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Stability and Agglomeration of Alumina Nanoparticles in Ethanol-Water Mixtures

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Abstract

Nanofluids have gained much attention in the last decade due to wide range of engineering applications. Agglomeration among nanoparticles in nanosuspensions accelerates settling of nanoparticles due to gravity and reduces overall thermal conductivity of nanofluid. Settling characteristics of alumina nanoparticles in six different concentrations in different proportions of ethanol and water mixtures are studied. Surfactant free nanofluids are prepared with Alumina nanoparticles of average diameter 40 nm, 50 nm and 100 nm using two-step method. Settling behaviour of nanoparticles in nanosuspensions is observed under natural and sonicated conditions. Photographic technique is used to measure sediment height in a batch sedimentation apparatus. Heights of the sediments are observed for 24 hours with and without sonication at room temperature. It is found that sonication has significant influence on the stability of nanofluids. Effect of ethanol concentration on the sediment ratio is studied with and without sonication. Aggregation among nanoparticles and interaction of particles with fluid mixtures are investigated by performing various analyses such as Fourier transform infrared spectroscopy (FTIR), transmission electron microscopy (TEM) and particle size analyser.

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Keywords: nanofluids; sedimentation; agglomeration; sonication; stability

1. Introduction

Dispersion of nanoparticles in liquids in low concentration is termed as nanofluid. Nanofluids have gained much attention due to its distinctive properties in the field of heat transfer, nanocomposite membranes, pigments and drug delivery [1-6]. Settling behavior of nanoparticles in nanosuspensions is a topic of significant interest towards their

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usage in different applications. Limited knowledge is available on the particle-liquid interaction and aggregation among particles. Nanoparticles have high surface area due to smaller in size which increases the Van der Waals attractive forces on the surface of particles. These attractive forces tend to attract other particles to form a cluster known as agglomeration [7]. Formation of agglomerates has negative impact on the stability of nanosuspensions [8-10]. Agglomeration in nanofluids can be reduced by ultrasonication of suspensions. Sonication is the phenomenon when ultrasonic waves pass through different folds of sediment causing disruption among particles. Hence the big agglomerates are broken in to smaller agglomerates.

Alumina is an amphoteric oxide of aluminum which has been used in different investigations for the heat transfer improvement [11]. Rehman et al. [12] investigated the dispersion behavior of alumina nanoparticles in water using different particle loading. They found that sonication has significant effect on the stability of nanofluid. Nanosuspensions with three hours of sonication showed high stability and low agglomeration. Witharana et al. [13] investigated the settling behavior of alumina suspensions (0.5 wt%) at different pH levels. They found that nanosuspensions were stable for 30 minutes at pH 6.3. In another study [14], dispersion behavior of alumina in low (1-5 wt% ethanol) and high (95-100 wt% ethanol) concentrations of ethanol were observed with and without sonication. Dispersed type settling behavior was observed in low concentrations of alumina. Liu et al. [15] studied agglomeration and sedimentation behavior of TiO_2 nanoparticles and reported that nanosuspensions with agglomerate size more than 1000 nm showed poor stability. In a recent study [16], sedimentation behavior of clay, Al_2O_3 and CeO_2 in water, EG and water/EG mixture (50 vol%) was observed using photographic method. It was found that nanosuspensions with low nanoparticle concentration showed better stability than concentrated nanosuspensions. Manjula et al. [17] investigated dispersion behavior of alumina nanoparticles in water and reported the effect of pH and stabilizer on the sediment heights of the nanosuspension. They found that stability of nanosuspensions can be improved by optimizing pH level and addition of stabilizer. In our previous work [18], dispersion behavior of ZnO nanoparticles in ethanol-water mixture was studies at different concentrations with and without sonication. It was observed that stability of the nanofluids can be improved using ultrasonication.

The objective of presented work is to study the effect of sonication on the dispersion behavior of alumina nanoparticles in ethanol-water mixtures. Settling behavior of nanoparticles in different proportions of ethanol and water are presented under natural and sonicated conditions. Stability of alumina based nanofluids is observed using sedimentation technique. Particle-liquid interaction and agglomeration has been studied using Fourier transform infrared spectroscopy (FTIR) and transmission electron microscopy (TEM), respectively. It is evident from many investigations [19-21] that sonication has significant effect towards the improvement in stability of nanosuspensions.

Nomenclature

SR	sediment ratio
H_S	sediment height
H_T	total height of sediment

2. Methodology

Alumina nanoparticles of average particle sizes 40 nm (≥ 99.5%, MK Nano), 50 nm (99.9%, SS Nano) and 100 nm (99.9%, MK Nano) are used to prepare nanofluids. Nanoparticles with six different concentrations (0.1, 0.3, 0.5, 1, 3, 5 wt%) are added in different proportions of ethanol concentrations (0-100 wt%) using Two step method. The nanosuspension samples are prepared in flat bottom glass test tubes (16 x 125 mm). Batch sedimentation apparatus is used to observe the settling characteristics of nanofluids using visualization technique at room temperature. FTIR analysis (Perkin-Elmer) has been performed to study interaction of nanoparticles with mixture of liquids. Agglomeration effect has been observed by using TEM images (Zeiss, 200 kV) for sonicated and without sonicated samples. Average agglomerate size is determined using particle size analyzer (Malvern Zetasizer Nano s90) for non-sonicated samples.

To study the natural settling behavior, the nanosuspensions are allowed to settle down under gravity and sediment heights are measured with respect to time for 24 hours. The nanofluid samples are then sonicated for 12 hours using