Heat Transfer Performance Analysis of Direct Absorption Solar Collector (DASC) using Nano-Fluids

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Abstract: *Productivity of sun oriented collector mostly relies upon the thermophysical properties of the fluid which is engrossing the heat. Research has been done to decipher that the thermal properties (thermal conductivity, heat capacity, viscosity, and so th.) of the fluids which is utilized to retain the energy has a noteworthy part to make the framework more viable. By thoroughly investigating the past research, it has been derived that ordinary fluids can assimilate heat up to a specific cutoff which, thus, confines the efficiency of the solar collector. The new class of fluids called "Nanofluids" possess very good thermal properties, due to this fact nanofluids can be employed in solar collectors the augmentation of performance. There, this thesis is the most part centered around execution and assessment of solar collectors using nanofluids.*
The primary targets of this experimental work are as follows:
1-Experimental examination of the collector efficiency the duration of the day utilizing water.
2-Investigation of collector efficiency the duration of the day (hourly) using $CuO - H_2O$ nanofluid.
3-Investigation of collector efficiency with varying volume fraction of nanoparticles.
4-To examine the temperature variation throughout the day (hourly).
5-To compare the performance of solar collector nanofluid and water.

Keywords: *nanofluid; solar thermal; volumetric absorption; DASC; exergy; optimization.*

I. INTRODUCTION

Solar Energy

Since time immemorial, the energy present in abundance is the solar energy. In fact, it is very much important energy source the entire solar system with it being the basic source of all the varieties of energy whether being conventional or non-conventional, renewable or non-renewable, wind or tidal energy. All these energy sources come indirectly from the ultimate source, the sun. The most intriguing reality about solar energy is the magnitude of the incident solar radiation striking the earth in one day is almost equal to the world energy requirement a year. Hence harnessing the solar energy poses significant problems that amount to such large-scale loss in energy.

Solar Energy Collector

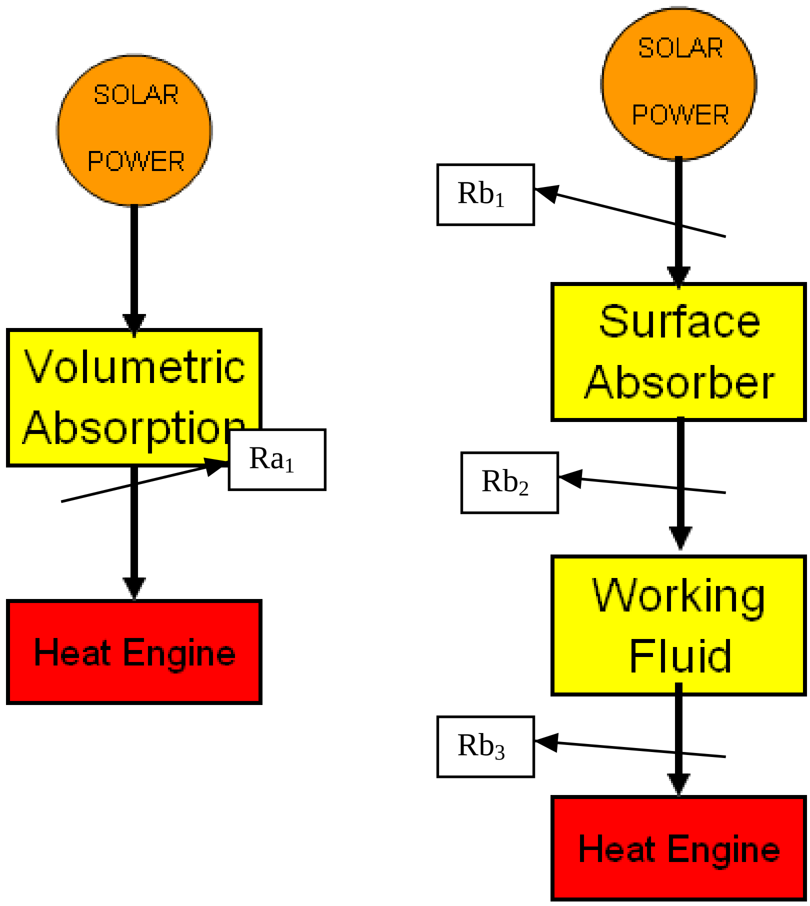
Solar Collectors are those which collects the directed radiation from the sun by directing or concentrating it on a device in such a manner so as to use it absorbing the incoming sun radiation.

Direct Absorption Solar Collector

The name DASC is given so as to simply get an increment in the efficiency of the collector by absorbing the incident radiation of the sun in fluid flowing in the collector in volumetric consideration [1]. The schematic resistance diagram is manifested in Figure 1.4. this diagram gives the difference between DASC and traditional plate collector. In conventional flat plate collectors, an absorbing plate is present to absorb the incident solar radiation whereas in case of DASCs the solar energy is absorbed directly by the fluid flowing thereby removing the absorber plate or in other words the flowing fluid acts as the absorbing plate. In this way, DASC lowers down the heat opposition offered when contrasted with traditional flat plate collectors. The equation concludes that the aggregate resistance of ordinary flat plate collector is large as that to DASC system. The collector's performance not only depends on how compelling absorber is but also onto the effectiveness in heat transfer and better thermal properties are (e.g. Thermal Conductivity, Heat capacity) of the fluid. The properties of absorption usually deployed in solar collectors are of low grade and in turn, resulting in limiting the efficiency of the collector.

Hence, there arises a requirement to utilize energy proficient heat exchange liquids the mere purpose of obtaining high efficiencies. One such method efficiency augmentation is the use of nanofluids in solar collectors. These fluids can be made use of in the solar collectors as nanofluids are the composition of nanosized particles which are dispersed in some base fluid or combination of base fluids.

$$Ra_1 + Ra_2 < Rb_1 + Rb_2 + Rb_3$$
$$\text{Where, } Rb_2 = Rcv + Rcd$$



Nanofluids

The term nanofluid was devised by Choi (1995). The suspension of nanoparticles into the base fluids is known as nanofluids [2]. Nanomaterials have distinct mechanical, optical, electrical, magnetic and thermal properties with mean particle size below 100nm. A very small number of nanoparticles when scattered in any host fluids (e.g. Water, Oil, Ethylene Glycol) can augment the thermal characteristics of the fluid comprehensively.

II. METHODOLOGY

In this chapter, the procedure to evaluate the objectives is discussed. Main steps of the methodology are as follows:

ASHRAE Standards 93-77 the testing of solar collectors.
Experimental Set-up.
Direct absorption method is used the experiment.
Nanofluid used:
Base fluid – Water
Nanoparticles – Copper Oxide (CuO)
ASHRAE Standards 93 – 77 [11, 12]

Following ASHRAE standards are used this study.

Finding the solar radiation in plane of collector, a pyranometer as classified by the World Meteorological Organization should be used.

Data ought to be taken amid the middle of the day, ideally when the sun rays incident angle is under 30˚.

A number of tests ought to be led, every one of which decides the average efficiency of a 5 – min period.

In computing efficiency, the gross frontal area is taken into account in lieu of aperture area.

The efficiency plot is manifested by devising efficiency as an element of contrast between the initial fluid temperature and the encompassing temperature divided by the incident solar radiation.

It is vital the collector to perm preconditioning test bee the start of experiments. The collector must be left in the open three consecutive days with no passage of fluid through it and with normal incident sun-based radiation estimated in the plane of the collector gap surpassing 17,000 kJ/m^2 days.

Bee the efficiency test, the time steady is resolved. The time consistent test decides the transient thermal properties of the collector.

All the tests might be made inside utilizing a sun-oriented simulation test system if wanted

Combined Cycle Analysis

The performance of combined cycle measured in terms of specific work output and thermal efficiency depends upon number of parameters. If all the parameters are taken into account in calculating specific work output and thermal efficiency it would be very tedious job.

Assumptions

In order to analyze certain assumption are made. They are:

1. The base wall is thought to be adiabatic.
2. The fluid is encased by a glass cover at the top.
3. The uppermost surface is thought to be presented to the encompassing atmosphere, so the heat losses are due to convection.
4. Atmospheric absorption is neglected.

III. ANALYSIS

The experimental efficiency of the collector is:

General Expressions Heat Absorbed by Solar Collector

Qa = m C (T2 – T1) x 1000 W…

Total Mean Solar Radiation falling on Solar Collector

Qi = GTACr

η = m C (T2 − T1) ⁄ GTACr

m = ρ x v…

Equations nanofluids

η = m Ceff(T2 − T1) ⁄ GTACr

m = ρeff x v….

ρeff = (1 – ϕ) ρf + ϕρp

ϕ = Vp/ (Vp + Vf) …

Ceff = {(1 – ϕ) ρf cf + ϕρpcp} / ρeff

IV. RESULT & DISCUSSION

Here a thorough elucidation of the result and their analysis, which were obtained after perming the experiment are given and shown. Here calculation DASC is followed by the variation it shows in efficiency and also the effect of nanofluid on the collector's performance.

Solar Collector Performance Calculations

The experimental efficiency of the collector is:

General Expressions

Heat Absorbed by Solar Collector

Qa = m C (T2 – T1) x 1000 W…

Total Mean Solar Radiation falling on Solar Collector

Qi = GTACr

η = m C (T2 − T1) ⁄ GTACr

m = ρ x v…

Equations nanofluids

η = m Ceff(T2 − T1) ⁄ GTACr

m = ρeff x v….

ρeff = (1 – ϕ) ρf + ϕρp

ϕ = Vp/ (Vp + Vf) …

Ceff = {(1 – ϕ) ρf cf + ϕρpcp} / ρeff

As per ASHRAE standard, this experiment inlet fluid temperature of the DASC is assumed as 29˚C. Correction factor 'Cr' the collector is taken as 0.92. The correction factor is introduced to compensate the heat lost from the collector via. convection, dust and wind.

As the augmentation of mass flow rate takes place in the DASC there is a minute change in temperature difference but a drastic increment in efficiency. The most convincing reason would be that percentage change in temperature difference is very less in comparison to efficiency. It is easily evident that there is augmentation of temperature difference till 1:00 PM and then it decreases, whereas collector efficiency, its lowest value is at 1:00 PM. The reason being the rate of heat absorption capacity is lesser than the rate in increment in solar irradiation falling on earth.

At CuO (φ = 0.05%) Nanofluid

Density of Base fluid (water)

ρf = 1000 kg/m3

Variation of temperature difference and collector efficiency CuO nanofluid of volume fraction 0.05% throughout the day graph that the value of efficiency of nanofluid is greater as compared to that of water because of better thermophysical properties possessed by it, although now and again the efficiency of water was found to be higher.

Solar collector performance using CuO nanofluid (ϕ = 0.005%)

The variation in temperature difference and efficiency gives same profile CuO nanofluid of volume fraction 0.005% throughout the day. During mid-day when solar irradiation is having peak value, efficiency has the lowest value and temperature difference has the highest value collector efficiency is greater CuO nanofluid (φ = 0.005%) than water and also CuO nanofluid (φ = 0.005%) temperature difference is more CuO nanofluids as compared to water. The variation though is in the range of 2˚C - 3˚C as the thermal conductivity of CuO nanofluid is higher as compared to that of water.

CuO – nanofluid line is lowering because at that day the radiation was not of good intensity.

Collector efficiency is function of mass flow rate and temperature difference. So, when temperature difference of CuO nanofluid increases, there is an augmentation in efficiency of the solar collector keeping mass flow rate the same, the reason being CuO-H2O nanofluid has a greater heat capacity when compared to water. Now, when there is an increment in rate of flowing fluid there can be seen an apparent augmentation in the efficiency of the solar collector both water and nanofluid.

It is viable from the values that density possessed by CuO nanoparticles is pronounced in comparison to water, theree, when nanofluid is made the specific heat of the fluid is high than base fluid, which there elevates the efficiency of the collector. In the plots manifested in some cases, it is seen that efficiency of water is more the reason is clearly coagulation of nanoparticles at increased mass flow rates and mixing time of particles

V. CONCLUSION

The current thesis focuses upon experiment and simplified analysis of how DASC perm. The concluded points of this experimental work are given below:

Use of CuO-H2O nanofluid increases the efficiency of the collector in the range of 4-6%.

Nanofluid with 0.005% volume fraction exhibit efficiency increment by 2-2.5 % than ϕ=0.05 nanofluid used.

The small particle size is the main reason augmented efficiency, steering it to an elevated heat absorption rate and leading to efficiency improvement.

The very basic complications associated in use of nanofluids which include particle agglomeration and cost of preparation of nanoparticles is high and should be focused upon.

The significance of nanofluids in sun based energy systems is a modern expedition field, there is also a numerous result and analysis available and in the same time various differences in results and principles used in application So, it is necessary to further theoretical as well as experimental work, investigations to increment efficiency of solar collector and to deduce solid and valid results.

There, it can be summarized that great potential of nanofluids is seen in solar thermal applications and they are answer the heat transfer limitation of conventional heat transfer fluid.

VI. REFERENCES

- *[1] Minardi.J.E, Chuang.H.N, Solar Energy 17, 179 (1975)*
- *[2] Das.K.S, Choi.S.U.S, YU.W, Pradeep.T, Nanofluids Science and Technology, ISBN 9780-470-07473-2, Page (1-30)*
- *[3] Otanicar.T.P, Phelan.P.E, Prasher.R.S, Rosengarton.G, Taylor.R.A, Nanofluid – Based direct absorption solar collector, (2010)*
- *[4] Tyagi.H, Phelan.P, Prasher.R, Predicted Efficiency of a Low-Temerature Nanofluid based Direct Absorption Solar Collector, Journal of Solar Energy, Vol.131(2009)*
- *[5] Taylor.R.A, Phelan.P.E, Otanicar.T.P, Walker.C.A, Nguyen.M, Trimble.S, Prasher.R, Applicability of Nanofluids in high flux solar collectors, Journal of Renewable and Sustainable Energy 3,023104 (2011)*
- *[6] Han.Z, Nanofluids with Enhanced Thermal Transport Properties, Department of Mechanical engineering, University of Maryland at college park, (2008)*
- *[7] Duffie.J.A, Beckman.W.A, Solar Engineering of Thermal Processes (Wiley, New York, (1988).*
- *[8] http://www.dg.history.vt.edu/ch2/conversion.html*
- *[9] Pyranometer CMP -11 from CWET.*
- *[10] Garg.H.P, Prakash.J, Solar Energy Fundamental and Applications, Tata McGraw Hill, ISBN 0-07-463631-6, Page (35, 46,116), (1997).*
- *[11] Sukhatme.S.P, Solar Energy (Principles of Thermal Collection and Storage), Tata Mcgraw Hill, ISBN 0-07-451946-8, (1984).*
- *[12] Khanafer.K and Vafai.K, A Critical Synthesis of thermophysical characteristics of Nanofluids, International Journal of Heat and Mass Transfer (Under press), (2011)*

[13] *Zhou.K, Wang.R, Xu.B, Li.Y, Synthesis, "Characterization and catalytic properties of CuO nano crystals with various shapes", Institute of Physics Publishing Ltd., Printed at UK, (2006)*

[14] *R.Winston, J.C.Minano, P.Benitez, Nonimaging Optics, Elsevier Academic Press, pp. 217, (2005)*

[15] *Goswami, Yogi.D, Kreith, Frank, and Kreider, Jan F., Principles of Solar Engineering, 2nd edition. Taylor and Francis, Philadelphia, PA, (2000)*

[16] *Chang.M.H, Liu.H.S, Tai.C.Y, "Preparation of Copper Oxide nanoparticles and its application in nanofluid", Powder Technology 207 (2011) 378 – 386.*

[17] *Rai.G.D, Solar Energy Utilization, Khanna Publishers New Delhi, (1996)*

[18] *Kalogirou.S.A, "Solar Thermal Collectors and Applications", Progress in Energy and Combustion Science, 30 (2004) 231 – 295.*

[19] *Yousefi.T, Veysi.F, Shojaeizadeh.E, Zinadini.S, An Experimental investigation on the effect of Al2O3 – H2O nanofluid on the efficiency of flat plate solar collectors, Renewable Energy 39 (2012) 293 – 298*

[20] *Lenert.A, "Nanofluid – based Receivers High – Temperature", High – Flux Direct Solar Collectors, Massachusetts Institute of Technology (June 2010)*

[21] *Wang.X.Q, Mujumdar.A.S, "Heat transfer characteristics of nanofluids": a review, International Journal of Thermal Sciences 46 (2007) 1 -19.*

[22] *Wang.X, Xu.X, Choi.S.U.S, "Thermal conductivity of nanoparticle-fluid mixture", Journal of Thermo physics and Heat Transfer 13 (4) (1999) 474 – 480.*

[23] *M.Karami and M. A. Bhabadi, "Experimental investigation of CuO nanofluid-based Direct Absorption Solar Collector residential applications", Renewable and Sustainable Energy Resources, 51 (2015) 793-801*

[24] *A.Kasaeien and Roya Rezeai, "Experimental investigation on the thermal behaviour of nanofluid direct absorption in a trough collector.", Journal Of Cleaner Production, 158 (2017) 276-284*