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Deagglomeration effects of hydrodynamic cavitation on Nanofluids

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Abstract: Agglomeration issue for nanofluids in heat transfer applications has motivated the researchers to search for solutions to overcome this problem. The proposed technique in this paper is using the energy release of the cavitating bubbles to deagglomerate the nanoparticles. The agglomerated nanofluid passes through a microchannel with a micro orifice at different inlet pressures. DLS measurements are done at different inlet pressures to investigate the practicality of the system. The results show the mean size of the nanoparticles after being subjected to cavitating flow decreases by 87%.

Introduction/Background: Nanofluids have attracted the attention of many researchers during the past decades due to their wide applications in different areas such as heat transfer [1], drug delivery [2], and cancer therapy [3]. Nanofluids are known for their high convection heat transfer coefficient and high dispersion stability due to the Brownian motion of nanoparticles. Because of the heat transfer enhancement by nanofluids, they are frequently used in different industries for applications such as cooling systems and solar energy collectors. Also, nanofluids have adjustable properties like thermal conductivity and wettability by changing the weight fraction of nanoparticles in the base fluid. Although they have many applications and advantages, they also face some problems in the long run. For instance, they are not very stable and also they are not reusable after short use. Nanoparticles stick to each other and get agglomerated as they receive heat and consequently sedimentation occurs. Many efforts have been made to deagglomerate nanoparticles to increase their stability. One of the widely used techniques for deaggolomerating them is using surfactants in the nanofluids. However they contaminate the heat transfer media and also they are not functional enough at high temperatures because the surfactants enlarge the thermal resistance between nanoparticles and the base fluid [4]. The other way to prevent agglomeration without surfactants is surface modification of nanoparticles. For example, grafting silanes directly to the surface of silica nanoparticles is a type of surface modifications that prevents the agglomeration [5]. Although this method is more functional than using surfactants, surface modification processes are hard and also expensive. Cavitation, as one of the main phase change mechanisms along with boiling, occurs due to the sudden pressure drop at a constant temperature. There are two methods to generate cavitation: i) hydrodynamic cavitation ii) acoustic cavitation. Hydrodynamic cavitation happens as a result of increasing the gravitational energy or kinetic energy of the fluid. A sudden reduction in cross-sectional area of the fluid flow path could decrease the pressure and cause hydrodynamic cavitation. The collapsing bubbles at the high pressure zone releases a massive amount of energy that could be used for different applications such as deagglomeration of nanoparticles [6, 7].

In this study, the proposed solution for nanoparticles deagglomeration exploits the energy release from the cavitation phenomenon in a microfluidic device. Titania-water nanofluid is prepared as the working fluid. The nanofluid is heated to make sure that agglomeration happens. Then, the effect of cavitating flow on the deagglomeration of the particles is investigated.

Experimental setup: Commercial TiO_2 rutile powder (Ionic Liquids Technologies, IoLiTec GmbH, Germany) with mean diameter of 30nm was mixed with the distilled water as the base fluid at the weight fraction of 0.05%. For nanofluid preparation, sonication and stirring were done simultaneously for 2 hours [8]. Then, it was heated up to 100℃ on the hot plate to agglomerate the particles. DLS measurement was used in each step to measure the average size of the dispersed particles.

As shown in Figure 1, the experimental setup consists of a high pressure nitrogen tank to drive the fluid into the system. The fluid container keeps the working fluid inside and the high speed camera monitors the fluid flow pattern while the microfluidic device is sandwiched between an aluminium package and Pyrex leads. Pressure gauges are installed at inlet, micro orifice, and outlet of the device. The microfluidic device is a dry etched micro orifice with the width of 152µm on a silicon substrate with one inlet and two outlets. The heated nanofluid is introduced to the system by increasing the inlet pressure. The high speed camera is used to ensure the inception, development, and supercavitation flow patterns.

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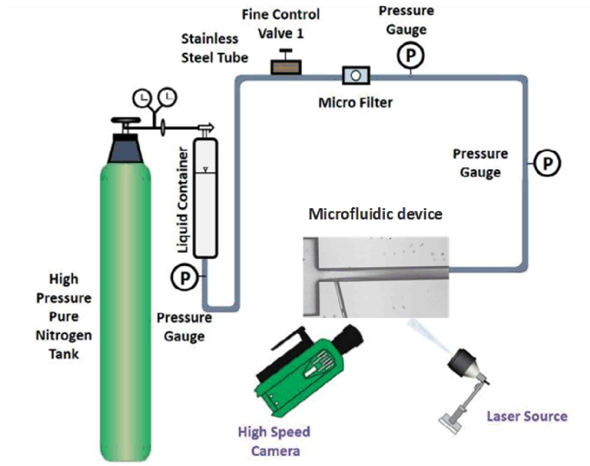

Figure 1. The experimental setup

Discussion and Results: The Dynamic Light Scattering (Zetasizer Nano ZS (Malvern)) technique is used for measuring the hydrodynamic diameter of the nanoparticles in the base fluid. DLS measurements were done in three stages; prepared nanofluid, heated nanofluid and after the experiments with different inlet pressures. The DLS results are shown in Figure 2. The mean diameter of the nanoparticles is measured as 255nm before heating while after heating, majority of the nanoparticles have a mean diameter of 1281nm. Since the cavitation intensity changes with alteration in inlet pressures, the size of the particles in the fluid decreases with increase in inlet pressure. The mean diameter of the nanoparticles as they passed through the micro orifice at 20bar, is 342 nm. At the inlet pressure of about 70 bar, the mean diameter of the nanoparticles reaches 164nm.

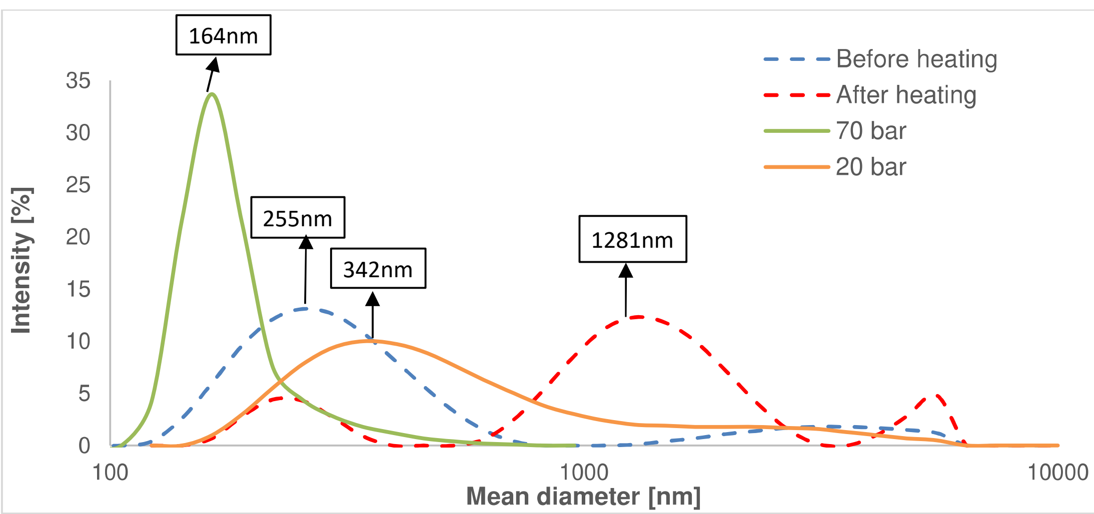

Figure 2. DLS results of the prepared nanofluid, heated nanofluid and after the experiments with two different inlet pressures

The DLS results show that the deagglomeration effect of this system has a direct relation with the cavitation intensity and inlet pressure.

Summary/Conclusions:

In this study, hydrodynamic cavitation is used as a technique to make the agglomerated nanoparticles inside nanofluid reusable. DLS measurements show that the mean dimeter of the nanoparticles decreases as they are subjected to cavitating flows. The experiments show that higher inlet pressures result in smaller mean dimeter of the nanoparticles, which is the result of enhanced shock wave propagation upon the collapse of the bubbles.

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