SYNTHESIS AND PROPERTIES OF TIO_2:CUO:CR_2O_3 COMPOSITE NANOFLUID FOR SOLAR EVACUATED WATER HEATERS

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Abstract: This study has been undertaken for the characterization and to study the effect of composite-based nanofluids on thermos-thermal conversion in solar evacuated tube water heating systems. Enhancement in solar radiation absorption leading in the direction of the optimum heat transfer rate. Ultimately which is resulted in effective and efficient heat transfer. This paper is an exploration of harvesting solar energy through the usage of nanofluid-based evacuated tube solar collector. The synthesis of TiO_2:CuO:Cr_2O_3 based nanofluid made of equal proportions of nanoparticles, prepared by the ultrasonic probe method. The most affecting parameter stability of nanofluid has been checked for different time intervals. Various important properties of nanofluid have been studied and observed shown remarkable improvement in thermal properties. The derived results can lead towards the development of highly efficient domestic solar water heating systems in replacement of water.

Index Terms – Composite nanofluid, photo-thermal, evacuated tube.

I. INTRODUCTION

The dispersion of nanoparticles in the basic fluid have revealed the relevance of applications requires effective and quick heat transfer [1,2]. In conventional heat transfer fluids like molten salts, water and ethylene glycol (EG), nanofluids are not transparent to the solar energy, hence they scatter significantly and absorb the solar radiation passing through them [3,4]. In connection to that, recently researchers propose non-concentrating solar collector with the use of nanofluids as the working fluid [5]. Similar attempts have been made to discover the viability of nanofluids in the case of high flux (heat) collectors [5,6]. A substantial rise of thermal conductivity, heat transfer coefficient and liquid viscosity, are the inevitable characteristics of nanofluids. It is observed that almost all the metals have higher thermal conductivity in solid phase than base fluids [7]. The thermal conductivity of metallic liquids is very much greater than that of non-metallic liquids. The liquids with suspended metal particles are subjected to thermal conductivity enhancement rather than pure liquids [8].

30% heat transfer enhancement is possible with Al_2O_3 nanofluid as compared to the base fluid especially water. The thermal conductivity of MWCNT (Multi-Wall Carbon Nano Tubes) nanofluid can be enhanced up to 150% [9]. For 2% volume concentration of Cupric-Water nanofluid, pumping power and overall heat transfer coefficients are more than base fluid [10]. Thermal conductivity, density and viscosity of the nanofluid increase with the increment of volume concentrations. The rise in the temperature, thermal conductivity & specific heat were observed to be intensified, and while the viscosity and density have been decreased.

II. PREPARATION OF NANOFLUID

The nanoparticles in powder form dispersed in the base fluid is called nanofluid. The enhancement of thermal conductivity of the nanofluid greatly depends on the preparation of nanofluid using nanoparticles. There are mainly two methods of synthesizing nanofluids.

1. One-step method
2. Two-step method

From the literature, it is noted that nanofluids with oxide nanoparticles as well as carbon nanotubes can be produced well by a two-step method. Above methods are executed by chemical and physical routs to ensure that the liquid-solid mixture is quite stable to avoid clogging, agglomeration, probable erosion, poor thermal conductivity, additional flow resistance and poor heat transfer.

(a) One-step technique

The nanoparticles are simultaneously prepared and dispersed directly into the base fluid in one step technique. There are total fourteen various methods to produce nanoparticles [11]. This method is highly advisable to produce nanofluids of better thermal conductivity metals to avoid oxidation of particles and erosion. Agglomeration minimization is the biggest advantage of this method. This tendency increases equal dispersion in the hot liquids and the stability of the suspensions. The quantity limit of the production due to the gradual production process, low nanoparticles concentration & the high synthesis cost are the main disadvantages of one-step technique. Various methods are used evaporation, physical or chemical one-step methods have been used to reduce the cost & time.

(b) Two-step technique

In a two-step method of nanofluid synthesizing, firstly the nanoparticles are produced separately and then these nanoparticles are dispersed in a base fluid for exactly measured quantity.

The advantage of two-step method is that nanofluid can be produced easily and economically. On the other hand, due to van der Waals effect force of cohesion between nanoparticles the fast agglomeration of individual particles before an achievement of complete dispersion takes place. This agglomeration is the biggest obstruction in achieving high heat transfer performance because the quick settling of nanoparticles out of the base fluids and becomes worse as the concentration volume increases [11]. Agglomeration is a critical issue in all kinds of nanopowders technology, especially during nanoparticles transportation, drying and storage.

Several methods are used to eliminate agglomeration in a two-step process exploration towards commercialization by facilitating nanofluids mass production. In Two-step methods like ultrasonic disrupter, stirrer, high-pressure homogenizer and ultrasonic bath are well-known methods of two-step technique. The TiO_2–Water nanofluid was prepared with ultrasonic equipment and introduced by S. Choi et al. [12].

III. NANOPARTICLES SELECTION

Production point of view TiO_2 nanoparticles can easily be obtained as they are readily produced on industrial scales. With respect to their physic-chemical profile, they have better stability when dispersed in a base fluid even without the addition of stabilizer [13]. The enhancement of thermal conductivity reported of TiO_2 nanofluids as compared to water-based nanofluids, when Ethylene Glycol (EG), Propylene Glycol (PG) or paraffin oil used as base fluids. Investigation shows that for CuO nanofluid preparation the sonication time greatly affects the heat transfer performance & influenced by the nanoparticles concentration [14]. The thermal conductivity enhancement depends on the particle volume concentration and temperature of nanofluid. For the 1.2% volume concentration of CuO nanofluids, 10.8% to 43.2% enhancement of nanofluid thermal conductivity of nanofluids is observed. Above mentioned characteristic is very much helpful in photo-thermal conversion kind of application for solar water heaters.

IV. NANOPARTICLES SIZE

The size of particles plays a decisive part in thermal conductivity as well as heat transfer enhancement of base fluids. Several suspension sizes of milli and micrometre particles in host liquid are used to enhance the thermal conductivity, at the same moment the particles agglomeration is quick and settled down in the liquid. The sedimentation time decreases to reach in few cases for more than a few days or weeks. Due to increase in surface area, the thermal conductivity increases for the nanoparticles size in the range of 1–100 nm. Larger the relative surface area of nanoparticles, significant improvement in thermal conductivity capabilities and also rises in the stableness of the intermissions. In addition to that the size of nanoparticles is being reduced, the Brownian motion will be generated [15]. The nanoparticles size in the base liquid is quite important in the research field of the present era.

In this experimental work of nanofluid preparation the, TiO_2 nanoparticles of size 25 ± 5 nm, CuO nanoparticles size up to 17 nm and nanoparticles of Cr_2O_3 are of size 35 nm as provided by Nano wings Pvt. Ltd has been used.

V. NANOFLUID PREPARATION

In this experiment of nanofluid preparation, TiO2 nanoparticles of an average size of 25 nm with the purity of 99.9%, were used as purchased from the Nano wings Pvt. Ltd Company, Khamam, India. The size of the nanoparticles supplied from the appropriate supplier and used in this experiment is 20 – 30 nm. The base fluid is distilled water because boiling characteristics of the base fluids (water) are well known. The TiO_2 nanoparticles are commercially available. No surfactant or buffer was added in the nanofluids during the dispersion. The mixture of nanoparticles and the base fluid was sonicated with an ultrasonic probe for an hour to obtain nanofluid.

Cupric Acetate Monohydrate $(CH_3COO)_2Cu.H_2O$ powder in equal proportion is added in double distilled water for 0.6 molarities. For complete dispersion, the correct proportion of water and Cupric Acetate is a pre-requisite condition. Again stirring for 35 minutes and heating at 150°C for the complete dispersion of powder.

$C_{14}H_{23}Cr_3O_{16}$ (Chromium Acetate) powder for 0.4 molarities added in distilled water. Acetic acid (CH_3COOH) in the same quantity has been mixed up for nanofluid preparation. Complete mixture is stirred for complete dispersion of nanoparticles. Stirring with heating takes place at 170°C for 45 minutes. At the end of this task, complete dispersion of powder takes place and nanofluid is prepared.

All above individual nanofluids are mixed up with each other in 1:1:1 proportion to prepare a new one. Nanofluid prepared in this way for these processes remains stable for about a week and without any agglomeration. The base fluid (distilled water) is taken for the dispersion of nanoparticles.

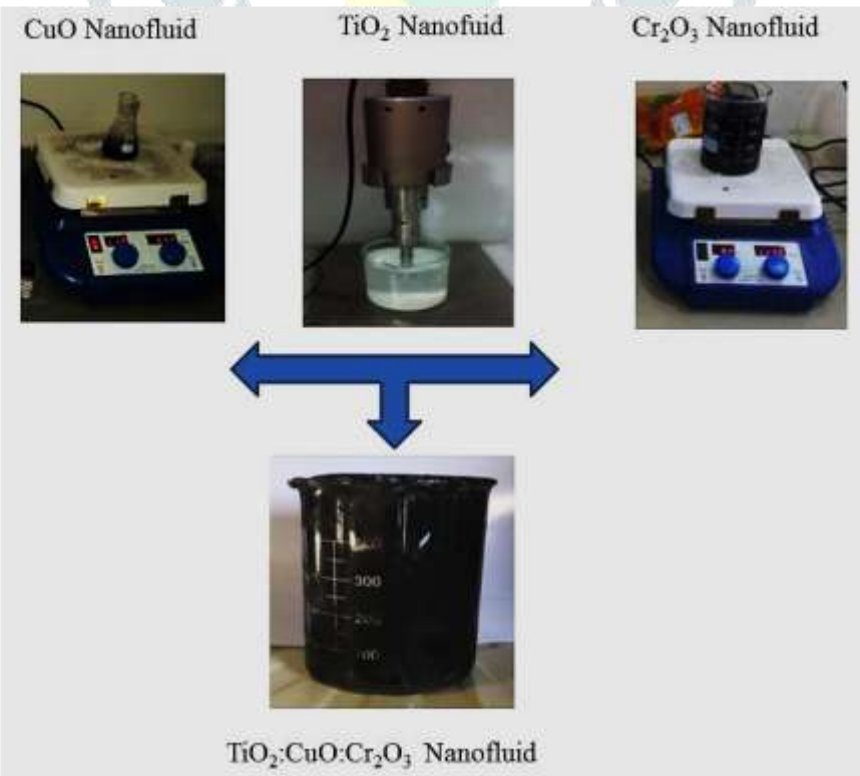


Fig. 1: Preparation of nanofluid in ultrasonication.

VI. RESULTS AND DISCUSSION

Tables 1 & 2 give all the required properties of the TiO_2, CuO, Cr_2O_3 nanoparticles and double distilled water as the base fluid.

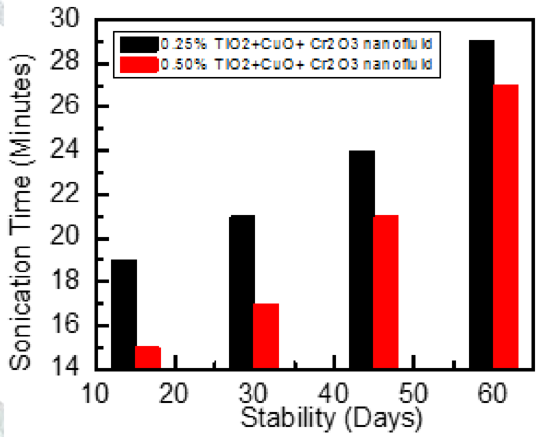
Nanoparticles (Powder phase)	Density g/cm^3	Specific Surface Area m$^{2/}$g	Thermal Conductivity W/mK	Specific Heat KJ/KgK
TiO2 (Anatase)	0.2-0.4	60	6	0.69
CuO (Monoclinic)	6.315	140	18	0.540
Cr Powder	0.13	80	42	0.46

Table 1 Major Properties of TiO_2, CuO, Cr_2O_3 nanoparticles

Powder phase	Density Kg/l	Thermal Conductivity W/m K	Specific Heat KJ/Kg K	Viscosity CST
Pure Water	1	0.669	4.19	1.79

Table 2 Major Properties of Double Distilled Water as a base fluid

It has been from the above-given results that in all methods the stability period increases with lesser % proportion of nanoparticles. Moreover, as the % proportion of the nanoparticles increase separation of nanoparticles from base fluid occurs rapidly.



Fig, 2 Sonication time effect on the stability of nanoparticles

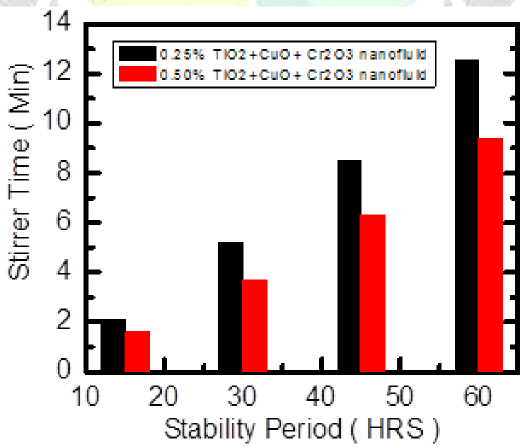


Fig.3 Effects of Mechanical stirring time on stability of nanoparticles

It has been from the above-given results that in all methods the stability period increases with lesser % proportion of nanoparticles. Moreover, as the % proportion of the nanoparticles increase separation of nanoparticles from base fluid occurs rapidly.

VII. CONCLUSION

This research paper revealed some excellent parametric changes in new nanofluid to be used in the solar evacuated tube for as a working fluid. It has drawn attention towards the parameters like, the positive changes regarding stability; specific heat, thermal conductivity; viscosity and density of nanofluid prepared and compared with the base fluid.

VIII. ACKNOWLEDGMENT

This work is supported by GUJCOST (Gujarat Council on Science and Technology) – Grant No. GUJCOST/MRP/2014-15/2543.

IX REFERENCES

[1] Roco, M. 2003. Broader societal issues of nanotechnology. Journal of Nano Research., 5(3):181–189.

[2] Guajardo-Pacheco, M., Morales-Sanchz J, Ruiz, F. 2010. Synthesis of copper nanoparticles using soybeans as a chelant agent. Material Letters, 64(12):1361-1364.

[3] Xi, Y., Hu, C., Gao, P., Yang, R., He, X., Wang, X. and Wan, B. 2010. Morphology and phase selective synthesis of CuxO (x=1,2) nanostructures and their catalytic degradation activity. Material Science and Engineering, 166(1): 113-117.

[4] He, Y. 2007. Novel solid stabilized Emulsion approach to CuO nanostructure microspheres. Material Research Bulletin, 42(1): 190-195.

[5] Qijie, X., Xiaohong, L. and Zhijung, Z. 2015. Preparation of Copper nanoparticles-improved polyamide 6 composites by an in-situ solution rout with cupric oxide as the metallic copper source and investigation of their properties. New Journal of Chemistry, 39(4): 3015-3020.

[6] Kawasaki, H.Y., Kosaka, Y., Myoujin, T., Narushima, T. and Yonezawa, R. 2011. Microwave-assisted polyol of synthesis of copper nanocrystals without using additional protective agents. Chemical Communications, 47(27): 7740–7742.

[7] Zhang, L., Yang, L., Yang, W., Chen,Y.H. and Ding, Y. 2008. Heat transfer and flow behaviour of aqueous suspensions of titanate nanotubes (nanofluids). Powder Technology, 183(1): 63-72.

[8] Kang, S., Park, S., Lee, I. and Bang, J. 2011. Investigation of viscosity and thermal conductivity of sic nanofluids for heat transfer applications. International Journal of Heat Mass Transfer, 54(1-3): 433–438.

[9] Yang, C., Mushed, M and Leong, C. 2008. Investigation of thermal conductivity and viscosity of nanofluids. International Journal of Thermal Science, 47(5): 560-568.

[10] Phelan, E., Golden, S., Praher, S. and Otanicar, T. 2009. Optical properties of liquids for direct absorption solar thermal energy systems. Solar Energy, 83(7): 969–977.

[11] Sansoni, P., Barison, S., Saini, E., Mercatelli, L. and Pagura, C. 2010. Carbon nanohorns based nanofluids as direct sunlight absorbers. Optics Express, 18(5): 5179–5187.

[12] Li, S., Choi, S., Lee, S. and Eastman, J. 1999. Measuring thermal conductivity of fluids containing oxide nanoparticles. Journal of Heat Transfer, 121(2):280–289.

[13] Manikandan, S., Silambarasan, M. and Rajan, S.K 2012. Viscosity and Thermal conductivity of dispersions of sub-micron TiO2 particles in water prepared by stirred bead milling and Ultrasonication. International Journal of Heat Mass Transfer, 55(25): 7991–8002.

[14] Wang, E., Lenert, A. and Zuniga, Y. 2010. Nanofluid-based absorbers for high temperature direct solar collectors. Proceedings of the International Heat Transfer Conference (IHTC14), 7: 8–13.

[15] Naik, M.and SyamSundar, L. 2015. Investigation into thermo-physical properties of glycol-based CuO nanofluid for heat transfer applications. World Academy of Science, Engineering and Technology, 2(29): 440-446.