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Comparison of Efficiency of Solar Water Heater Using Different Nanofluids In CFD

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ABSTRACT

Since the industrial revolution, fossil fuel has been the main resource for generating power and energy. However, with an increase in environmental awareness, people realized the huge negative impact of fossil fuel burning on Earth. Consequently, the concept of renewable energy emerged, and the field of renewable energy has seen an increasing number of researchers devote effort to solving the energy crisis facing humanity. Among all the renewable energy sources, solar energy plays one of the important role in the development of industry. This study on workbench 2021R1 was used to model nanofluid flow and heat transfer in the tube of a flat plate solar collector. The flow in the tube is laminar. Two types of nanoparticles, i.e., Al2O3 and CuO, with three different volume concentrations, i.e., 0%, 0.5%, and 1% in water, were chosen for comparison purposes. The inlet temperature of the fluid was assumed to be uniform at the room temperature of 300K. In this thesis, the results of a simulation are discussed on outlet temperature, efficiency. The outlet temperature of the nanofluid was greater than that of pure water, and the difference increased with the volume concentration of the nanoparticles. Furthermore, the water-based CuO nanofluid has better performance than the water-based Al2O3 nanofluid. The efficiency of the solar collector did not increase when nanoparticles were added, owing to limitations of the model; an example of a limitation is that solar energy absorption by nanoparticles was not considered in the model.

Keywords : - Fossil Fuel, Nano fluid, Nano particles, Solar collector, Solar energy

I. INTRODUCTION

1.1 Solar energy

Conventional fuel has been the main source of energy since the industrial revolution, and it has been a major contributor to environmental pollution. According to a report by the United States Energy Information Administration coal, petroleum, natural gas, and other gases accounted for about 60.8 % of total amount of electricity produced in the US in 2021, nuclear power accounted for about 18.9%, and renewable energy sources accounted for about 20.1% [1].While in india total use of energy from coal, petroleum, natural gas 70%,nuclear energy 1%,renewable energy 4%,hydroelectricity 4% other by 11%.

People discovered that using fossil fuels for energy generation harmed the environment as their environmental awareness grew. Each and every government is actively looking for solutions to meet its energy of the future needs through alternative energy sources. One of the renewable energy sources is solar energy. It is one of the most plentiful and clean alternative energy sources, and it may be used to generate electricity. The US has 72 GW of capability for solar energy, enough to power over 14.2 million house, according to the SEIA website. Five countries, according to Boyle are the most solar-powered. China, for example, has 1305 GW of capability for solar energy and the big operating solar power plant. Total energy generation in india is 3,99 GW . The electricity generation target of thermo, hydrolic, nuclear power and Bhutan import for the year 2021-22 get fixed as 1456 Billion Unit (BU) [2].

Increasing the efficiency of solar power generation and storing solar energy efficiently are currently the most difficult tasks. The strength of the sun fluctuates depending on where you are .As a result, certain places are better suited to solar energy production than others. are not in your favour. Solar energy, as stated by the National Renewable Energy Laboratory, The Mojave Desert's intensity is double that of the Pacific Northwest, implying that Solar energy can be used to generate additional electricity in the Mojave Desert. More For this, study into the materials used in PV cells as well as the design of solar power collectors is required. Developing the amount of solar energy produced. On earth tropical zone is get more sunlight than other place on earth. Since we know that india come in this region so solar energy can play important role in development of india.

1.2 Solar Collectors

Solar collectors include flat plate solar collectors (FPSCs), evacuated tube collectors, line focus collectors, and point focus collectors. Each form of solar collector has its own distinct characteristics. Solar power can be generated with high efficiency using line focus and point focus collectors. However, both collectors are expensive, and their installation requires a large amount of room. Although the evacuated tube collector is one of the most effective solar collectors and can operate in extremely cold temperatures, it is also the most costly form of hot water solar power collector. Some solar collectors turn solar energy into heat, which is subsequently transferred to a working fluid. Solar water heating (SWH) is a term used to describe such a system. The working fluid n solar collector is water.

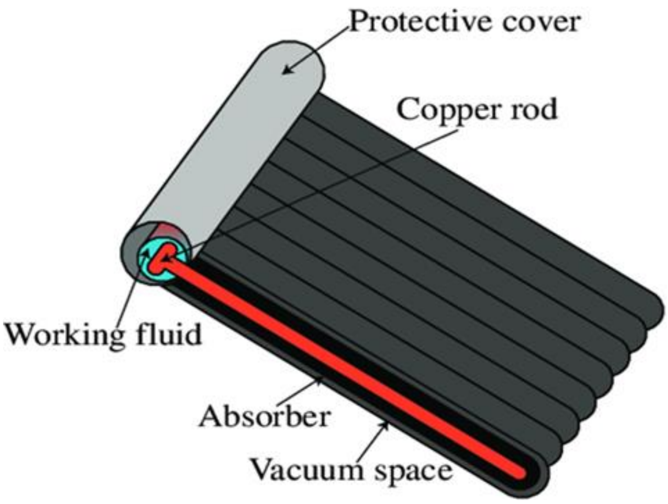


Figure 1. Evacuated tube solar collectors [8]

1.3 Nanofluids

Researchers have recently started looking at using different materials as the working fluid in solar collectors to improve efficiency, and the concept of nanofluid has arisen. Choi and Eastman said in 1995 that the creation of a workable fluid was limited by low thermal conductivity. They came up with the novel idea of enhancing the heat transfer fluid's thermal conductivity by adding metallic nanoparticles (aluminium nanophase material) to it [3]. More academics began to look at this new notion, which was a significant advancement in heat transmission. Nanofluids are suspensions or solid-liquid mixes created by dispersing small nonmetallic and metallic solid nano material across fluids. Nanofluids are the fluids which comes after mixng of nanosixe nanopaticle in base fluid. Nanoparicles size should be less than 100nm in base fluid which is useful to easily copatiable with base fluid. Today nanoparticles-based fluid is useful to heat transfer. Because of the mix of convection and conduction, nanofluids can provide improved heat transmission as well as additional energy transfer γ-particle dynamics and collisions. Thermophysical properties like conductivity, heat transfer rate of metallic nanofluid better that that of its base fluid like water, oil. Nanofluids have shown more promise in recent years in a variety of sectors, including solar collectors and solar thermal storage. Till now study on nanofluid is not more than than two dacde still due to its themophysical properties are better than other base fluid so majority of resercher is focused on study on nanofluid.

1.3.1 Classification of Nanofluids

Nanofluids are basically two type

(1) metallic nanofluids are those nanofluids

Example for metallic nanofluids are Cu, Al, Ti, Ag, Au.

(2) Non-metallic nanofluids

Example for non metallic nanofluids are CuO, TiO_2, Al_2O_3,

Nnaostructured materials can be classified in four types acouding totheir dimentional studies.

a) Zero dimensional are those has no dimention like Gold nanoparticles, Quantum dots.

b) One dimensional are those which has only one dimension for example Wires, Nanotube.

c) Two-dimensional nanostructure are those which ate thinfilms, plates layered structure.

d) Bulk tree dimensional namomaterial which form 3D material like lipsome, dendrimer.

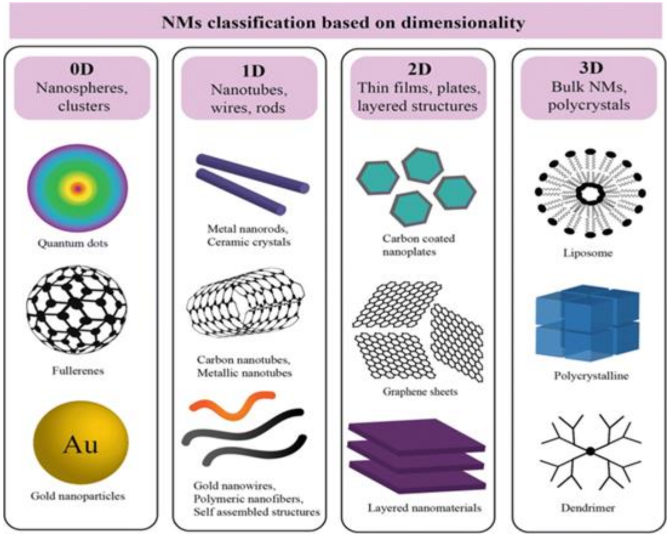


Figure 2. Nanoparticles type on dimensionality[10]

Nanofluids are created by diffusing nanostructured components into pure working fluids at a Nano scale.The classification of Nano fluids is based on commonly used base fluids and nanomaterial's. For making Nano fluids it depend on based fluid like water, oil, synthetic oil, vegetable oil, ethylene glycols, propylene glycols operating range of thermal system. When it is used in its has it's on pro and con depending on their thermal properties. Since nanofluid has better physical properties than other based fluid also has low cost and availability so it is used in many low temperature based application.

1.3.2 Formation of nanofluids

Nanofluids thermo physical properties like conductive heat transfer coefficient thermal diffusivity thermal conductivity and heat storage capability are better than other thermo fluids like water and oil so nanofluid is called as advanced thermofluid. Nanofluids have unique features that make them useful in a variety of applications and allow them to work more effectively than microfluids. The formulation of nanofluid suspensions is critical because it affects a number of key factors, like as suspensions stability and optical properties. The production of nano linked materials, which are then coupled with base fluids to produce a liquid-solid suspensions, is the initial stage of nanofluids formulation.

A lot of physiochemical, chemical and physical processes are employed to produce nanoparticle in nanotechnology. Furthermore, nanoparticles are evaluated using several systematic methodologies such as transmission X-ray, infrared, X-ray diffraction, and Raman spectroscopy during the synthesis process. Two standard methods are used to prepare stable nanofluids first is the single step method for making it two unique way for fabrication and mixed with based fluids, and other one is the two step method for making it two different processes for making stability technics after that dispersion for uniform solid particles. In terms of flexibility, thermo physical characterisation, and economics, both fundamental techniques have advantages and disadvantages.

Two-step technique

The two step technique aslo called top-down dispersion method. This technique is most straightforward, cost efficient, and adaptable method. In this method firstly make solid nanomaterials then it is suspended in pure fluid stabilised chemical mechanical process to stable nanofluid in base fluid. Huge material to breake into nanomaterial various method is used like wet chemical etching or mechanical prosses

Bulk materials are initially broken down into an appropriate Nano range utilising a variety of methods, including wet-chemical etching and/or physical techniques. A few intermediate procedures, such as particle drying, storage, and dispersion, are also included in the synthesis step.

Single-step technique

The single-step called bottom-up synthesis technique employs wet-chemistry procedures to manufacture nanofluids by fabricating nanomaterials and dispersing them into a base fluid simultaneously. This process uses a variety of chemical vapour decomposition techniques to create a stable nanofluid, electric explosion, including plasma arc, spraying, laser. These methods avoid the two-step process's clustering difficulties and produce a stable nanoparticles suspension in the base fluid. Using copper wiring for electrode, Lo produced CuO/water Nano fluids in a single step. They discovered that the method may produce a stable, uniformly distributed dispersion with no particle agglomeration.

Figure 3. Nanoparticles silver oxide Ag2O [11]

1.3.3 Physical properties of water-based nanofluids

The physical parameters of a fluid are influenced by the inclusion of nanoparticles, such as density, thermal conductivity, specific heat and dynamics viscosity. The thermophysical characteristics of the nanofluid have been calculated.

Density of Nanofluid(ρ_{nf})

Density

$$\boldsymbol{\rho_{nf}} = (1 - \emptyset)\boldsymbol{\rho_{bf}} + \emptyset\boldsymbol{\rho_{np}}$$

Where ρbf = Density of base fluid, ρ_{np} = Density of nanoparticle, and $\emptyset$ = volume concentration of nanoparticle.

(a) **Specific Heat of Nanofluid ($_{p,nf}$)**

Specific heat, a property of nanofluids, is used to quantify the working fluid's ability to store energy. The change in specific heat is caused by factors like its size, and accumulation of volume of nanoparticle in its base fluid at different temperature. As a result, accurate Cp values are required for energy balance. Specific heat of nanofluid increase with increase in concentration of nanoparticls.

$$C_{p,nf} = \frac{(1-\emptyset)\rho_{bf}C_{p,bf}+\emptyset\rho_{np}C_{p,np}}{(1-\emptyset)\rho_{bf}+\emptyset\rho_{np}}$$

Here, $C_{p,bf}$ = Specific heat of nanoparticle

$C_{p,bf}$ = Specific heat of base fluid.

Thermal Conductivity of Nanofluid(k_{nf})

To a large part, the applicability of nanofluids in every application is determined by their thermal conductivity. Many parameters, including particle composition, proportions or form of nanoparticls, base fluids substance, tempe, and others, impact the ability to conduct heat of Nnanofluids, according to experiments. the ability to conduct heat rise with rise in concentration of nanoparticles. Mathematical formula for thermal conductivity is

Thermal conductivity

$$k_{nf} = \frac{k_{np}+2k_{bf}+(k_{np}-k_{bf})\emptyset}{k_{np}+2k_{bf}-(k_{np}-k_{nf})\emptyset} k_{bf}$$

Where k_{np} = Thermal conductivity of the nanoparticls, k_{bf} = Thermal conductivity of the base fluids.

Viscosity of Nanofluid(u_{nf})

Viscosity is a measurement of a fluid's reluctance to deform under shear force, generally referred to as its thickness. The impact of viscosity on heat transfer and the energy required to pump Nano fluids in circuits where they are employed as secondary fluids is critical to understand. Viscosity increase linearly with increase in concentration of Nano fluids up to 2% concentration and also decrease with increase in temperature.

Viscosity of nanofluids

$$\mu_{nf} = \mu_{bf}(1- \emptyset)^{-2}\emptyset m$$

$$\emptyset_m = 5.10^{-6}T^2-4.10^{-4}T+0.118$$

Where μbf =Viscosity of the base fluid, $\emptyset$ =Volume concentration of the nanofluid, and $\emptyset_m$ =Maximum packing fraction of nanoparticles may accomplish.

Table 1. Physical property of materials [7]

Material	Thermal Conductivity $k(w.m^{-1}.k^{-1})$	Specific heat $C_p(J.kg^{-1}.k^{-1})$	Viscosity μ(Pa.s)	Density $\rho(kg.m^{-3})$
Water	0.577	4180.1	0.0008893	1000
AL_2O_3	40.2	765.2	0.0008891	3970
CuO	18.1	540.2	0.0008891	6510

Table 2. Physical properties of nanofluid

Nanofluid	Thermal conductivity $K(w.m^{-1}.k^{-1})$	Specific heat- $C_p(J.kg^{-1}.k^{-1})$	Viscosity-* μ(Pa.s)	Density- $\rho(kg.m^{-3})$
AL_2O_3 0.5%	0.5843	4113.2	0.0010443	1014.85
AL_2O_3 1%	0.5927	4048.33	0.0012427	1029.7
CuO 0.5%	0.5839	4064.69	0.0010443	1027.7
CuO 1%	0.5919	3955.41	0.0012427	1055.1

II. LITRATUR REVIEW

Choi & Eastman 1995 [1] demonstrated that employing nanoparticles, traditional liquid thermal performance may be significantly enhanced.

Yousefi et al. 2012 [2] studied the impact of utilising an Al2O3 nanofluid as an absorbing medium in a flat-plate solar water heater, and found that by using 0.2% Al2O3 nanofluid relative to water has higher efficiency by 28.3% and if surfactant is use efficiency increase by 15.63%. He use two step method for making nanofluid and where size of nanoparticle is 30nm.

Said et al. 2013 [3] hasd study on thermophysical by using AL2O3 nanofluid and their influence on a flat plate collector that used Al2O3 to distribute water or glycol. Since base fluid has low thermal thermal conductivity than nanofluid. As volume concentration of nanoparticle increase viscosity also increase and when temperature of nanofluid increase linearly viscosity decrease exponatinaly. He had use two step method for this experiment and size of nanoparticle is 14nm.

Moghadam et al. 2014 [4] had study the efficiency of flat plate collector by using CuO as nanofluid and found that efficiency increase by 16.7%. Here mass flow rate is taken 1.3kg/min and vol concentration of CuO is 0.4%. He use two step method while size of nanoparticle is 40mn.

Meibodi et al. 2015 [5] had study on efficiency of flat plate collector by using SiO2 and found its efficiency is 63.2% and as concentration increase SiO2 particles rise from 0 to 1% its efficiency increase from 4 to 8%. He use two step method for making SiO2 nanofluid whre particle size is 40nm.

Zeng et al. 2014 [6] had study the efficiency of flat plate collectors by using CuO as nanofluids and found that when concentration of nanofluid increase will increase then efficiency decrease he show that in CuO-H2O and size is 25nm 0.1% vol concentration and efficiency is 23.5 and when he use 0.2% vol concentration efficiency get decrease which show that after increasing volume concentration of nanoparticle efficiency decrease.

Faizal et al. 2015 [7] had study on flat plate collector using SiO2 nanofluid and found that when he work on 0.2% SiO2 by volume concentration efficiency increase by 23.5% and also found that Nusselt and Reynolds number also increase while pressure drop by small margin. Hethake size of nanoparticle is 15nm and process of mixing nanofluide is two step methodVerma 2016 [8] examined MgO nanofluid effectiveness in flat plate solar collectors. and found that when concentration is 0.75 % by volume of MgO nanoparticles and water as base fluid by mixing by two step method efficiency increase by 9.34% and rate of mass flow at 1.5 lpm and size of nanoparticle is 40nm.

Ziyadanogullari et al. 2018 [9] had study on flat-plate solar collectors by using different nanofluids and found that when concentration of nanolide is 0.2% by vol and size of nanofluide less than 50nm then maximum rise of efficiency in CuO nanofluid while lowest efficiency by using TiO nanofluid.

Mirzaei et al. 2018 [10] had study of flat plate solar collector and Al2O3 nanoparticles water as base fluid and size of nanoparticles 20nm while volume concentration is 0.1% and optimum flow rate is 2L/min and efficiemcy increase by 23.6%. and storage tank temperature increase by 8.4% compare to water.

Tong et al. 2019 [11] had study on comparison of a flat plate collector using Al2O3 nanofluid, CuO nanofluid and water found that highest efficiency 77.5% when AL2O3 and 0.01% Al2O3 nanoparticles which is 21.3 % higher than water fluid. Where size of nanoparticles 20nm.

Mousavi et al. 2019 [12] Had investigated by mixing two nanofluid together MgO/TiO2 with ratio of 80/20 and then base fluid as water with 0.1 % nanoparticles with size of 30nm and found that themal conductivity efficiency increase by 21.3%.

Sundar et al. 2020 [13] had study on thermosypson solar collector twisted tape inserts with Cu nanofluid and found that Thermal conductivity is increased by 8.97% and 23.56% at 0.3% concentration, respectively, while viscosity is increased by 1.081-times and 1.153-times at 30 C and 70 C, respectively, when compared to water.

Gupta et al. 2020 [14] had study on solar water heater using nanofluid with size of 30nm & nanofluid Al2O3 with flow rate is 60L/h and found improvement in efficiency 40% with 0.02% Al2O3 nanofluide in solar water heater as a volumetric absorber.

Alwan et al. 2021 [15] had study on flat plate solar water collector and found that maximum temperature vary from day to day temperature 50 to 70°C and average day temperature difference is vary from morning to mid day 5 to 8°C.

Singh G. et al 2021[16]. Had study on different type solat collector using nanofluid nanofluids and found that evacuated tubular collector increase temperature by using CuO nanofluid with base fluid as water and for parabolic through solar collector Al2O3 and TiO2 nanofluids base fluid is water increase efficiency.

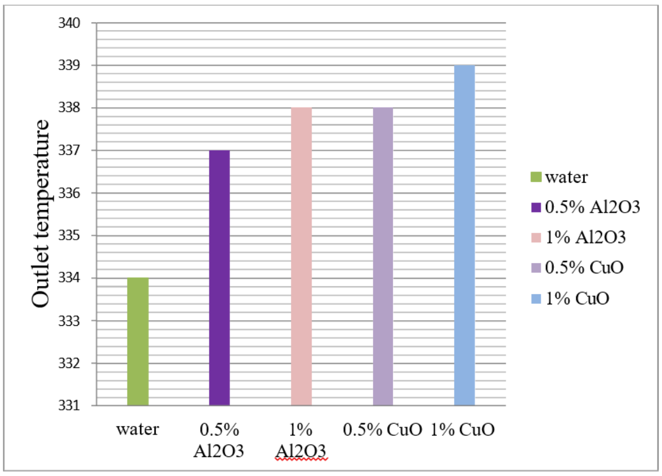
Rahul kumar et al. 2022[17] had study on cerium oxide nanofluid based fluid as water on flat plate collector at rate of mass flow is 0.1% of cerium oxide and flow rate as 0.5 L/min which increase efficiency by 18.5%.

III. Results and Discussion

Here we discuss on the simulation result in ansys, outlet temp of fluids, efficiency of flate plate solar collector.

6.1 Outlet temperature

In this study five type of fluid 0.5%Al2O3, 1%Al2O3, water, 0.5%CuO, 1%CuO by using workbench software of ansys. The findings for these five-operation fluid might be computed at the same time, making it easy to compare the results. The addition of nanoparticles to the base fluid affected the fluid's thermophysical characteristics, causing the change in simulation results. Input temperature is at 300K. As working fluid is nanofluid outlet temperature is higher comparison to water and also as concentration increase of nanofluid outlet temperature even higher as shown in figure 10.



As result shown in figure 10 Al2O3 has less performance CuO because specific heat of CuO is smaller so that outlet temperature CuO is higher.

Figure 10. Comparison of outlet temperature

Here as a working nanofluid is AL2O3 with 0.5% concentration which show fluid temperature vary from inlet to outlet.

Outlet temperature 337K

Inlet temperature 300K

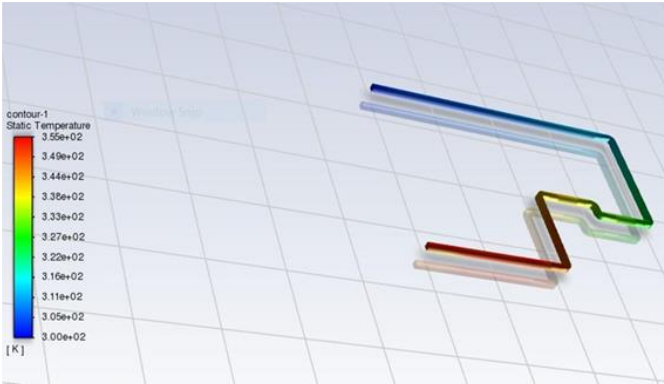


Figure 11. Contour of pipe

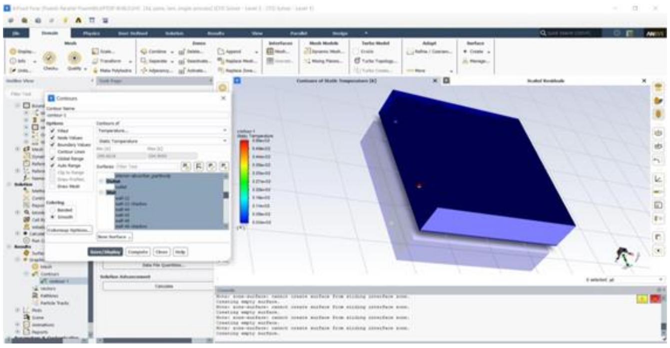


Figure 12. Contour and result

4. Efficiency of solar collector

Efficiency is is among the most crucial important factors to consider when evaluating the solar collector efficiency. Many studies has found by adding nanoparticle to solar collectors improves their efficiency. The outcomes of past investigations are also addressed in this session, in addition to the simulation results.

To assess the effectiveness of the FPSC, five unique substances were employed as the working fluids in the simulation: water, 0.5% Al2O3, 1% Al2O3, 0.5%CuO, and 1%CuO. The conclusions of the computations were substantially different from those of other investigations. Water efficiency was 51.6% at flow rate mass of 0.04 kg/s; 0.5% and 1% Al2O3 efficiency was 61.36% and 62.11%, respectively; and 0.5% and 1%CuO efficiency was 63.21% and 64.94%, respectively.

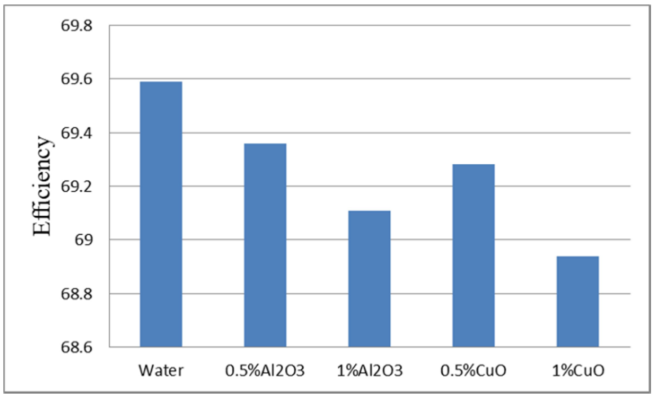


Figure 13. Efficiency graph

IV. Conclusion

One way for improving solar collector performance is to add nanoparticles to the working fluid (water).In this experiment study that as by using nanofluid outlet temperature increase. As volume concentration increase outlet temperature increase. CuO has better performance than Al_2 O_3.Efficiency of flat plat collector is low while using nanofluid.

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