ELK ASIA PACIFIC JOURNAL OF APPLIED THERMAL ENGINEERING

Volume 1 Issue 1, September (2014)

ELK Asia Pacific Journals

www.elkjournals.com

STUDY ON THE THERMAL CONDUCTIVITY OF NANOFLUIDS

Prof. Kartik M. Srinivasa
Mechanical Engineering Department,
Dayananda Sagar College of Engineering,
Bangalore, India

ABSTRACT

This article investigates about the process of nanofluid preparation that includes a powder form of nanofluid and a liquid base. With the help of this process some elements of nanofluids are made. The illustration of both even suspension and stability is provided by their TEM pictures. In addition, a theory based on nanofluids and their thermal conductivity was popularized using the hot wire equipment. The study also details about the various shapes, properties and dimensions of nanofluids. The article also proposes the performance of nanofluid heat transfer with particular reference to solid particles.

Keywords: Nanofluids, Heat transfer, Hot-wire apparatus, Thermal Conductivity

Introduction

The process of low thermal conductivity slows down the effectiveness and compactness of the heat exchangers even when different methods were used to improve the transfer of heat. It is also difficult to improve the energy transmission of nanofluids. When an industrial operation test is held the thermal conductivity of nanofluids is expected to be higher than other fluids (Li et al, 1998). In this test the size, pressure drop of slurry and the operation of heat transfer were identified. The suspended particles consist of mm dimensions during the conventional method. Sometimes the intervention of large particles may lead to log and abrasion of the elements. Therefore nanofluids that have large particles may contain some practical application during the improvement of heat transfer and it also offers some efficient ways for enhancing the characteristics of nanofluids. These particles expose different kind of properties when compared to the conventional samples. Some research also gave a trial to convert the suspended nanoparticles to form as particles that offer large amount of heat transfer. Choi in the year 1995 was the first person to refer nanofluid as suspended nanoparticles. The performance of heat transfer can be enhanced by suspending the nanoparticles in cool or hot fluids. Some of the other main factors that improve the heat transfer of nanoparticles are, by mixing the effectuation of the fluids, the suspended Nano particles also improve the capacity of heat and surface of the nanofluids and the distribution of nanoparticles also increase the gradient temperature of nanofluids.

Preparation of nanofluids

The preparation of nanofluids is the primary step to change the performance of heat transfer conventional fluids. It does not just mean that it is a mixture of solid or liquid. Some important factors needed for this preparation are namely durable suspension, change of fluid chemical change and stable suspension. The common techniques that are used in the preparation of suspensions are first done by changing the pH value of the suspension, second with the help of dispersants and finally by using vibration that is obtained from ultrasonic. The aim of all these techniques is to alter the properties of the suspended particles. These methods are used by the verification based on the applications. The most commonly used dispersants in this method are laureate salts and oleic. The dispersant elements are picked for the preparation of nanofluids based on the properties of the particles. This paper uses nanostructured Cu particles that contain 100 nm diameters to produce the suspended particles. The particles and the fluid are mixed in a direct pattern. During the preparation of these suspensions a variety of dispersants are used for the testing. For instance, let us consider the below examples.

Example 1: Suspension of Oil Transformer and Cu nanoparticle

Nanoparticles that consist of Cu are mixed with the oil transformer in 2 and 4% volume, accordingly. In order to make the suspension stable the dispersant oils are chosen to wrap the nanoparticles. The volume of oleic acid that is mixed is estimated with the help of a Cu particles weight percent. Then the suspension is kept under ultrasonic vibration for nearly 10 hrs. After that, no sedimentation was found. It gives the TEM pictures of the Oil Transformer and Cu nanoparticle suspension. Finally, there occurs some form of clustering in the electron micrographs when the particles are distributed.

Example 2: Suspension of water and Cu nanoparticles

This type of suspension consist 5% of Cu nano particles. In this technique the laurate salt is used in order to improve the suspension stability. For this the laurate salt has been tested several times and finally 8% wt of salt with a minimum for forming the stable water and Cu nanoparticles was used in this method. Then the suspension is kept under ultrasonic vibration where the stable suspension exists till 30 hrs in a state of stationary. It gives the TEM pictures of the water and Cu nanoparticles suspension. Here also, there occurs some form of clustering in the electron micrographs and the particles distributed are deionized in water.

From the above two examples of suspension it is inferred that the dispersion and stability of Cu particles in the oil transformer contain greater aspects when compared to that of the Cu particle suspension. Moreover, this helps to detail about the fluid viscosity and it is considered as an important factor that affects the stability of the suspension particles. In addition, the dispersants also play a vital role in the preparation of suspensions.

Thermal conductivity of nanofluids

As discussed earlier, nanofluids expose large amounts of heat transfer when compared to the conventional nanofluid samples. One of the main aspects of suspended particles is that it improves the nanofluid’s thermal conductivity. The nanofluid’s thermal conductivity highly depends on the fraction volume of the nano particle. Still now it is difficult to identify the thermal conductivity of nanofluids, even though there is some semi correlation that helps to measure the thermal conductivity of the two phase mixtures. This below formula helps to calculate the solid and liquid mixtures for both the phases.

$$\text{Keff} = kp \propto p \left(\frac{dT}{dX}\right) p + Kf \propto f \left(\frac{dT}{dX}\right) f \,/ \propto p \left(\frac{dT}{dX}\right) p + \propto f \left(\frac{dT}{dX}\right) f$$

Crosser and Hamilton in the year 1963 introduced a pattern for solid and liquid mixtures in which the conductivity ratio of both the phases is greater than 100. This

ELK ASIA PACIFIC JOURNAL OF APPLIED THERMAL ENGINEERING

Volume 1 Issue 1, September (2014)

ELK Asia Pacific Journals

www.elkjournals.com

research gave a fair coincidence among the theoretical part and the data obtained from the nano particles ranged up to 40%. If the particles have different shapes, then it can range from 0.5 to 5.0. On the other hand another formula was introduced by Wasp in 1997 to calculate than the thermal conductivity of liquid and solid mixtures.

Keff/Kf = $Kp + 2Kf - 2 \propto \frac{Kf - Kp}{Kp} + 2Kf + \propto (Kf - Kp)$

Both the formula can be fairly used to thermal conductivity of nanoparticles with diameters in micrometer. For instance, if there is no suitable pattern to depict the thermal conductivity then the above mentioned two methods can be used for approximate estimation of thermal conductivity. By implementing the Crosser and Hamilton pattern of alumina and water based nanoparticle suspension, the thermal conductivity can be calculated effectively from 0.2 to 2.0. Moreover the obtained results are related with the results that are obtained through preliminary experiments (Eastman et al, 1998). The thermal conductivity improves if the sphericity of alumina is more than 0.2 and the fraction of volume is also expected to be 2 to 3%. Apart from this, the effectiveness of thermal conductivity can be increased by reducing or decreasing the sphericity of the particles. If a particle has volume fraction of 5% then the thermal conductivity of the nanofluids can be improved from 1.3 to 2.6 and sphericity at the rate of 0.4. The properties and dimensions of the nanoparticles make use of devastating effects on the suspension thermal conductivity. These results help to identify that the nanoparticles improve the thermal conductivity of conventional heat of nanofluids.

Measurement of thermal conductivity of nanofluids

Nanofluids are supposed to exhibit heat transfer properties that are superior when compared to conventional heat transfer fluids. One of the major reasons is that the suspended particle extraordinarily increases the thermal conductivity of nanofluids. It is well known that the nanofluid's thermal conductivity highly depends on the dimensions, fraction of the volume and properties of nanoparticles. It is not possible to identify or measure the thermal conductivity by theory based approach. The thermal conductivity of nanofluid can be calculated only by experimental approach. Hence, to estimate this transient hot wire method is used. In This method is a vertical, long zero heat capacity line sources that is submerged in a sample fluid and when the heat is immersed in a stepwise process and the energy is conducted to the fluid. Then the increase of temperature between the wire and the thermal conductivity of the fluid is found out (Wakeham, 1992). In the hotwire apparatus including two platinum wires that consist of both line source and thermometer of radius 0.145 and 0.065 are used to determine the thermal conductivity of the nanofluids heat transfer. These wires are then submerged in the sample nanofluids with some amount of current. Then the temperature rise in both the wires is found using an automatic wheatstone bridge and the end effect is experimentally removed. The digital voltmeter is used to measure the voltage of the wire. Prior to calculating the thermal conductivity of nanofluids the equipment is subjected to a sample liquid with a known current as it exhibits a high thermal conductivity. The hot wire apparatus is used here to determine the Suspension of both Oil Transformer and Cu nanoparticle and water and Cu nanoparticles. On the other hand, the results gained through experiments are compared with the preliminary results and the thermal conductivity is analyzed. From the analysis it was found that one of the aspect that affect the thermal conductivity of nanofluid is the fractional volume of the particles. The thermal conductivity of the nanofluids enhances the fractional volume of Cu particles. When the results obtained from both the experimental and preliminary techniques are compared it reveals that Eastman’s nanofluid show properties higher than the sample nanofluids. The basic reason for this is that Eastman’s nanofluid use Cu particles with variable diameter and it is 4 times greater than the particle used. Usage of this kind of nanofluid shows an effective increase in the thermal conductivity of the nanofluid and decrease in the size of the particle. But the preparation of Eastman’s nanofluid is costly and it cannot satisfy the needs of the applications easily. The nanofluid present in this study is gained through direct mixture of base liquid and the nanoparticles.

Enhanced heat transfer analysis

In many application cases the nanofluids exhibit greater increase in the heat transfer when compared to the already present methods that are used to improve the thermal conductivity of nanofluids. Choi in 1996 stated some important advantages of nanofluids for improving the transfer of heat, reduce the size and weight. There are two types of methods to determine the increase in heat transfer suspensions namely two phase one and single phase one. In which the two phases offers the feasibility to understand the operation of solid phase and fluid phase in the process of heat transfer. But the only drawback is it takes more time and capacity to transfer heat. Sato el al in 1998 combined DNS and Lagrangian statistics method to investigate the unstable transport of solid particles in a suspended gas. The second method imagines that the particles and fluid phase are in a state of thermal equilibrium and they flow with almost similar velocity. The second method is simple in nature and its computation time is also very low when compared to the first method. So this method is more suitable for the process of heat transfer of nanofluids through tubes. The distribution of nanofluid coexists due to the following factors such as Friction present among the nanofluid, pressure, by diffusion of Brownian and sedimentation. In order to view the fast movement of the particles in the tube the dispersed method is chosen. This model is commonly utilized to rectify multi and one dimensional diffusion complication.

In the year 1954 Taylor was the first researcher to use this method to simulate the diffusion of salt in water. The back mixture approach is mostly utilized to detail the effect of fast moving fluid and it attains the temperature gradient (Mecklenburg and Hartland, 1976). Thus, it can be inferred from the above two methods that the augmentation of nanoparticles enhance the transfer of heat. The nanoparticles improve the thermal conductivity of the fluid and it also increases the robustness of the heat transfer process. The increased enforcement of nanofluids exhibits high thermal conductivity from the fast distribution of the nanoparticles. With the help of experiments the comprehensive parameter for the fluid is determined. These parameters help us to enhance high thermal conductivity of the nanofluid in a better way when compared to the choi's technique (Choi 1997) and it also offers a refined method to determine the increased transfer of heat in nanofluid. The expressions and results obtained from this method are necessary to enhance the performance of nanofluid through transfer of heat.

Conclusion

A technique for the preparation of nanofluid particles has been refined in the article. Many samples of nanofluid particles are prepared by direct mixture of both the base fluids and sample nanofluids using this method. In addition, it also reveals about the various application case of nanofluids practically. The nanofluids exhibit high potential in developing the process of heat transfer in nanofluids. One of the major aspects is that the ultra-one suspended nanoparticles enhance the thermal conductivity of nanofluid remarkably to a great extent. The factors that affect the thermal conductivity of nanofluids are fraction of volume, shape dimension and the properties of the fluids. In this article the hot wire approach is mainly utilized to estimate the thermal conductivity of a nanofluid. The measured results reveal that the fraction volume of nanofluid is rapidly increased due to the thermal conductivity of nanofluids. For the Suspension of water and Cu nanoparticles the base liquid ranges from 1.22 to 1.76 and the fraction of volume increases from 2.4% to 7.4% respectively. Thus from the Brownian diffusion and sedimentation it is clearly inferred that the distribution of nanofluid coexist due to the following factors such as Friction present among the nanofluid and pressure. In order to view the fast movement of the particles in the tube the dispersed method is chosen. This model is commonly utilized to rectify the multi and one dimensional diffusion complication and it determines the improved transfer of heat in nanofluids. There are also some relations that are under research that are used for investigating Nu. In spite of all these some experimental methods and approaches are necessary to determine the enhancement in the process of heat transfer in nanofluids.

References

[1] Ahuja, A.S., 1975. Augmentation of heat transfer in laminar flow of polystyrene suspensions. J. Appl. Phys. 46, 3408-3425.

[2] Beckman, L.V., Law, V.J., Bailey, R.V., von Rosenberg, D.U., 1990. Axial dispersion for turbulent flow with a large radial heat flux. AIChE J. 36, 598-604.

[3] Choi, U.S., 1995. Enhancing thermal conductivity of fluids with nanoparticles. ASME FED 231, 99-103.

[4] Dankwerts, P.V., 1953. Continuous flow systems, distribution of resistance times. Chem. Eng. Sci. 2, 1-10.

[5] Eastman, J.A., Choi, U.S., Li, S., Thompson, L.J., Lee, S., 1997. Enhanced thermal conductivity through the development of nanofluids. In: Komarneni, S., Parker, J.C., Wollenberger, H.J. (Eds.), Nanophase and Nanocomposite Materials II. MRS, Pittsburg, PA, pp. 3-11.

[6] Hamilton, R.L., Crosser, O.K., 1962. Thermal conductivity of heterogeneous two-component systems. I & EC Fundamentals 1, 182-191.

[7] Kaviany, M., 1995. Principles of Heat Transfer in Porous Media. Springer, Berlin.

[8] Liu, K.V., Choi, U.S., Kasza, K.E., 1988. Measurements of pressure drop and heat transfer in turbulent pipe flows of particulate slurries. Argonne Nantional Laboratory Report, ANL-88-15.

[9] Masuda, H., Ebata, A., Teramae, K., Hishinuma, N., 1993. Alternation of thermal conductivity and viscosity of liquid by dispersing ultra-fine particles. Netsu Bussei (Japan), 4 (4), 227-233.

[10] Mecklenburg, J.C., Hartland, S., 1975. The Theory of Backmixing. Wiley, London.

[11] Sato, Y., Deutsch, E., Simonin, O., 1998. Direct numerical simulations of heat transfer by solid particles suspended in homogeneous isotropic turbulence. Int. J. Heat Fluid Flow 19 (2), 187-192.

[12] Taylor, G.I., 1953. Dispersion of soluble matter in solvent flowing through a tube. Proc. R. Soc. (London) A 219, 186-203.

[13] Wakeham, W.A., Nagashima, Sengers, J.V., 1991. Measurement of the Transport Properties of Fluids. Blackwell, Oxford.

[14] Wasp, F.J., 1977. Solid-Liquid Flow Slurry Pipeline Transportation. Trans. Tech. Pub., Berlin.