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The Synthesis of CuO-Based Nanofluids as a Cooling Media:

A Review

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***Abstract*—Nanofluids have received significant attention due to their increased thermal characteristics. This increase was due to the addition of nanoparticles in the basic fluid. This research uses literature study method. Based on the literature study that has been done, the thermal conductivity of water and CuO is high. However, the value of the thermal conductivity of water-CuO nanofluids also varies according to experiments conducted by Das et al., Sahooli et al., and Micali et al. This can occur due to several factors such as the size of the nanoparticles, agglomeration, pH value, and others. With this high thermal conductivity value, water-CuO nanofluid can be used as a cooling medium.**

Keywords— CuO-based nanofluids, cooling media, review

I. INTRODUCTION

Nanofluids are fluids that contain nanometer-sized (<100 nm) particles, called nanoparticles. This fluid is a colloidal suspension engineered from nanoparticles in the base fluid. In recent years, nanofluids have received significant attention due to their increased thermal characteristics. This increase was due to the addition of nanoparticles in the basic fluid. The type of nanoparticles is one of the factors to obtain high thermal conductivity. Copper oxide (CuO) is included in the oxide nanoparticles, these nanoparticles are used because they have high thermal conductivity. so that the nanofluids synthesized with CuO nanoparticles also have better conductivity compared to other oxide nanofluids [1]. To make nanofluids more stable, you can adjust the pH (electrostatic stabilization) and add a dispersant or surfactant (steric stabilization) [2,3]. There are two methods for preparation in the manufacture of nanofluids: the one-step method and the two-step method.

The process of cooling media, which are absorbing heat and transferring heat to the fluid, functions as a coolant. Cooling efficiency using nanofluids is influenced by specific heat density, thermal conductivity, and various other heat transfer properties [4]. Of these, the thermal conductivity of nanofluids is the most complex and the most important for many applications [5]. Such as electronic cooling media, nuclear reactor coolers, car radiator water and various other applications.

Sahooli, et al. synthesized CuO-ethylene glycol with the addition of PVP as a surfactant. As a result, the addition of surfactants increases the stability and nanofluids thermal conductivity [6]. Septiadi, et al. conducted research on the characterization of the thermal conductivity of oxide nanofluids. The result is that the thermal conductivity of CuO-air is higher than that of Al2O3-air and TiO2-air nanofluids at both low and high-volume fractions [7]. Noor et al. discussed the synthesis of egg white mediated CuO-based nanofluids for ethanol distillation applications. From these results, it was found that the addition of nanoparticle levels influenced the increase in the thermal conductivity of the nanofluids [8]. The CuO nanoparticles thermal conductivity (k_p) is 18 W/mk, and the thermal conductivity of water (k_f) is 0.613 W/mk [9]. In this paper we report the thermal conductivity of water-CuO nanofluids in existing experiments and several theories with a volume fraction of 1%-4%.

II. PREPARATION NANOFLUIDS

The synthesis Nanofluid is a colloid suspension which has a particle size between 1-100 nm which is dispersed in the base fluid. The method in preparing the manufacture of nanofluids can be done in two ways, one-step method and two-step method.

A. One-Step Method

The one-step method is a method that directly combines the manufacture of nanoparticles with nanofluid synthesis [10]. The one-step method is also divided into two, namely the physical method and the chemical method. Physical methods include vapor deposition, laser ablation, and submerged arc. Meanwhile, chemical methods use chemical reactions for the manufacture of nanofluids. The advantages of the one-step synthesis method are that the agglomeration of the nanoparticles is reduced, and it is more economical.

1) Physical methods: Vapor deposition, a method developed by Choi, is the most common method to use. The principle can be seen in Figure 1. On the vessel wall, this thin layer of base liquid is formed using the centrifugal force of a rotating disk. In the process, the raw material is heated and evaporated in a resistive heated container. Then, the vapor is condensed into nano-sized particles when it meets the cold base fluid. So that the nanofluid was obtained [11]. Lee et al. prepared ethylene glycol-TiO2 nanofluids using the pulsed wire evaporation method [12]. The results showed that the thermal conductivity of the nanofluids increased the volume concentration of the nanoparticles but there was no increase in temperature variations.

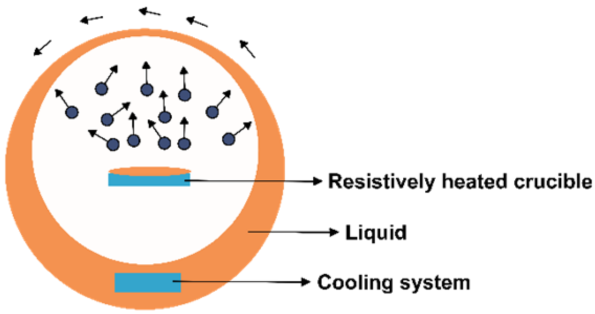

Fig. 1. Schematic diagram of the Vapor deposition method [13].

Laser Ablation Method, this method consists in the synthesis of nanoparticles during the interaction of a laser pulse with a solid target surface in a liquid environment. There are several promising advantages of laser ablation in liquids such as simplicity of the technique and rapidity compared to other methods [14]. Figure 2 shows the experimental equipment for the PLAL method. Lee et al. presented the PLAL method in the manufacture of CuO/DIW nanofluids with the aim of controlling the morphology of the nanoparticles [12].

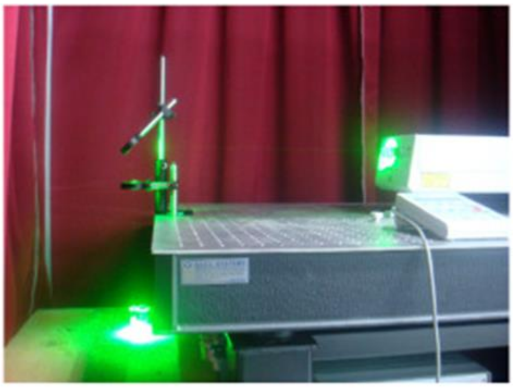

Fig. 2. Experimental equipment for the PLAL method [15].

Submerged Arc Nanoparticle Synthesis System (SANSS) Method, The SANSS method involves the evaporation of bulk metal by Submerged Arc produced by high temperatures. Dielectric fluids are used to immediately quench evaporating metals to suppress the growth of nanoparticles. Then, centrifugation and sedimentation were carried out on the nanoparticle suspension condensed in the dielectric fluid. Then from this process to produce nanofluids [16]. Lo et al. presented the SANSS method to prepare silver nanofluids (figure 3). The result with this method can reduce the particle size to the nanoscale [17].

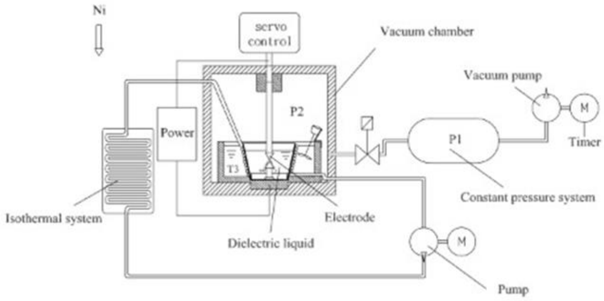

Fig. 3. Schematic diagram of the SANSS [17].

2) Chemical methods: Chemical methods have advantages in terms of controlling particle size, reducing agglomeration, and can produce nanofluids on a large scale [17,18]. Zhu et al. has conducted research using microwave irradiation in a one-step chemical method to prepare copper nanofluids by reducing CuSO4.5H2O with NaH2PO2.H2O to ethylene glycol [19]. The results showed that the use of microwave irradiation and the addition of NaH2PO2.H2O were two significant factors that influenced the reaction rate and properties of Cu nanofluids. Shenoy et al. reported on the synthesis of copper oxide nanofluids by a one-step chemical method with the addition of polyvinyl pyrrolidone (PVP). The results of the study increased the stability of the nanofluid produced for about 9 weeks [20].

B. Two-Step Method

The two-step method is the method most widely used for the preparation of nanofluids. In this method, nanoparticles must be prepared in advance through a physical or chemical synthesis process, such as: co-precipitation [21], sol-gel, spray pyrolysis and others. The most popular and effective two-step method for preparing long-stable, homogeneously dispersed nanofluids is ultrasonication. This method utilizes vibrations with ultrasonic waves. Various parameters affect the dispersion of nanofluids using different treatments such as the type of ultrasonication, time of ultrasonication, power of ultrasonication and so on. The type of ultrasonication consists of direct ultrasonication (ultrasonic horn/probe) or indirect ultrasonication (ultrasonic bath) [22] (figure 4).

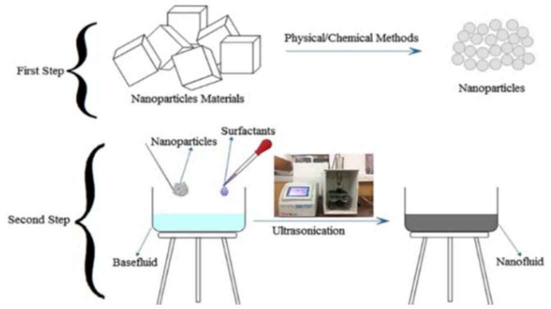

Fig. 4. Two-step nanofluid preparation [23].

C. Theoritical and Experimental Nanofluid Thermal Conductivity

One of the well-known theoretical models that can be used to predict the thermal conductivity of nanofluids is the investigation phase of Maxwell's Model [24]. This model is suitable for particles with a low volume fraction that have a spherical shape. The equation is as follows:

$$\frac{k_{nf}}{k_{bf}} = \frac{k_p + 2k_{bf} + 2\varphi\left(k_p - k_{bf}\right)}{kp + 2k_{bf} - \varphi\left(k_p - k_{bf}\right)} \quad (1)$$

Where k_{nf} is the nanofluid thermal conductivity, k_p is the thermal conductivity particles, k_{bf} is the thermal conductivity base fluid, and φ is the volume fraction.

$$\frac{k_{nf}}{k_{bf}} = \frac{k_p + 2k_{bf} + 2\left(k_p - k_{bf}\right)\left(1+\beta\right)^3 \varphi}{k_p + 2k_{bf} - 2\left(k_p - k_{bf}\right)\left(1-\beta\right)^3 \varphi} \quad (2)$$

Based on the above equation, β = 0.1 is used to calculate the effective thermal conductivity of the nanofluid. Which β is the ratio of the thickness of the nanofluid layer to the particle radius.

Timofeeva et al. introduced a new model for calculating the thermal conductivity of nanofluids as follows [25,26]:

$$\frac{k_{nf}}{k_{bf}} = \left(1 + 3\varphi\right) \quad (3)$$

From Equations (1), (2) and (3), the nanofluid effective thermal conductivity has a relationship to the volume fraction in Figure 5.

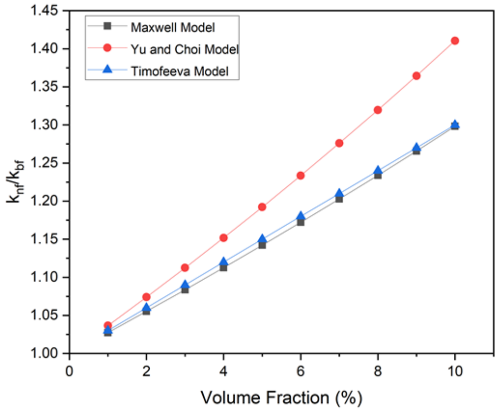

Fig. 5. Effective thermal conductivity of water-CuO nanoparticles.

This thermal conductivity was obtained from experiments of Das et al., Sahooli et al., and Micali [14,27,28]. The effective thermal conductivity (k_{nf}/k_{bf}) is obtained as in table 1.

TABLE I. EFFECTIVE THERMAL CONDUCTIVITY FOR WATER-CUO NANOFLUIDS FROM SEVERAL EXPERIMENTS

Author	Volume Fraction (%)	k_{nf}/k_{bf}
Das et al. (2003)	1-4	1-1,14
Sahooli et al. (2012)	1-6	1-1,17
Micali et al. (2018)	1-4	1-1,17

The effective thermal conductivity with increasing water-CuO volume fraction in the existing experiments has the same tendency when compared to the Maxwell model, Yu and Choi model, and Timofeeva model. As can be seen in Figure 6. The effective thermal conductivity between the thermal conductivity model and the experimental results increases with increasing volume fraction.

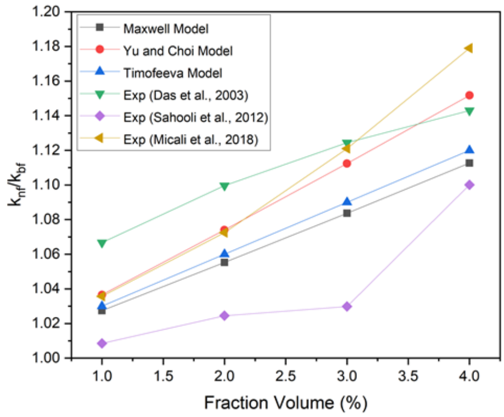

Fig. 6. Graph of the effective thermal conductivity of Water-CuO with respect to volume fraction.

In the Sahooli experiment there was the addition of the surfactant Polyvinyl Pyrrolidone (PVP) in the Water-CuO synthesis. The addition of surfactants can increase the thermal conductivity of the nanofluids and make the nanofluids more stable [29]. However, it appears that the effective thermal conductivity is lower than that of Air-CuO nanofluids without the addition of surfactants. This can be caused by many factors such as: nanoparticle size, agglomeration, pH value, and others.

III. NANOFLIUDS APPLICATION

Nanofluids in theory have a high thermal conductivity which can be used as a cooling medium. According to Ramadhan et al., nanofluids can be used as a cooling fluid for electronic devices such as to cool semiconductors on a computer CPU so that the chip can last a long time when operated. This nanofluid can also be applied as a cooling fluid in nuclear reactors [30]. The use of nanofluids aims to increase the heat transfer that occurs in the core of a nuclear reactor, which causes heat from nuclear fission to be taken and converted into a steam generator or heat exchanger which is then streamed to turbines and generators.

IV. CONCLUSION

The results of literature studies that have been conducted regarding the thermal conductivity of water-CuO are based on theory and experiment. Each of them shows a significant increase in thermal conductivity at low volume fractions. Based on the model results and the experimental results of thermal conductivity, the effective thermal conductivity increases with increasing volume fraction. Therefore, this increase in thermal conductivity can be used as a cooling medium.

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