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HP11704806-Experimental investigation on Heat Transfer Enhancement of solar water heater with Multisize Particles in Nanofluid

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Abstract

Recent studies of nanofluids have shown that the Single size nanoparticles when mixed in fluid medium such as water and ethylene glycol enhance the thermal conductivity of the colloids when compared to the fluid medium. However, experimental studies conducted on theEffective thermal conductivity of Nanofluid, while using initial particle distribution consisting of range of diameters, has reported their results at volume-weighted average diameters. Here, we use experimental studies to investigate ether effect of initial particle distribution or the effect of heat enhancement on the effective thermal conductivity of nanofluids. The study reveals that the experimental performed with multi-sized nanoparticles predict the effective
Thermal conductivity values of nanofluids closer to the experimental values than the corresponding volume weighted average diameters. Inhomogeneous coagulations
in the multi-sized nanofluids were found to be a major factor for the deviation of effective thermal conductivity of the nanofluids in single- and multi-sized nanofluids. Our results suggest that initial distribution of particles has a significant role in predicting the enhancement Heat Transfer of solar flat plate collector by using MultisizeNanofluid.

Keywords:*Nanofluid, thermal conductivity.nanoparticles,*

1. Introduction

Energy consumption increases very rapidly as the world developing. Conventional sources are not able to fulfill the today energy needs. Fossil fuels are the main conventional sources for energy production till now. The two main limitations of fossil fuels: Limited in quantity and environment pollution makes the world think for alternative energy sources. Renewable energy sources eliminate the weaknesses of conventional sources. But because of less knowledge about these sources and high initial cost of the conversion systems limits the use of these resources. From the renewable energy resources, solar energy has a huge potential for the fulfillment of today energy needs. Solar Water Heating systems are generally very simple using only sunlight to heat water. A working fluid is brought into contact with a dark surface exposed to sunlight which causes the temperature of the fluid to rise.

The concept of nanofluids is developed at Argonne National laboratory (Choi, 1995) is directly related to trends in miniaturization and nanotechnology. Recent reviews of research programs on nanotechnology in the U. S., China, Europe, and Japan show that nanotechnology will be an emerging and exciting technology of the 21st century and that universities, national laboratories, small businesses, and large multinational companies have already established nanotechnology research groups or interdisciplinary centers that focus on nanotechnology. It is estimated that nanotechnology is at a similar level of development as computer/information technology was in the 1950s. Solids have orders-of-magnitude higher thermal conductivities than those of conventional high heat transfer rate.

Many different particle materials are used for nanofluid preparation. Al_2O_3, CuO, TiO_2, SiC, TiC, Ag, Au, Cu, and Fe nanoparticles are frequently used in nanofluid research. Carbon nanotubes are also utilized due to their extremely high thermal conductivity in the longitudinal (axial) direction. Base fluids mostly used in the preparation of nanofluids are the common working fluids of heat transfer applications; such as, water, ethylene, glycol and engine oil. In order to improve the stability of nanoparticles inside the base fluid, some additives are added to the mixture in small amounts.

Since thermal conductivity is most important parameter responsible for enhanced heat transfer, many experimental studies were reported on this aspect. The thermal conductivity of nanoparticles was found to vary with the size, shape and material of nanoparticles.

Some researcher have used single size Nanofluid as absorbing medium in flat plate solar collector due to their enhanced thermal properties than that of conventional fluid and their results are quite promising. At this stage it is necessary to select a multisize nanoparticle material for preparation of nanofluid which gives comparatively higher enhancement in thermal performance and at same time cost effective so that such research can come close to practical feasibility.

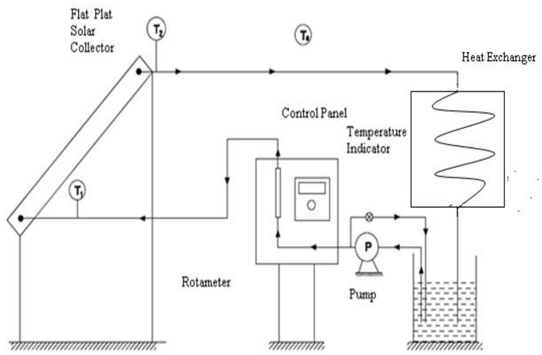


Fig.2.1Schematic diagram of developed experimental system.

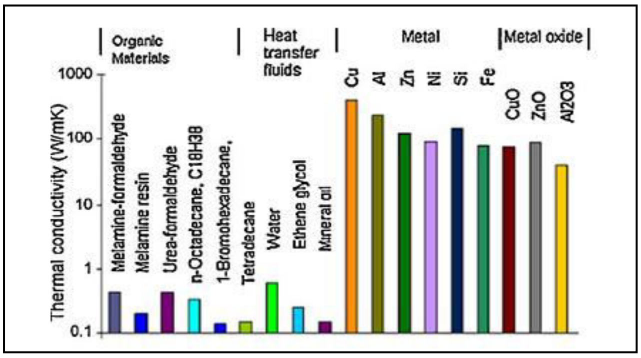


Fig 2.2.Shows the thermal conductivity of typical materials. Solids have thermal conductivities that are orders of magnitude greater than those of traditional heat transfer fluids.

2. Preparation of Nanofluid:-

The selected nanopowder for the proposed study is (Cu) 50 nm & 100 nm size mix with (DIW) water as base fluid. The nanopowder is to be purchased from the NanoshelUSA.The amount of nanopowder required for the same can be calculated as below.

The total volume of nanofluid to be prepared =Volume of collector pipes + Volume of heade pipe + Volume of footer pipe + Volume of nanofluid filled by the connecting pipes of the set up + Volume of Nanofluid occupied by the pipes in the heat exchangerThe amount of nanopowder required is calculated by,

Thus for given volume fraction of nanofluid and decided amount of nanofluid to be prepared the mass of nanoparticle to be added in the base fluid can be calculated. As the quantity of nanopowder required for the same for volume fraction basis is large and considering the cost of same it will be later decided the weathered to conduct the experiment with preparation of nanofluid on volume basis or weight basis.

Fig.2.3 Cuo(Multisize)nanopowder(50&100) nm Size

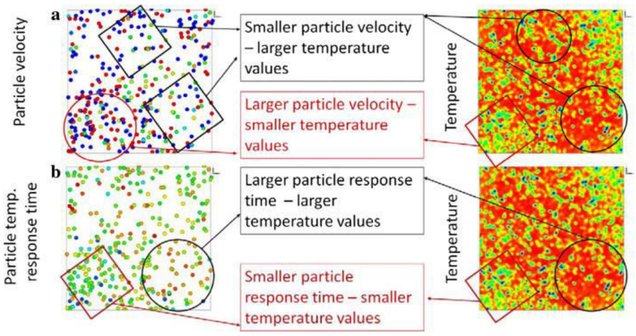


Fig 2.4 Fluid temperature in correlation with the particle velocities and particle temperature response time

3. Mathematical model

Assumptions made before developing mathematical model:

Temperature stratification of the water within the tank is neglected as a first approximation.

1. Diffuse radiation is neglected.
2. Adiabatic side and bottom surfaces of the SWH.
3. Constant ambient temperature.
4. The (cold) supply water temperature is 20°C.
5. The regular flow and in case stability in the pipeline.
6. There is no energy stored in the glass cover and absorber plate.
7. The neglect of the temperature difference through the glass cover.

The properties of the fluid constant.

The useful energy can also be expressed in terms of the energy absorbed by the absorber and the energy lost from the absorber as given by Eq. (6).

$Q_u = m\, Cp\, (To - Ti)$

$Qu = Ac\, F_R [(G_T\, (\zeta\alpha) - U_L (Ti - Ta)]$

The instantaneous collector efficiency relates the useful energy to the total radiation incident on the collector surface by Eq.

$\eta_i = Q_u / (A_c G_T) = [m\, C_p (T_o - T_i)] / [A_c G_T]$

$\eta_i = F_R (\zeta\alpha) - F_R U_L [(Ti - Ta) / G_T]$

The rate of thermal energy input *(Q_{in})*, the rate of thermal energy gain *(Q_g)* and the instantaneous efficiency *(η)* of each collector were calculated as below:

$$Q_{in} = I_t \cdot A_{coll}$$

Where $A_{coll}$is the area of collector.
Measuring the collector area on which solar radiations fall we get,

$$Q_g = m\, C_w (T_o - T_i)$$

Where *m* is mass flow rate and *Cp* is specific heat of water

$$\eta_{inst} = Q_g \; / \; Q_{in}$$

Whereη_{inst} is the instantaneous efficiency

Considering the parameter affecting on the collector efficiency i.e. mass flow rate of nanofluid, mass fraction of nanofluid, inlet temperature of nanofluid and collector tilt (inclination angle) mathematical model can be developed. The developed model can help to analyze the effect of said parameters on the efficiency of flat plate solar collector. In addition to this, correlations available in literature to find the properties of nanofluid can be utilized. The correlations are as follows,

4.Nanofluids Thermal and Flow Properties

The thermal and flow properties of Nanofluid are calculated using different available correlations as below:
Thermal conductivity using **Timofeeva** correlations as below:

$$K_{nf} = [1 + 3\phi] K_w$$

Inclination angle 30° and flow rate 50 LPH				
Time	Temperature Rise(ΔT)			
	water	1 % vol fraction		
		CuO (50 nm)	CuO(100 nm)	CuO(50 nm + 100 nm)
11	9.1	11.6	11.9	12.2
11.3	9.3	13.3	13.8	14.3
12	12.1	12.7	13.2	13.5
12.3	11.5	14.5	14.9	15.5
1	10.9	15.8	16.2	16.6
1.3	11.3	14.6	14.9	15.1
2	8.3	14.4	14.5	14.6

Viscosity of nanofluid using Drew and **Passman**correlations as below:

$$\mu_{nf} = [1 + 2.5\phi] \mu_w$$

The density and specific heat using **Pak and Cho** correlations as below:

$$\rho_{nf} = \phi\rho_{np} + (1-\phi)\rho_w$$

$$Cp_{nf} = \phi Cp_{np} + (1-\phi) Cp_w$$

5.Literature Review:

Nanofluid is suspensions of metallic or nonmetallic nanoparticles in a base fluid; this term was introduced by Choi (1). A substantial increase in liquid thermal conductivity, liquid viscosity, and heat transfer coefficient are the unique characteristics of Nanofluid. It is well known that metals in solid phase have higher thermal conductivities than those of fluids (2). For example, the thermal conductivity of copper at room temperature is about 700 times greater than that of water and about 3000 times greater than that of engine oil. The thermal conductivity of metallic liquids is much greater than that of nonmetallic liquids. Thus, fluids containing suspended metal particles are expected apparent enhanced thermal conductivities rather than pure fluids (3). Masuda et al. (4).dispersed oxide nanoparticles (Al_2O_3 and TiO_2 with 4.3 wt%) in liquid and showed that the thermal conductivity is increased by 32% and 11%, respectively. Grimm dispersed aluminum particles (1–80 nm) in a fluid and claimed a 100% increase in the thermal conductivity of fluid for 0.5–10 wt%. Using the Nanofluid in solar collectors has been subjected to a few recent studies. Yosefi et al. [6] investigated the effect of MWCNT as an absorbing medium on the efficiency of a flat-plate solar collector experimentally and reported 35% enhancement in the collector efficiency for 0.4 wt%. Also the same researchers [7] repeated the experiments with Al_2O_3–Water Nanofluid and reported 28.3% enhancement in the collector efficiency for 0.2 wt%.Otanicaret al. [8] studied experimentally the effect of different Nanofluid on the efficiency of the micro-thermal-collector. He reported an efficiency improvement up to 5% by utilizing the Nanofluid as the absorption medium. Mahian et al. [9] examined the Nanofluid applications in solar thermal engineering systems; in this review, the effects of nanofluids on the performance of solar collectors and solar water heaters were investigated from the efficiency, economic and environmental considerations viewpoints.

6. RESULT AND DISCUSSION

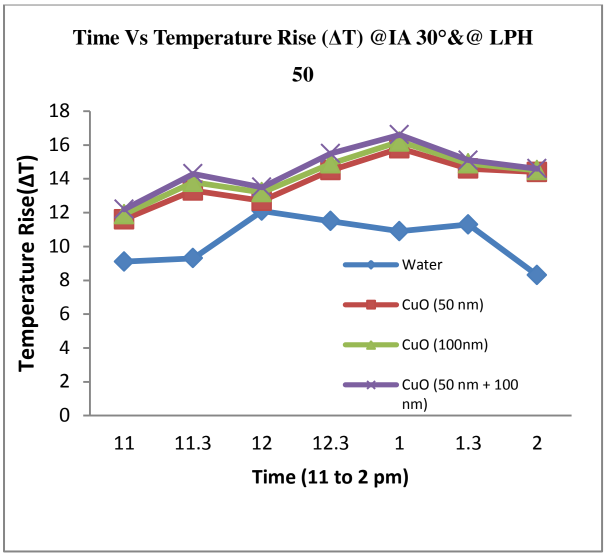
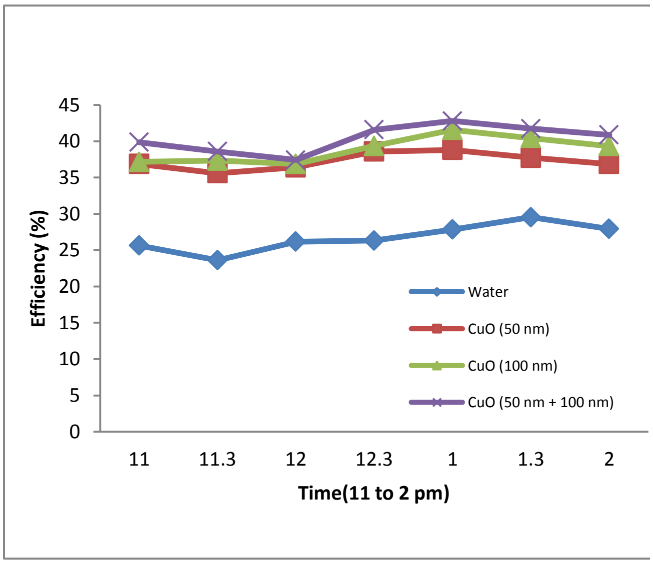


Table No. I. Variation of Temperature rise with time at 30^0 inclination angles for mass flow rate 0.01389 kg/sec.

Figure 1.& 2 shows the curves for efficiency of 1% vol. concentration of different range of nanofluidnanofluid for 30 degree inclination angle and for mass flow rate of the water 0.13389kg/s during time 11.00 am to 2.00 pm among all vol. Concentration the efficiency 9 temperature rise of CuoMultisize(50+100 nm) nanofluid and from graph it is clear that as time span increases efficiency will going to vary. As mass flow rate and inclinationangle increases collector efficiency& temperature also goes on increasing for all 2% or 3 % vol. concentration.

Table No. II. Variation of instantaneous collector efficiency with time for 30^0 inclination angles and mass flow rate of 0.01389 kg/sec.



5. Conclusion

The effective thermal conductivity of nanofluids was found to alter significantly with the presence of multi-sized distribution of nanoparticles in fluid. The multi-sized nanofluid

Experimental predicted the effective thermal conductivity of nanofluid closer to the experimental value when compared to the volume weight averaged single-sized nanofluid.The effect of multi-sized nanoparticle distribution on the heat transfer in nanofluids was studied by experimental nanofluids with multi-sized particles and corresponding single sized particles. The study revealed that the dispersion of particles and the heat transport in nanoparticles were affected by the presence of multi-sized nanoparticles. Thus, both these mechanism had significant contributions in affecting the effective thermal conductivity of nanofluids.Deviation in the effective thermal conductivity values was found to increase with the increase in the size difference in the initial distribution. It was also found that this deviation was more predominant when the particle sizes were smaller.The experimental concluded the observed in the multi-sized particles can be responsible distribution of the effective thermal conductivity of multisizednanofluids from the single-sized nanofluids. This study concludes that initial distribution of particles has a significant role in predicting the effective thermal conductivity of nanofluids. The experimental result data a compare to single size nano particle 100 nm cu /DIW with Multisized Cu/DIW (50 nm & 100 nm) found effective Heat transfer rate.

5. References

Time	Instantaneous collector Efficiency (%)			
	Water	1% Vol Fraction		
		CuO (50 nm)	CuO (100 nm)	CuO (50nm+100nm
11	25.63113	36.87064	37.15424	39.87064
11.3	23.61586	35.58365	37.33654	38.58365
12	26.15896	36.41339	36.86986	37.41339
12.3	26.32624	38.58349	39.35965	41.58349
1	27.8468	38.79614	41.56257	42.79614
1.3	29.53188	37.7355	40.42535	41.7355
2	27.92482	36.86914	39.32566	40.86914

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