8
0.4	375.7

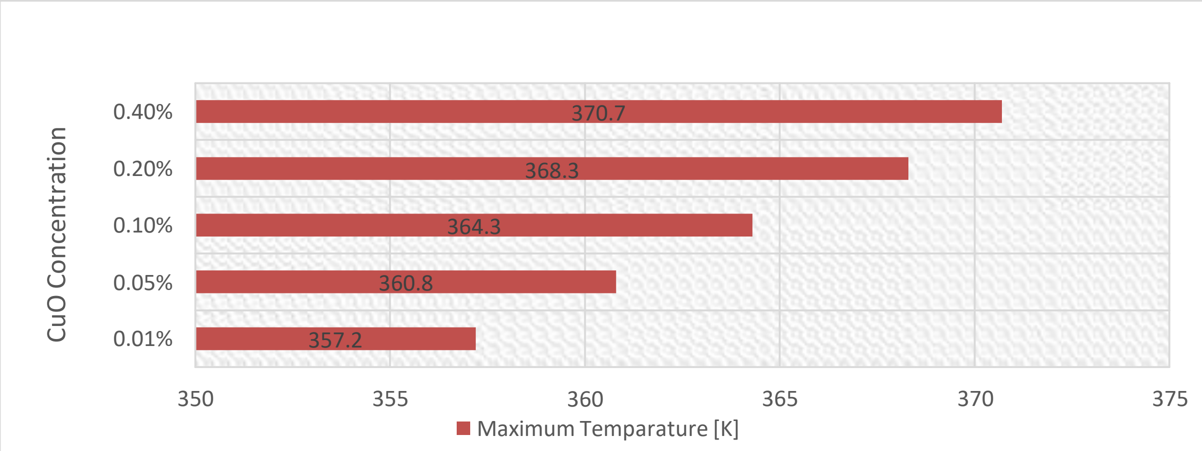


Grapgh 1: Maximum outlet temperature of Al_2O_3 - water nanofluid

The maximum outlet temperature of CuO - water nanofluid is shown in the table below.
Table2: Maximum outlet temperature of CuO - water nanofluid

CUO Concentration [%]	**Maximum temperature [k]**
0.01	357.2
0.05	360.8

0.1	364.3
0.2	368.3
0.4	370.7



Graph 2: Maximum outlet temperature of CuO - water nanofluid

Conclusion

Improvement in the thermal performance is reported through the CFD simulation results of parabolic trough collector, when nano fluid is used as working fluid when compared to water. Also, when volumetric concentration is made to increase, corresponding improvement in the performance of the parabolic trough collector is witnessed. With 0.4% vol.con. of Al2O3 - water nanofluid as working fluid, 0.5 kg/s of inlet mass flow rate and 300K inlet temperature the maximum outlet temperature of 375.5K is observed.

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