

Experimental Investigation on Preparation and Stability of $\text{Al}_2\text{O}_3/\text{CuO}$ -water Nanofluids

Lu Liu, Mo Wang, Yanfeng Liu

School of Energy, Power and Mechanical Engineering
North China Electric Power University
Baoding, 071003, China
e-mail: wangmo7829@163.com

Abstract—As a new working substance of heat transfer, nanofluids have broad application prospects in the field of heat transfer enhancement. The preparation of nanofluids is the foundation for further study on other areas of heat transfer, such as the cooling of electronic components, the use of solar energy, etc. This paper reports the preparation and stability of two common kinds of nanofluids. The Al_2O_3 -water nanofluids with different particle sizes and different mass fractions, and the CuO -water nanofluids with different mass fractions were explored. These nanofluids were prepared by using the two-step method, in which magnetic stirring and ultrasonic vibration were used, and the sodium dodecyl benzene sulfonate was used as the dispersant. By exploring the stable situation of these nanofluids, the influences of particle size and mass fraction on nanofluids' stability were discussed. There come to the conclusions that with a higher mass fraction or a larger particle diameter, the nanofluids will easier to precipitate, which means a worse suspension stability.

Keywords—Nanofluids, Preparation; Stability; Magnetic stirring.

I. INTRODUCTION

Heat transfer enhancement technology plays a very important role in the process of the development and utilization of energy, but its traditional methods focusing on the heat exchange equipment manufacturing process will not meet the demand of the development of science and technology. It has become a new way to researching on new type working substance with high heat transfer performance to solve this problem [1]. Against this background, in 1995, Choi [2] put forward a new concept - nanofluids, which have become a hotspot in the field of heat transfer enhancement. Nanofluids refers to a new type of heat transfer medium which disperse the nanoparticles of which the average particle size is less than 100 nm into water, alcohol, oil or other traditional heat transfer medium. This kind of nanofluids has the characteristics of uniformity, stability and of high thermal conductivity.

Many researchers have carried out the study of nanofluids and some progress has been made [3-6]. Murshed [7] mainly explored the influences of particle shape and particle size on the thermal conductivity of nanofluids, and the TiO_2 -water nanofluids was researched as an example. The results show that particle shape and particle size have important effects on thermal

conductivity which can improve 33% and 30% respectively in the same conditions. Hwang [8] compared the thermal conductivity of multi-wall carbon nanotube-water nanofluids with the thermal conductivity of the other three kinds of nanofluids. It is discovered that the multi-wall carbon nanotube-water nanofluids has the highest thermal conductivity, and the thermal conductivity increases 11.3% while the mass fraction of multi-wall carbon nanotube is just 1%.

Among these studies, the preparation of nanofluids is the primary problem to be solved. Generally, there are two methods to prepare nanofluids: the one-step method and the two-step method [9-11]. The one-step method can prepare the nanoparticles as while as make the nanoparticles disperse into the base fluid, while the two-step method should prepare the nanoparticles first and then disperse them into the base fluid by appropriate means.

Eastman [12] prepared the Al_2O_3 -water nanofluids, CuO -water nanofluids and Cu -engine oil nanofluids using the one-step method of vapor deposition. By electron microscope and stand test, it is discovered that the nanoparticles can well dispersed in the base fluids and the nanofluids prepared with this method have a good stability. The thermal conductivity of these nanofluids is much higher than the base fluids, and the higher mass fraction is, the higher thermal conductivity will be. Li [13] prepared the SiO_2 -water nanofluids by the two-step method and analyzed their stability. The results show that the stability will be best if the nanofluids are ultrasonic vibrated for 5 hours. But in other reports [14-18], the most proper time of ultrasonic vibration is various.

Thus it can be seen that there has not yet formed a unified mode to prepare nanofluids, nor achieved a large number of productions to meet the demand of industrial application. In this paper, a preliminary study on the preparation method of $\text{Al}_2\text{O}_3 / \text{CuO}$ - water nanofluids has been carried on. These nanofluids were obtained by using the two-step method, in which magnetic stirring and ultrasonic vibration were used. The stable situation of these nanofluids was observed, and the influences of particle size and mass fraction on nanofluids' stability were discussed. The experimental results can be generalized to the similar preparation of nanofluids, and lay a foundation for the further study on other properties of nanofluids.

II. EXPERIMENTAL SETUP

A. Experimental Materials and Instruments

The reagents required for this experiment: Al_2O_3 nanoparticles with the particle size of 20nm and 30nm, and the purity of 99.9%; CuO nanoparticles with the particle size of 40nm and the purity of 99.9%; The Sodium Dodecyl Benzene Sulfonate (SDBS) had the purity of analytical reagent (AR); The distilled water was laboratory owned.

The instruments used in this experiment: An Electronic balance with the precision of 0.0001g; A ultrasonic cleaning machine with the ultrasonic power of 120W; A magnetic stirrer was used to stir the fluids to make them suspended better.

B. Experimental Method

The two-step method was used because its simpler technique and lower cost than the one-step method to prepare nanofluids. The Al_2O_3 -water nanofluids with two different particle sizes and the CuO - water nanofluids were prepared. Every kind of nanofluids had all the mass fractions of 0.1%, 0.5 %, 1.0% and 1.5%.

Fig.1 shows the common procedures to prepare nanfluids use the two-step method. The specific steps are as follows: weigh a certain amount of nanoparticles, SDBS and distilled water obey their proportions. Add the nanoparticles and the SDBS into the distilled water slowly to make the nanoparticles suspended better, and the nanoparticles suspensions were obtained. Place the beaker containing the suspension on a magnetic stirrer and stir it for 30 minutes. Then make the suspension take ultrasonic vibration for 2 hours to get the nanofluids. The magnetic stirring and ultrasonic vibration are physical methods to make the fluids more corresponding which affected by the time of stirring and vibration, but the time have not gotten consistent recognition.

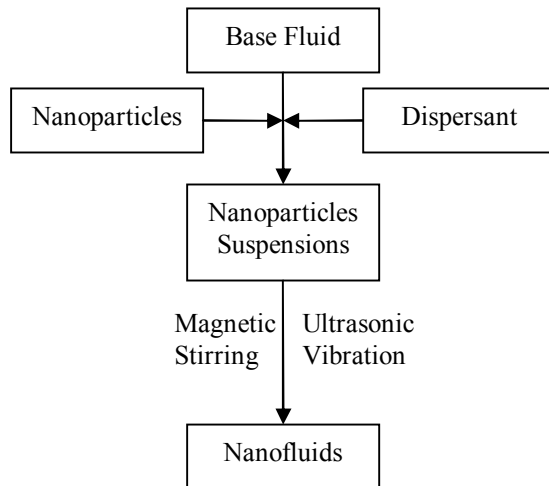


Fig.1: Procedures to prepare nanfluids using two-step method

During the initial experiments, there appeared many bubbles at the surface of nanoparticles suspensions after magnetic stirring, these bubbles can adhere to the beaker wall when shift the suspension from a beaker to colorimetric tubes, which affected the mass fractions of the

suspension in colorimetric tubes. This is because SDBS has high surface activity, and air is easy to dissolve into the fluid in the stirring process, so that bubbles form easily. To solve this problem, the stirring speed was reduced from 1200r/min to 800r/min, and the stirring time was extended from 20min to 30min. It was confirmed that this method is effective to reduce the formation of bubbles, and improve the quality of the obtained nanofluids.

III. EXPERIMENTAL PHENOMENA

A. The Stability of Al_2O_3 - water Nanofluids

As is shown in Fig.2, the freshly prepared Al_2O_3 -water nanofluids were milky white and had the uniform color, and the transmission of light was consistent, which showed that the nanoparticles were well dispersed in the liquid.



Fig.2: Freshly prepared Al_2O_3 -water nanofluids

Placed the nanofluids in the gravitational field, then observed the precipitation and analyzed the suspension stability. Fig.3 and Fig.4 present the compared photos of Al_2O_3 -water nanofluids prepared by the method above, which show the differences between the freshly prepared nanofluids and the nanofluids that have been stood for three days. Among them, the nanofluids shown in Fig.3 are made of the 30nm nanoparticles and the nanofluids shown in Fig.4 are made of the 20nm nanoparticles.



a) Freshly prepared

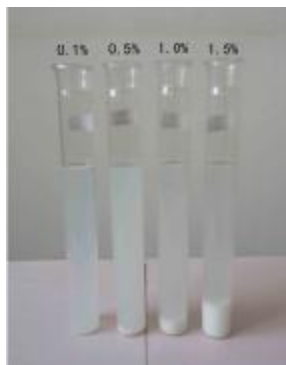


b) After 3days

Fig.3: Al_2O_3 -water nanofluids made of the 30nm nanoparticles



a) Freshly prepared



b) After 3days

Fig.4: Al_2O_3 -water nanofluids made of the 20nm nanoparticles

By comparing the same kind of nanofluids' differences before and after standing, it is clear to see that the nanofluids of different mass fractions have suffered precipitation in different degrees. Their upper liquid was clearer than before and the nanofluids of 1.5% mass fraction changed most. With the mass fraction decreasing, the change degree also decreased. It can be seen that the nanofluids of 30nm nanoparticles was earlier to precipitate than the 20nm nanofluids. The amount of precipitation of 30nm nanofluids was also higher than the 20nm nanofluids.

It follows that all nanofluids have precipitated after standing, but the precipitation situation varies. The higher the mass fraction is, the earlier and more precipitation appears, and the worse the suspension stability of

nanofluids will be. Meanwhile, the larger the particle diameter is, the faster and more precipitation appears, and the worse the suspension stability of nanofluids will be.

B. The Stability of CuO- water Nanofluids

The freshly prepared CuO-water nanofluids presented in Fig.5 were jet black and had the uniform colour and the transmission of light was consistent, which show that the nanoparticles were well dispersed in the liquid.



Fig.5: Freshly prepared CuO-water nanofluids

Placed them in the gravitational field, then observed the precipitation and analyzed the suspension stability. Fig.6 shows the differences between the freshly prepared nanofluids and the nanofluids that have been stood for three days. For picture b, the lower half of all the colorimetric tubes have precipitation and the upper liquid become clearer in varying degrees. The nanofluids of 1.5% mass fraction have changed most, while the nanofluids of 0.1% mass fraction have the least change.



a) Freshly prepared



b) After 3days

Fig.6: CuO-water nanofluids made of the 40nm nanoparticles

The experimental results show that all nanofluids have precipitated after standing, but the precipitation situation varies. The higher the mass fraction is, the earlier and more precipitation appears, and the worse the suspension stability of nanofluids will be. These results are consistent with the experimental results of Al_2O_3 -water nanofluids.

IV. RESULTS AND DISCUSSION

In this paper, Al_2O_3 -water nanofluids and CuO-water nanofluids have been prepared by the two-step method. As the dispersant, SDBS plays a good role to make the nanofluids disperse better. The physical dispersion method of stirring and oscillation make nanofluids more uniform and stable. Through observing before and after standing, it is proved that with the mass fraction increases, the suspension stability of nanofluids decreases. The main reason is that the higher the mass fraction is, the greater the impact of Brownian motion will be, so that the nanoparticles aggregate more easily, which means that the nanofluids have lower stability.

Meanwhile, with the particle sizes increase, the suspension stability of the nanofluids gets worse. The main reason is that when the nanoparticles are added to the liquid, there will be a liquid film on the solid-liquid interface. Since the overall diameter of the nanoparticles becomes larger after the liquid film formed, the probability of aggregation due to Brownian motion increases, so that the stability gets worse.

V. CONCLUSIONS

Through magnetic stirring and ultrasonic vibration, the Al_2O_3 -water nanofluids with two different particle sizes of 20nm and 30nm, and the CuO - water nanofluids with particle size of 40nm were prepared by the two-step method, to which added SDBS as dispersing agent. Every kind of nanofluids had all the mass fractions of 0.1%, 0.5 %, 1.0% and 1.5%. By comparing their precipitation conditions, the influences of particle size and mass fraction on nanofluids' stability were discussed, and the main conclusions are as followings.

(1) A higher mass fraction causes a greater impact of Brownian motion and then the nanoparticles aggregate more easily, so that the nanofluids have lower stability.

(2) With a larger particle diameter, the overall diameter of the nanoparticles will be larger after the liquid film formed, and the probability of aggregation due to Brownian motion will increase more quickly, leading a worse stability.

REFERENCES

- [1] Xuan Yi-Min & Li Qiang, *Theory and application of nanofluids in energy transferring*, Beijing: Science Press, pp. 3-5, 2009.
- [2] Choi S.U.S. & Eastman J.A., Enhancing thermal conductivity of fluids with nanoparticles, *Development and Applications of Non-Newtonian Flows*, 1995.
- [3] Hong T.K., Yang H.S. & Choi C.J., Study of the enhanced thermal conductivity of Fe nanofluids, *Journal of Applied Physics*, 97(6), pp. 1-4, 2005.
- [4] Hong K., Hong T.K. & Yang H.S. Thermal conductivity of Fe nanofluids depending on the cluster size of nanoparticles, *Applied Physics Letters*, 88(3), pp. 31901, 2006.
- [5] Ding Y., Alias H. & Wen D., Heat transfer of aqueous suspensions of carbon nanotubes (CNT nanofluids), *International Journal of Heat and Mass Transfer*, 49(122), pp. 240-250, 2005.
- [6] Assael M.J., Chen C.F. & Metaxa I.N., Thermal conductivity of suspensions of carbon nanotubes in water, *International Journal of Thermophysics*, 25(4), pp.971-985, 2004.
- [7] Murshed S.M.S., Leong K.C. & Yang C., Enhanced thermal conductivity of TiO_2 -water based nanofluids, *International Journal of Thermal Sciences*, 44(4), pp. 367-373, 2005.
- [8] Hwang Y.J., Ahn Y.C. & Shin H.S., Investigation on characteristics of thermal conductivity enhancement of nanofluids, *Current Applied Physics*, 6, pp. 1068-1071, 2006.
- [9] Kanjirakat Anoop, Jonathan Cox & Reza Sadr, Thermal evaluation of nanofluids in heat exchangers, *International Communications in Heat and Mass Transfer*, 49, pp.5-9, 2013.
- [10] Li Qiang, Research on preparation and transport parameters of nanofluids, *M.E.D. Dissertation*, Nanjing: Nanjing Technology University, 2001.
- [11] Guo Shou-Zhu, Research on preparation of magnetic nanofluids and performance of enhanced heat transfer, *M.E.D. Dissertation*, Shanghai: East China Normal University, 2010.
- [12] Eastman J.A., Enhanced thermal conductivity through the development of nanofluids, *Nanophase and Nanocomposite Materials Pittsburgh*, 17(8), 1997.
- [13] Li Dong-Dong, Li Jin-Kai & Zhao Wei-Lin, The stability and thermal conductivity of SiO_2 -water nanofluids, *Journal of Jinan University (Engineering Science)*, 24(3), pp. 247-250, 2010.
- [14] S.Harikrishnan & S.Kalaiselvam, Preparation and thermal characteristics of CuO-oleic acid nanofluids as a phase change material, *Thermochimica Acta*, 533, pp.46-55, 2012.
- [15] Han Dong-Xiao, Research on preparation, characterization and properties of cupric oxide and cuprous oxide nanofluids, *M.E.D. Dissertation*, Qingdao: Qingdao Science and Technology University, 2011.
- [16] Peng Xiao-Fei, Yu Xiao-Li, Xia Li-Feng and Zhong Xun, The factors on suspension stability of nanofluids, *Journal of Zhejiang University (Engineering Science)*, 41(4), pp. 577-580, 2007.
- [17] Ma Xue-Hu, Su Feng-min & Chen Jia-bin, Heat and mass transfer enhancement of the bubble absorption for a binary nanofluids, *Journal of Mechanical Science and Technology*, 21, pp.1813-1818, 2007.
- [18] Kim J.K., Jung J.Y., & Kang Y.T., Absorption performance enhancement by nano-particles and chemical surfactants in binary nanofluids, *International Journal of Refrigeration*, 30, pp. 50-57, 2007.