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Synthesis and thermal characterization of Al_2O_3 nanoparticles

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Abstract. Al_2O_3 nanoparticle has been successfully synthesized using sol gel method from AlCl3. The obtained nanoparticles was then characterized for grain size measurement, the size of nanoparticles was 6 nm by using surface area meter (SAM) and Transmission Electron Microscopy (TEM). The crystallinity property of the product was then checked with XRD spectroscopy, the result shows that the diffraction peaks were match with the 10-0425 JCPDS database. Thermal property of the Al2O3 nanoparticles was then studied by mixing it with engine base fluid as nanofluid. The usage of nanofluid was expected to be heat absorber and woulo increase cooling process in cooling machine. The results showed that cooling time increases when the concentration of nanofluid was increased. Finally, it is concluded that thermal property of Al2O3 was studied and applicable to be mixed with engine coolant of cooler machine to reduce cooling time process.

1. Introduction

Recently, many researches about the application of nanosize material to enhance heat transfer process has already been introduced by the researcher, that is popularly known as nanofluid. A nanofluid is a mixture of base fluid with the solid nanoparticle to be used in some applicaton, for example electronic components[1], vehicles[2], nuclear reactor [3-5] and building cooler system[6]. So many metal and metal oxide compound have been synthesized and applied in several kind application. Ravi et.al [7] studied about the application of CuO nanoparticle as nanofluid, they concluded that CuO increase thermal conductivity and sensitivity, they also depend on concentration and different variation of base liquid. Metal oxide nanoparticle is the popular one compare to others since it has high value of thermal conductivity, easy to produce, lighter than dense nanoparticle which is not easier become an agglomeration[8]. Many research has been conducted in order to study the effective thermal conductivity, convective heat transfer and phase change in nanofluid. In this research, nanoparticle powder of Al_2O_3 were synthesized using a very simple, cheap and easier method, sol gel method. Nanoparticles obtained from the synthesis process was applied in a model of coolant engine to characterize their thermal property. As can be seen, the thermal conductivity increases when concentration increases. The effect of different concentration of nanoparticle in the

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nanofluid was studied, and it is found that higher amount of nanoparticle in a nanofluid absorbed heat more than less concentration.

2. Experimental Method

We divided this research into three sections, the first step was the synthesis of Al_2O_3 nanoparticle using sol-gel method, the second step was the characterization of the powder product, and the last section was the application of nanoparticle as nanofluid in a model of cooling engine system. To synthesis Al_2O_3 nanoparticle, $AlCl_3$ with 95%-98% purity purchased from Yixing Cleanwater Chemicals Co., Ltd. was used as the initial material. $AlCl_3$ powder was then processed by Sol-Gel method, 30 g $AlCl_3$ powder was mixed with 160 g sucrose ($C_{12}H_{22}O_{11}$) as a binder in this method. The mixture of $AlCl_3$ with sucrose were then heating up in the furnace with temperature of 900^{o}C for seven hours. After seven hours heating, there were white powder product found in the ceramic beaker and predicted as the Al_2O_3 nanoparticle. The result product were then characterised for their properties. X-Ray Difraction (XRD) spectroscopy, Surface Area Meter (SAM) and Transmission Electron Microscopy (TEM) were then used for studying the crystalline property, particle size and structure of the nanoparticle obtained, respectively. Al_2O_3 nanoparticle were then applied as nanofluid, it was mixed with base fluid for helping cooling process in a model cooling engine. The mixture of different concentration of Al_2O_3 nanoparticle were then studied and characterised for their thermal conductivity in a cooling engine model.

3. Results and Analysis

Al_2O_3 nanoparticle have been synthesized using sol-gel method. Several characterization have been used to characterize the material obtained from the process. Firstly, to ensure the size of nanoparticle, SAM Quantachrome NovaWin v.11.03 have been used for this purpose by using Brunauer-Emmett-Teller (BET) methods. Surface area for Al_2O_3 nanoparticle was 240.624 m^2/g. The average particle diameter is obtained by assuming the particles is spherical according to the Equation 1 :

$$D = \frac{6}{\rho \times As} \tag{1}$$

Where:

ρ = density of Al_2O_3 (g/cm^3)
A_s = surface area of Al_2O_3 (m^2/g)

By using above equation it can be calculated the size of Al_2O_3 nanoparticle, the result was 6.26 nm. From this result it is confirmed that the result from sol-gel process was in the nanosize. TEM using JEOL JEM 1400 was then used to double confirm the size and structure of the obtained nanoparticle and shown in the Figure 1. From the TEM image it is believed the size of the nanoparticle was less than 20 nm, it is confirmed that sol gel method was successfully done to synthesis the nanoparticle, even though some agglomeration between the particle still occurred.

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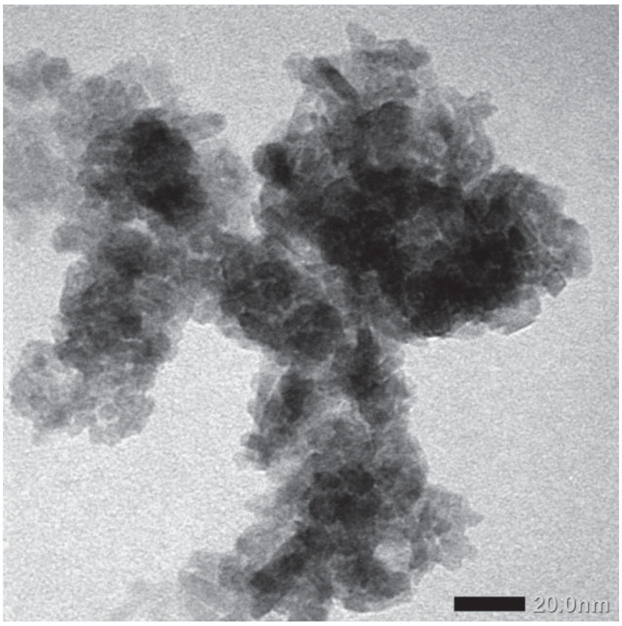

Figure 1. TEM image of Al_2O_3 nanoparticle shown that the size of nanoparticle less than 20 nm and the agglomeration still occurred among them.

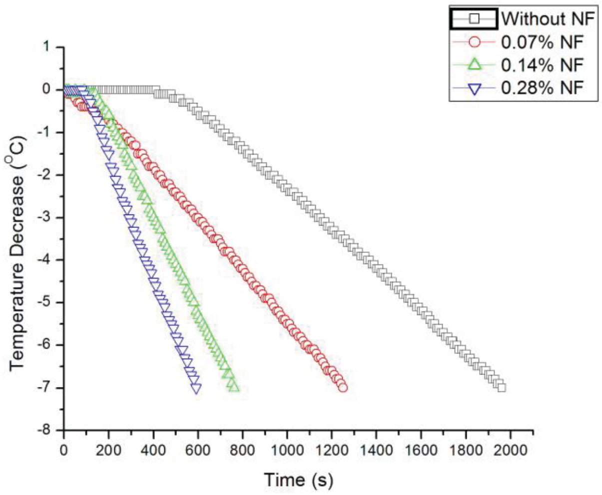

Figure 3. Decreasing time by using different concentration of Al_2O_3 nanoparticle in the nanofluid.

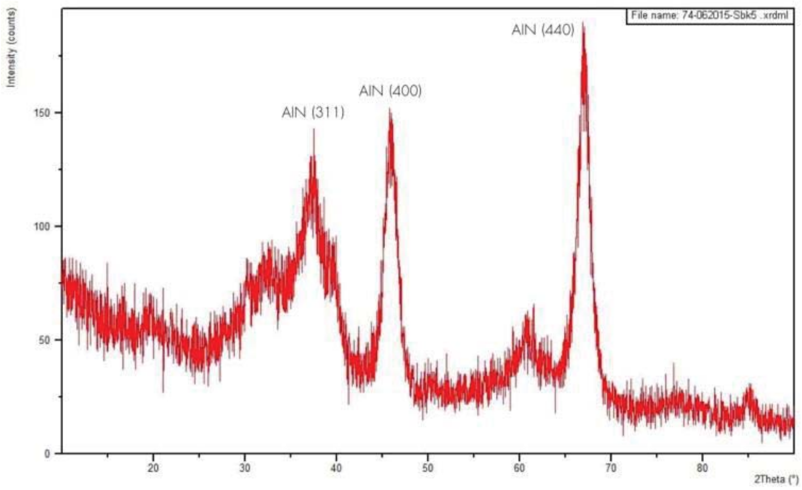

Figure 2. XRD spectrum of the obtained Al_2O_3 nanoparticle using sol gel method match with the 10-0425 JCPDS database.

Crystallinity of the nanoparticle was then characterized with XRD and the result was depicted in Figure 2 above. From the figure it is clearly shown that the obtain particle was a crystal, it is confirmed from the high and narrow peaks of the diffraction spectrum. All the peaks were belong to Al_2O_3 and matched with the 10-0425 JCPDS database.

After doing some characterizations, the nanoparticle was then mixed with base liquid to be used in a model of cooling engine. The performance of cooling engine was then tested by adding different concentration of Al_2O_3 nanoparticle into base fluid of cooling engine and later we can say as nanofluid. Different concentration of Al_2O_3 nanofluid was then applied to decrease 7°C the temperature of cooling engine. The concentration used in this experiment was 0 %, 0.07 %, 0.14 % and 0.28 % and the result shown in Figure 3 below. From the figure it is clearly depicted that the decreasing temperature was depend on the concentration of the nanofluid. When the concentration of Al_2O_3 increased, the decreasing rate will become higher. To decrease 7°C of cooling engine without using nanofluid it is needed around 2000 s, after adding 0.07 % the decreasing time was around 1300 s, and then for 0.14 % and 0.28 % it was around 800 and 600 s respectively.

The shorten time to decrease cooling engine's temperature was predicted by the different physical properties of the nanofluid used comparing to the pure base fluid itself. We believed that the addition of Al_2O_3 nanoparticle would change thermal characteristic of the nanofluid. The usage of nanosize particle in the nanofluid would increase surface area of the $Al_2O_{3,}$ since the heat absorption property of the Al_2O_3 would take part in this process[9-11]. As the concentration increase, meaning that the available surface area also increase and resulted shorter time to reduce temperature.

Power cooling cycle usage in the system was also would be determined and show in the Table 1. During the experimental process, power can be measured from the system as we compare from input and output power. Power was obtained by measuring power that goes into the system by using a watt meter, since the required power usage is directly proportional to the time. It is shown that more concentration used will applied less power.

Table 1. Electrical power used for the each experimental process based on the concentration of Al_2O_3 nanoparticle

	a	b	c	d
Concentration of Al_2O_3 nanoparticle	0 %	0.07 %	0.14 %	0.21 %
Electric Power usage (kWH)	0.0613	0.032	0.0211	0.0183

The performance of cooling engine was then defined by comparing output and input power. Input and output power defined as the input of electrical power and output thermal power, respectively, and the result shown in Table 4.2 below. It is shown that the performance of the engine was also increase by increasing the concentration of Al_2O_3 nanoparticle.

Table 2. Performance index of the cooling engine directly depend on the concentration of Al_2O_3 nanoparticle

	a	b	c	d
Concentration of Al_2O_3 nanoparticle	0 %	0.07 %	0.14 %	0.21 %
Performance index	0,199	0,383	0,580	0,667

Effective thermal conductivity can be understood by considering all the data obtained, and can be calculated by using the Equation 2. The effective thermal conductivity plotted in the Figure 4 below. From the figure it is clearly understood that the effective thermal conductivity was also increase by increasing the concentration of Al_2O_3 nanoparticle. Actually many parameters will also take part in process, such as viscosity, boiling point of the mixing material, the present of stabilisation agent and so on[12]. In this paper, we just study about the effect of using different concentration of base fluid without considering others parameter.

$$\frac{keff}{kf} = \frac{kp + 2kf - 2\alpha\,(kf - kp)}{kp + 2kf + 2\alpha\,(kf - kp)} \quad (2)$$

Where:
k_{eff} = Effective Thermal Conductivity
k_f = Thermal Conductivity of base fluids (Lubricant)
k_p = Thermal conductivity of Al_2O_3 (90% purity)
α = k/(1+k) ; k = Concentration ratio between the volume of base fluid and nanoparticles Al_2O_3.

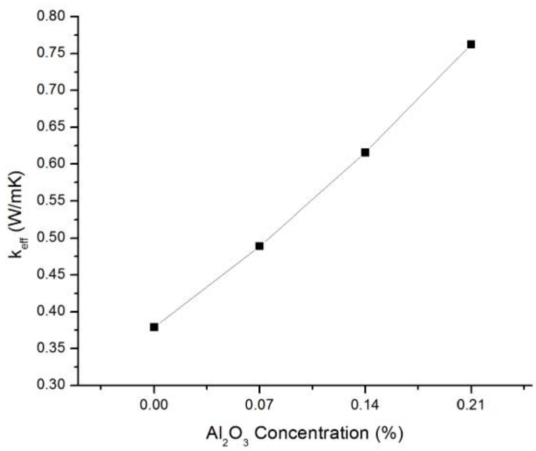

Figure 4. Effective thermal conductivity of the different concentration of Al_2O_3 nanoparticle

4. Conclusion

Al_2O_3 nanoparticle have been successfully synthesized using sol gel method. Some characterization revealed that the size of nanoparticle was around 6 nm, while it has also a high crystallinity structure. Nanofluid, the mixture between Al_2O_3 nanoparticle and base fluid has been applied to reduce the temperature of an engine cooling model system. Thermal properties of nanofluid was proved linearly proportional to the concentration of Al_2O_3 nanoparticle, the higher concentration in nanofluid would have shorter time to reduce temperature. This mechanism was indicated that higher concentration of Al_2O_3 nanoparticle supply higher surface area of the material that resulted higher thermal absorption occurred during the cooling process.

5. Acknowledgement

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6. References

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