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Effect of particle size, shape upon rheological properties of methanol based nanofluids at 303k.

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ABSTRACT

The past decade has seen the rapid development in the study of acoustical and thermal properties of nanofluids for potential applications. Most of the researcher has focused their attention on the thermal conductivity of these fluids. However, rheological properties of nanofluids are also important which affects the acoustical and thermal properties of nanofluids. In this paper, results on density and viscosity in methanol based nanofluids at low concentration (0.002M-0.01M) are presented. The purpose of present study was to identify effect of particle size, shape on rheological properties of nanofluids at 303K. The experimental results show that the viscosity and density increases with an increase of particle volume fraction. Also it is observed that nanoparticles with higher surface area exhibit lower density and viscosities. The changes in density and viscosity occur as a result of interfacial forces, surface area and particle shape and size distribution.

Keywords: Nanofluids, TEM, Viscosity, Density.

INTRODUCTION

Nanofluids are composites consisting of solid nanoparticles with sizes varying generally from 1 to 100 nm dispersed into a liquids such as water, methanol, ethylene glycol and propylene glycol etc [1]. Nanofluids are of great significance because of their enhanced acoustical and rheological properties.

Results like these have drawn much interest from the industrial and science communities to explore the rheological properties of nanofluids[2].

Rheological properties of nanofluids are strongly related to the nanofluids microstructure[3].It is depends upon the particle concentration, particle shape and size, particle distribution and the extent of particle-particle interactions. Also agglomeritio and clustering of nanoparticles can lead to an undesirable changes in nanofluids. Therefore, a proper understanding of nanofluids is a prerequisite for effective utilization of nanofluids for various applications. Rheological properties of nanofluids provide information on the nature of interactions in the constituent. Many literature provides extensive data on the density and viscosity of liquids and liquid mixtures but a combined study of viscosity and density of nanofluids is quite scarce. Therefore results of effect of particle size on viscosity and density of methanol based SnO_2, $CaCO_3$, CaF_2, ZnS and silver nanofluids are presented.

METHODOLOGY

Materials

Aniline, ammonium persulphate, ammonium hydroxide, Stannic chloride and hydrochloric acid were used for the synthesis of SnO_2 nanoparticles. In the preparation of CaF_2, we used calcium chloride dehydrate ($CaCl_2{\cdot}2H_2O$, Merk-99.9%), nitric acid (conc. HNO_3, Merk-99.99%), ammonium fluoride (NH_4F, Merk-99.50%), bismuth nitrate ($Bi(NO_3)_3{\cdot}5H_2O$, Merk-99.50%), and ethanol as raw materials. The synthesis of ZnS nanoparticles was carried out by chemical method using Zinc Acetate [$Zn(CH_3COO)_2$], DMF [$H\text{-}CO\text{-}N(CH_3)_2$] and Na_2S as source materials. The silver nanoparticle were synthesized by thermal decomposition method at 700°C. Reducing agent NH2CONH2 is added to the mixture of AgNO3 in order to form the silver nanoparticle. All the reagents were of analytical grade and used without further purification.

Methods

Preparation of Samples

Nanofluids preparation is not as simple as mixing some solid nanoparticles in a base fluid[4].There are two techniques mainly used for synthesizing nanofluids: single step method and two step method.

In a single step[5] method both preparation of nanoparticles and synthesis of nanofluids are done in a combined process. This method has advantages such as stability increase and minimized agglomeration. There are some disadvantages like the fact that only low pressure fluids are suitable for this process hence limiting the scope of utilization.

In two step method[6] nanoparticles are initially prepared and then dispersed into the fluid by some techniques like ultrasound [7]. Nowadays, availability of nanoparticles from commercial sources makes this method fairly attractive to the researchers and different industries. Most of the researches utilized two step dispersion method and ultrasonic vibrations for proper mixtures.

In present work, methanol based nanofluids with molar fractions of 0.002, 0.004, 0.006, 0.008 and 0.01 were prepared using two step methods. Nanofluids with a required molar concentration was prepared by dispersing a specified amount of nanoparticles in methanol under stirring process to get a uniform dispersion of nanofluids.

RESULTS AND DISCUSSION

The SEM images of synthesized SnO_2, $CaCO_3$, $CaF_2$and ZnS particles are shown in fig 1(a), 1(b), 1(c) and 1(d) respectively. It can be seen from the images that the particles size are in the range of nanometer. SnO_2, $CaCO_3$, CaF_2 nanoparticles are spherical in shape while ZnS nanoparticles are elongated in shape.

Effect of particle size on rheological properties

All researchers and most of the investigations available in the literature on the viscosity and density of nanofluids, regarding the effect of volume fraction agree upon the fact that viscosity and density of nanofluids increases with increasing the volume fractions. Das et al.[8], Putra et al.[9],Prasher et al.[11],Chevalier et al.[12]showed that viscosity of nanofluids increased with increasing the particle concentration.

There are very few results available in literature about particle size and shape effect on rheological properties of nanofluids. However, viscosity of nanofluids has a strong dependence with nanoparticle shape.Timofeeva et al.[12]report that elongate particles like platelets and cylinders result in higher viscosity at the same volume fraction. Nguyen et al.[13]studied particle size effect for Al_2O_3/water nanofluids and observed that particle size effects are more significant for high particle volume percentage. They found that viscosity of nanofluids decrease with increasing the diameter of the particle.

Fig. 2 shows that viscosity of nanofluids increased with increase in molar concentration. For methanol based SnO_2 nanofluids, the viscosities were 0.8742cP, 0.9224cP, 0.989cP, 1.0353cP and 1.1087cP higher than that of methanol based $CaCO_3$ nanofluids which is 0.5704cP, 0.5862cP, 0.5998cP, 0.6155cP and 0.6357cP respectively. Experimental investigation revealed that viscosity of all prepared nanofluids depends on the particle size, particle size distribution and shape of nanoparticles. In present system, it is observed that the viscosity of methanol based calcium carbonate nanofluids is lowest among all the studied nanofluids because of its larger particle size and the viscosity of nanofluids increases with reducing particle size. The distinguish feature of this dispersed system is that the area of contact between the dispersed particles and the methanol is relatively large and it increases with reducing particle size. Hence viscosity of nanofluids increases with decrease in particle size. But in case of methanol based zinc sulphide nanofluids, even though particle size is large still it shows higher viscosity. This can be explained on the basis of particle size distribution and shape of dispersed nanoparticles. All the particles used for the preparation of nanofluids have spherical shape but ZnS nanoparticles have elongated shape and hence due to elongated shape ZnS nanofluids have larger viscosity among all nanofluids[14]. Also in case of methanol based silver nanofluids, due to its narrow particle size distribution it provides less free space to move around and eventually makes the sample more viscous[15].

It is observed that the density of methanol based nanofluids becomes size dependent and increased with decrease in particle size as shown in fig. 3. The density of nanofluids is higher than the base fluids. The experimental value of density of methanol based calcium carbonate nanofluids having particle size 63 nm is minimum and it is 795.2 kg/m^3 for 0.01M concentration, where as the density of methanol based tin oxide nanofluids having particle size 12 nm is maximum and it is 863.88 kg/m^3 for 0.01M concentration. The increase in density of methanol based nanofluids is due to dispersion of high density nanoparticles in the base fluids. Again the number of particles per unit area is greater for smaller size particles as compared to bigger size particles.

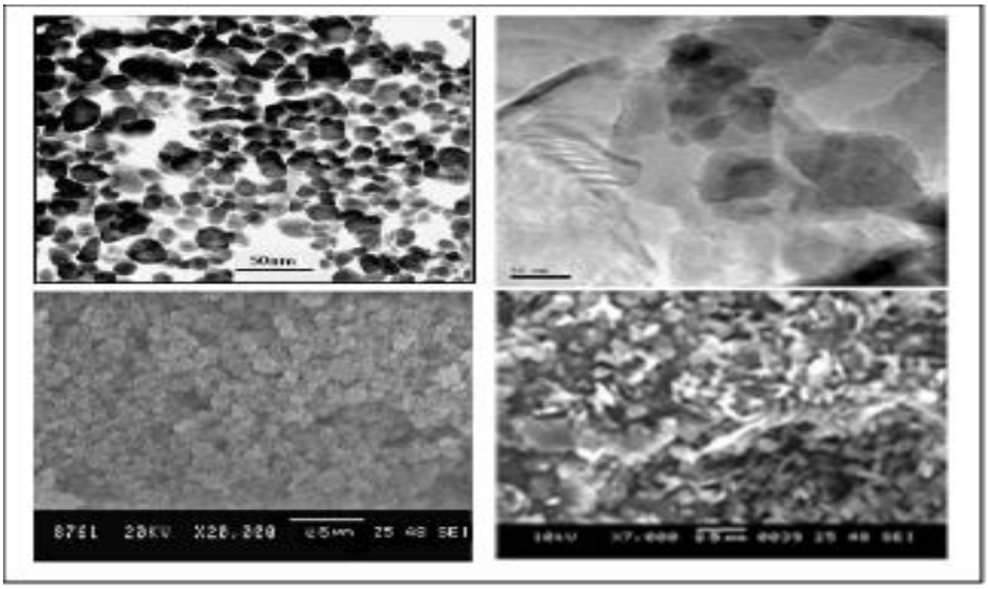

Fig. 1.SEM images of SnO_2, $CaCO_3$, CaF_2 and ZnS.

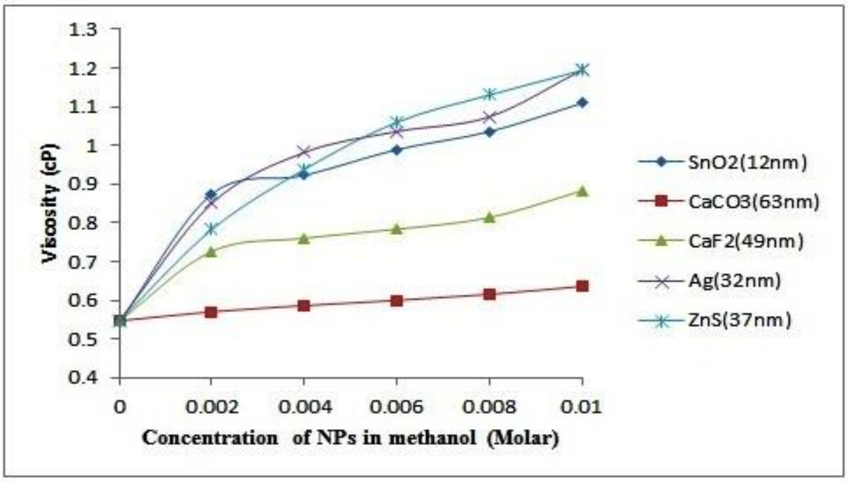

Fig. 2. Variation of viscosity of SnO_2, $CaCO_3$, CaF_2, ZnS and silver nanofluids of different particle size at 303K

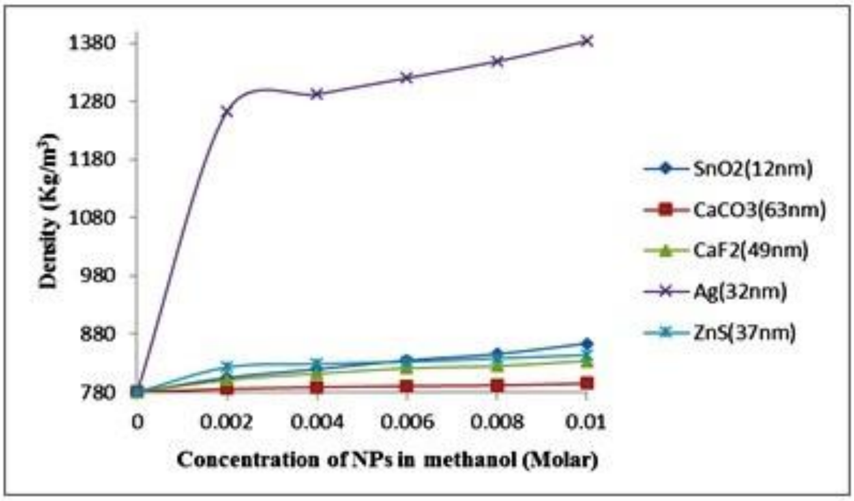

Fig. 3. Variation of density of SnO_2, $CaCO_3$, CaF_2, ZnS and silver nanofluids of different particle size at 303K

CONCLUSION

The viscosity and density of methanol based SnO_2, $CaCO_3$, CaF_2, ZnS and silver nanofluids was measured using capillary tube viscometers and density bottle respectively. The results show that the viscosity of nanofluids decreases with increasing particle diameter. The particle shape and size distribution also influence the viscosityof nanofluids. Elongated size ZnS nanoparticles shows higher viscosity than spherical size SnO_2, $CaCO_3$, CaF_2, and silver nanoparticles at the same concentration.The density of nanofluids increases somewhat with increasing concentration. Silver nanoparticles shows highest density among all studied nanofluids because of dispersion of high density nanoparticles in methanol.

Conflicts of interest: The authors stated that no conflicts of interest.

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