The Study of Nanofluids Rheological Properties

S. Zeinali Heris*1, M. Khodadadi Yazdi1

1- Department of Chemical Engineering, Faculty of Engineering, Ferdowsi University Of Mashhad, Mashhad, Iran; zeinal@ferdowsi.um.ac.ir

Introduction

Nanofluids are suspension of metallic or metal-oxide solid nanoparticles with size varying generally from 1 to 100 nm dispersed in heat transfer liquids such as water, ethylene glycol and engine oil. It has been found that important heat transfer enhancement may be achieved using nanofluids instead of conventional fluids. This is of major importance for electronics and microelectronics where liquids cooling systems are necessary and miniaturizing is needed. In this regard, determination of the nanofluids viscosity is essential to establishing adequate pumping power as well as the convective heat transfer coefficient, because the prandtl number and Reynolds number are functions of viscosity. The conventional correlations such as Einstein model [1] consider only the nanoparticles volume concentration on nanofluid viscosity prediction. Nguyen et al. [2, 3] during their experimental investigation studied the influence of temperature and the particle size on dynamic viscosities of water/ Al_2O_3 and water/CuO suspension. In the present study the various models for nanofluids viscosity determination is studied and the advantage and disadvantage of each models discussed.

The Study of Nanofluids Rheological Properties

S. Zeinali Heris*[1], M. Khodadadi Yazdi[1]

1- Department of Chemical Engineering, Faculty of Engineering, Ferdowsi University Of Mashhad, Mashhad, Iran; zeinal@ferdowsi.um.ac.ir

Introduction

Nanofluids are suspension of metallic or metal-oxide solid nanoparticles with size varying generally from 1 to 100 nm dispersed in heat transfer liquids such as water, ethylene glycol and engine oil. It has been found that important heat transfer enhancement may be achieved using nanofluids instead of conventional fluids. This is of major importance for electronics and microelectronics where liquids cooling systems are necessary and miniaturizing is needed. In this regard, determination of the nanofluids viscosity is essential to establishing adequate pumping power as well as the convective heat transfer coefficient, because the prandtl number and Reynolds number are functions of viscosity. The conventional correlations such as Einstein model [1] consider only the nanoparticles volume concentration on nanofluid viscosity prediction. Nguyen et al. [2, 3] during their experimental investigation studied the influence of temperature and the particle size on dynamic viscosities of water/ Al_2O_3 and water/CuO suspension. In the present study the various models for nanofluids viscosity determination is studied and the advantage and disadvantage of each models discussed.

The viscosity of nanofluids

The simplest formula that relates viscosity of nanofluid to particles volume fractions is Einstein's formula as follow [1]:

φμμμ5.21bfnfr+== (1)

In above correlation φ is nanoparticles volume fraction, and bfμis base fluid viscosity, and is the viscosity of nanofluid and nfμrμ is the ratio of nanofluid viscosity to the viscosity of base fluid. The Einstein's model, Equation (1) is valid for a very low volume fraction, say 2.0% by volume approximately [4].

Brinkman [5] presented a viscosity relation that extended Einstein's formula to concentrated suspension as follows:

5.2r)1(1φμ−= (2)

Lundgren [6] has proposed the following equation under the form of Taylor series:

)(O4255.2132rφφφμ+++= (3)

In all of the above relations, the relative viscosity is a function only of the base fluid viscosity and nanoparticles volume concentration and can be used when linear fluid assumption is satisfied. Viscosity is a strong function of the temperature. Kulkarni et al. [7] proposed the formula for the viscosity of water/CuO nanofluids as a function of temperature and nanoparticles volume concentration in as follows:

C50°

BT1A)(Lnnf− =μ (4)

In correlation (4) the Parameters A and B are functions of nanoparticles Volume fraction(.

Namburu et al. [8] for Copper oxide nanoparticles suspended in (60:40 by weight) ethylene glycol and water mixture have proposed the following formula in the form of Arrhenius expression:

BTnfAe)log(−=μ (5)

Nguyen et al. [2,3] during experimental investigation on water/Al_2O_3 nanofluid represented that for nanoparticles volume fractions lower than 4.0%, viscosities corresponding to 36 nm and 47 nm particle size are approximately identical but for nanoparticles concentration higher than 4.0% by volume viscosities of 47 nm nanoparticles size are clearly higher than those of 36 nm size [1,2]. They proposed some relation for computing viscosities of 36 nm and 47 nm particles size nanofluids.

Hysteresis phenomenon on viscosity

Nguyen's experimental results on water/Al_2O_3 and water/CuO nanofluids in the range of to clearly revealed that for a given nanoparticles volume concentration, there is a critical temperature beyond which nanofluid viscous behavior drastically altered. In fact, if the nanofluid sample is heated beyond such a critical temperature, a striking increase of viscosity occurs. And if it is allowed to cool after being heated beyond a critical temperature, then a hysteresis phenomenon can occur. In this temperature: C25◦C75◦

$0T_{cr}T_r=\partial\partial\mu$ (6)

In equation (6) subscript, refer to critical temperature. Thus, we have temperature dependent viscosity relation; we can calculate the critical temperature.)cr(

Conclusion

Viscosity of nanofluids is a function of nanoparticles volume fractions, temperature and nanoparticles size. Several correlations are provided to compute nanofluids viscosity. Considering the effect of the nanoparticles volume fraction, size and temperature, the effect of nanoparticles size on viscosity become important only when volume concentration is higher than 4.0%. In addition, the experimental results indicated that there is critical temperature that for higher temperatures the viscosity begins to increase; such a critical temperature is a strong function of both nanoparticles concentration and size. The hysteresis phenomenon observed on viscosity has raised serious concerns regarding the use of nanofluids for heat transfer enhancement purposes.

References

[1] D.A. Drew and S.L. Passman, Theory of multi component fluids, Springer, Berlin, 1999.

[2] C. T. Nguyen, F. Desgranges, N. Galanis, G. Roy, T. Mare, S. Boucher and H. A. Mintsa, " Viscosity data for Al_2O_3-water nanofluid-hysteresis: is heat transfer enhancement using nanofluids reliable?", Int. J. Thermal Science, 47, 103-111, 2008.

[3] C. T. Nguyen, F. Desgranges, G. Roy, N. Galanis, T. Mare, S. Boucher and H. A. Mintsa, " Temperature and particle size dependent viscosity data for water-based nanofluids- Hysteresis phenomenon", J. Heat Fluid Flow, 28, 1492-1506, 2007.

[4] S. Zeinali Heris, M. Nasr Esfahany, and S.Gh. Etemad, "Numerical Investigation of Nanofluid Laminar Convective Heat Transfer through Circular Tube", Numerical Heat Transfer, Part A: Applications, 52, 1043-1058, 2007.

[5] H. C. Brinkman, The viscosity of concentrated suspensions and solutions" J. Chemistry Physics, 20, 571-581, 1952.

[6]T.S. Lundgren, "Slow flow through stationary random beds and suspensions of spheres", J. Fluid Mech., 51, 273-299, 1972.

[7]D.P. Kulkarani, D.K. Das, G.A. Chukwa, "Temperature dependent rheological property of copper oxide nanoparticles suspension", J. Nanoscience and Nanotechnology, 6, 1150-1154, 2006.

[8] K.p. Namburu, D.P. Kulkarani, D. Misra and D.K. Das, "Viscosity of copper oxide nanoparticles dispersed in ethylene glycole and water mixture", Exp. Thermal Fluid Science, 32, 397-402, 2007.