Sonication Effects on Stability and Thermal Properties of Silica- Paraflu Based Nanofluids

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ABSTRACT: *Cooling is one of the most important challenges in industries especially in the automotive industry. Coolant which is used in engine radiators possess lower thermal conductivity. To enhance the thermal properties, coolant was dispersed in nano sized particles and the fluid is called as Nanofluid. In this Study, Silica Nanoparticle was dispersed in Paraflu Engine coolant using Bath Sonicator and Probe Sonicator. The effect of Sonication on thermal Conductivity and the effect of concentration on thermal conductivity was studied. Characterization Studies like UV-Vis Spectroscopy, XRD (X-Ray Diffraction) and TEM (Transmission Electron Microscopy) results confirmed the size of silica particles in the nanometer range. Stability time was also calculated by Sedimentation method for the fluids prepared by Bath sonicator and Probe Sonicator. For the commercial application purpose, an optimization process is required for the creation of nanofluids and the forces affecting it.*

KEYWORDS: *Bath sonicator; Probe sonicator; Coolant; Stability; Thermal conductivity.*

INTRODUCTION

One of the major challenges in chemical process industries is cooling. Conventional heat transfer fluids lack cooling capabilities since conventional fluids have poor heat transfer properties [1]. One way to improve the heat transfer performance is to increase the available surface area for heat exchange which is impracticable [2]. Crystalline solids have thermal conductivities larger than conventional fluids. When these conventional heat transfer fluids dispersed in crystalline solids, one can expect enhanced thermal conductivity [3]. Crystalline solids with nanometer dimension are dispersed in heat transfer fluid (Base fluid) and the fluids are called as nanofluids [2, 4]. High performance heat transfer devices depend on the thermal properties of nanofluids.

Nanofluids are engineered colloidal suspension and it is a combination of nanoparticle and base fluid like water, glycol or oil [5]. Nanofluids are the emerging field of heat transfer since nanofluids show enhanced heat transfer characteristics when compared to base fluids. The advantages of smaller particle size are (i) High surface to volume ratio which yields higher energy and mass transfer rates (ii) Low mass resulting in high colloidal stability and (iii) Low inertia lead to less erosion. The main drawback of nanofluids for practical applications is high viscosity and low stability [6].

Synthesis of nanofluids can be done either by (i) one step method or by (ii) Two step method [7]. One step method has the ability to overcome the problem of stability.

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In Two step method first synthesis nanoparticle and particles are dispersed in basefluid.

In two step method, stable nanofluids are formed either by (i) adding surfactant (ii) Altering the pH or (iii) by effective sonication. The thermal properties of nanofluids are affected by its size and particle size distribution [8]. Adding surfactants reduce thermal properties leading to reduced heat transfer rate. Ultrasonic irradiation is used for the physical dispersion of a powder in a liquid for achieving homogeneous nanofluid [8-10]. Sonication is the act of applying sound energy to agitate particles in a sample. Ultrasonic frequencies are used and so the process is called ultrasonication. There are two methods of sonication namely (i) Direct/Probe methods and (ii) Indirect or Bath method. Direct sonication involves inserting a probe directly into a sample vessel for uniform mixing of particles whereas indirect sonication uses high intensity ultrasonic bath.

Nanofluids can be used as coolant in automobile radiators because of its high thermal properties. Industries like Ford, GM and many others are concentrating research on Nanofluids projects [11].

Silica nanoparticle was used in this study because of its thermal stability and it can also be used as an insulator and Paraflu which is used by FIAT as an engine coolant was used as base fluid. Base fluids will be usually water, ethylene glycol or oil, but in this study, engine coolant was taken as base fluid to study the heat transfer characteristics of engine coolant and engine coolant based nanofluids. This paper studied the effect of ultrasonication in bath method and in probe method for the preparation of silica nanofluids. Thermal conductivity measurements for the nanofluids and base fluid were measured using KD2PRO and stability was measured by sedimentation method.

EXPERIMENTAL SECTION

Synthesis of silica nanoparticles

Silica nanoparticles were synthesized by sol gel method. 1M ethanol was mixed with 10 ml water and kept in an ultrasonication bath. After 10 minutes, 0.012 M Tetra Ethyl Ortho Silicate (TEOS) was added and stirred in a magnetic stirrer. The 2.8 M Ammonia solution was added dropwise after 20 mins of stirring and kept for 90 mins to form a white turbid suspension. Silica nanoparticle was formed after oven drying and calcination [13].

Preparation of Silica Nanofluid

Silica nanofluid was prepared by two step method. Various concentrations for silica nanofluids (0.025 Vol %, 0.05 Vol%, & 0.1 Vol%) were prepared using the 50% Water and 50 % radiator coolant (Paraflu) as a base fluid by varying the sonication time in sonication bath and in probe sonicator and the optimum conditions are measured. The weight of the nanoparticles required for preparation of 100 ml silica nanofluids of a particular volume concentration, using water – paraflu base fluid is calculated by the following relation.

% volume concentration = A/A+B

A = weight of the nanoparticle/Density of nanoparticle.

B = weight of the basefluid/Density of basefluid.

The Energy given to the sample was constant for both the sonicators. To maintain stability of nanofluids, pH was maintained in the basic range.

RESULTS AND DISCUSSION

Particle Size Characterization

UV Spectroscopy

UV visible spectroscopy calculates the reduction of scattering and absorption of light passing through the sample. The absorption of visible electromagnetic waves by the collective oscillation of conduction electrons at the surface was exhibited by small metal nanoparticles [22]. This is known as the surface plasmon resonance effect. The interest in this effect is the possibility of using it as a tracer for the presence of metal nanoparticles with a simple UV-visible spectrometer.

The presence of Silica nanoparticles in the suspension was checked by scanning its absorbance in the wavelength range of 200-750 nm in a spectrophotometer for three different concentrations (0.025%, 0.05% and 0.1%). A UV Vis spectrograph of the silica nanoparticle suspension can be seen in Fig. 1. A plasmon resonance peak at ~223 nm for 0.025 % Concentration , 230 nm for 0.05 % Concentration and 238 nm for 0.1 % is seen in the spectra. It has been suggested that this peak is associated with the formation of silica nanoparticles.

When the concentration of silica nanoparticle changed from 0.025 to 0.1 %, the maximum extinction of Surface

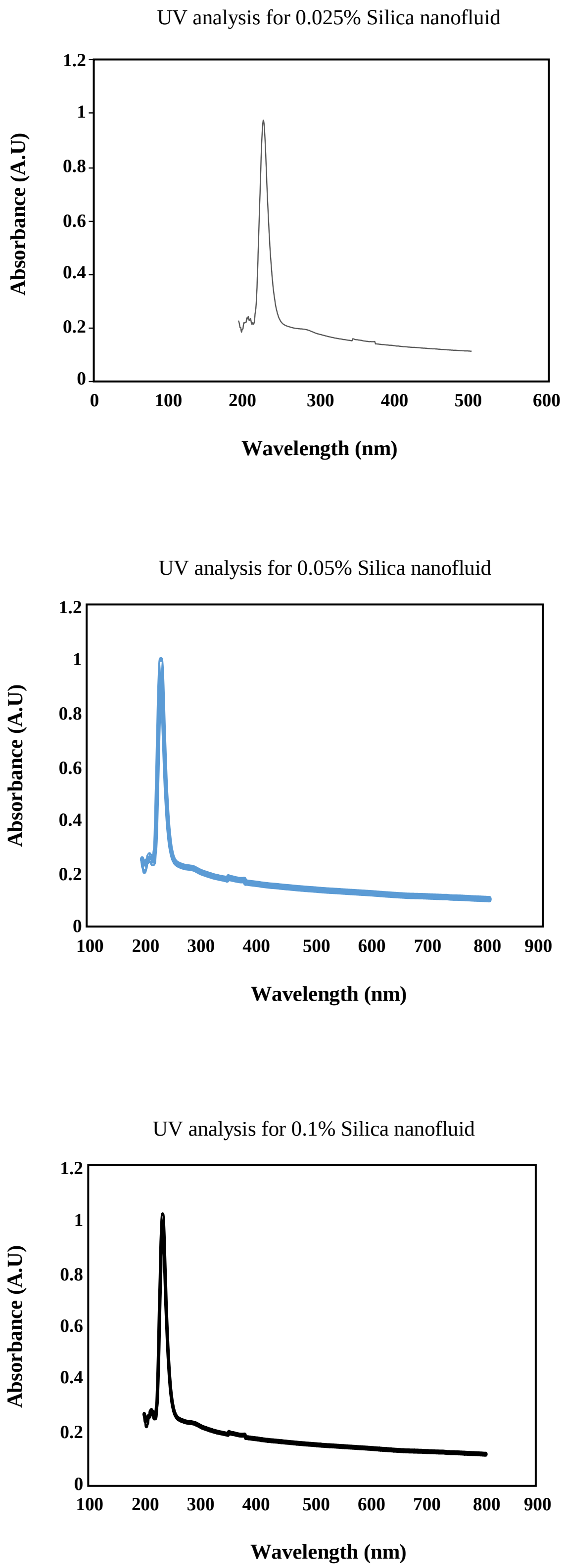

Fig. 1: Analysis of Nanofluid using UV Spectroscopy.

Plasmon Band (SPB) shifted from 223 nm to 238 nm in the visible region which may be attributed to the surface plasmon oscillation of free electrons. The surface Plasmon resonance of the silica particles is shifted to increase in particle concentration in accordance with Mie theory [23].

XRD Analysis:

The crystal structure, crystallite size, and strain, x-ray diffraction patterns can be obtained from the XRD analysis which is a primary characterization tool. The broadening of diffraction peaks is caused by the randomly oriented crystals. In a finite sized lattice, the absence of constructive and destructive interferences of x-rays has been attributed. The broadening of peaks in the diffraction patterns is also because of the inhomogeneous lattice strain and structural faults[24]

Powdered silica particles were analyzed using X-Ray Diffractometer (XRD) and the particle size was determined using Debye-Scherrer formula:

$$D = \frac{0.9\lambda}{\beta\cos\theta}$$

Where ‘λ’ is the wave length of X-Ray (0.1541 nm), ‘β’ is FWHM (full width at half maximum), ‘θ’ is the diffraction angle and ‘D’ is particle diameter size. By Using Debye Scherrer formula, the average particle size of the silica nanoparticle was found to be 41.73 nm.

The particle size, which is calculated from x-ray diffraction is a measure of the smallest unfaulted regions or the scattering domains of the material. The particle size region is bounded by defects and grain boundaries and separated from surrounding by a small misorientation.

TEM Analysis:

The particle size, size distribution and morphology of the nanoparticles can be obtained from TEM analysis. Microscopy is the only method to observe the individual particles in particle size measurement.

Fig. 3 shows a representative Transmission Electron Microscope image of the produced silica nanoparticles. This image displays that the synthesized nanoparticles are non-agglomerated, and generally spherical in shape. Also images show and confirm silica nanoparticles production at nano-size.

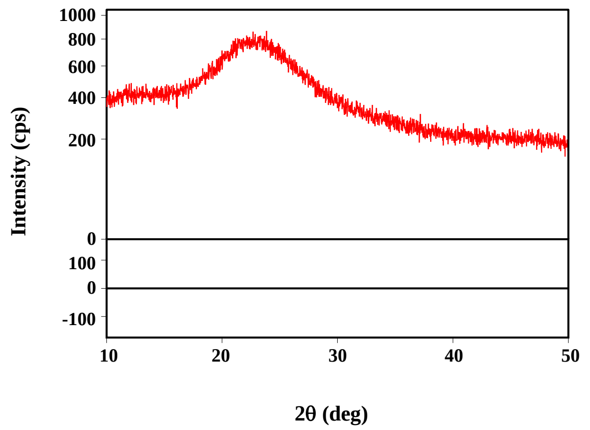

Fig. 2: Characterization of silica nanofluids using XRD analysis.

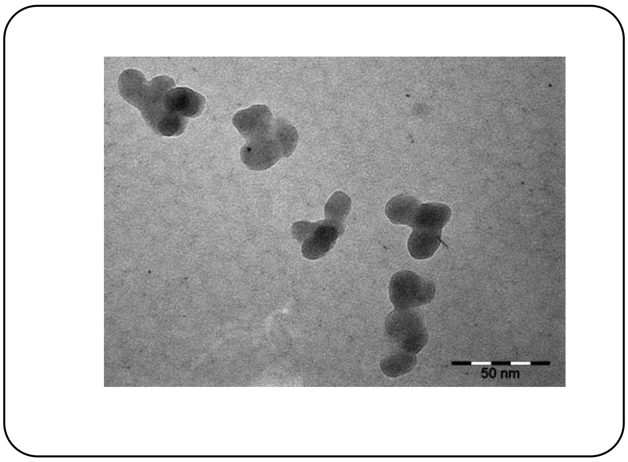

Fig. 3: Characterization of silica nanofluid using TEM analysis.

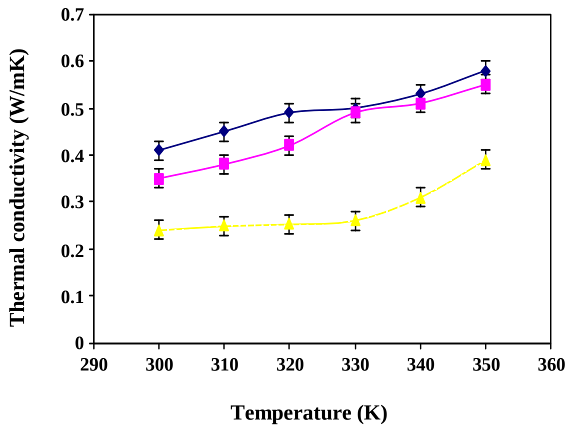

Fig. 4: Comparison of thermal conductivity for 0.025 Vol% Nanofluid.

Effect of sonication on thermal conductivity:

Thermal conductivity for three different concentrations (0.025%, 0.05% and 0.1%) were measured using KD2Pro for the nanofluids prepared by both Bath type and Probe type sonicator. Thermal conductivity was calculated from the change in temperature - time data from the equation

$$D = \frac{0.9\lambda}{\beta \cos\theta}$$

Where q is the constant heat rate in W/m^2.

The thermal conductivity of coolant was first measured and the thermal conductivity values for three different concentrations using bath sonicator and probe sonicator was measured using KD2PRO and the graphs are plotted and compared in Figs. 4, 5 and 6. It has been inferred that higher the concentration higher will be the thermal conductivity. Higher concentration also increases the viscosity, so the concentration has to be optimized.

For the enhancement of thermal conductivity, Brownian motion and thermal conductivity play a significant role. In order to make use of nanofluids for commercial application, an optimization process for the creation of nanofluids and the forces affecting it may be necessary for commercial application possible.

Stability time was also calculated by the sedimentation method for 0.1% Concentration. It was found that the thermal conductivity was high for bath sonicator when compared to Probe sonicator. Also the nanofluids prepared by bath type sonication was more stable when compared to probe type sonication.

CONCLUSIONS

In this work**,** Silica Nanofluids was prepared because of its high thermal conductivity using bath type sonication and Probe type sonication. Nanofluid was characterized by UV spectroscopy, XRD and TEM analysis and the influence of sonication on thermal conductivity was studied. It has been inferred that the thermal conductivity enhancement was about 80% more than that of base fluid using Bath type sonication whereas in Probe type sonication thermal conductivity enhancement was about 75%. Also the nanoparticles stay suspended in a base fluid for a longer time in Bath type. Nanofluids have been stable for more than 90 days in Bath type whereas in Probe type stability time was only 75 days. Stability time can be increased by adding a surfactant,

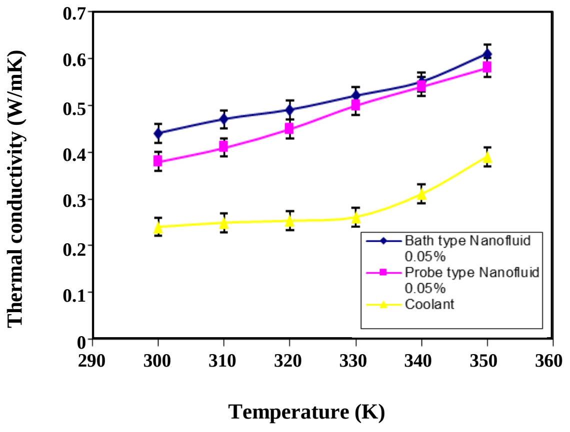

Fig. 5: Comparison of thermal conductivity for 0.05 Vol% Nanofluid.

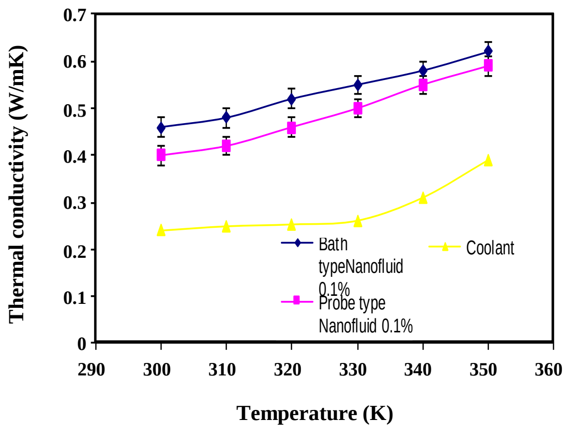

Fig. 6: Comparison of thermal conductivity for 0.1 Vol% Nanofluid.

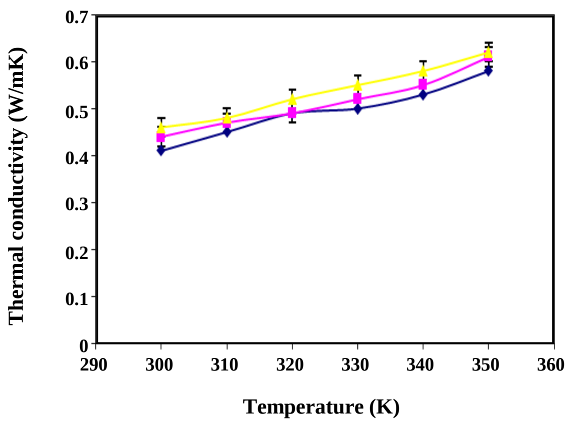

Fig. 7: Comparison of thermal conductivity for various concentrations using Bath Sonicator.

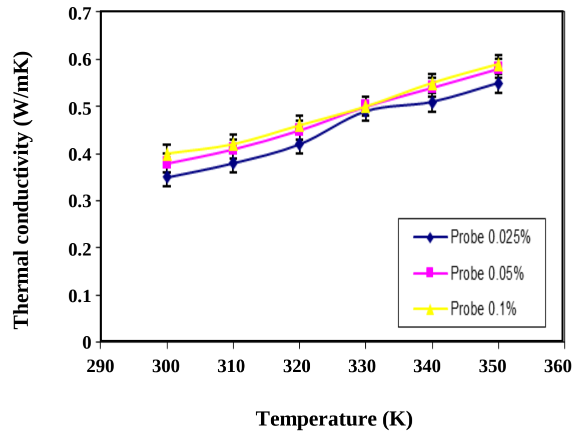

Fig. 8: Comparison of thermal conductivity for various concentrations using Probe Sonicator.

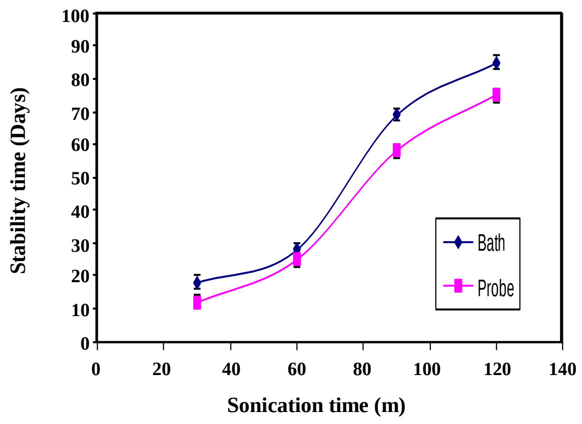

Fig. 9: Estimation of Stability using Sedimentation method for Bath and Probe sonicator.

but the addition of surfactants reduces the thermal conductivity. It has been concluded that for the preparation of silica nanofluid Bath type sonication is effective because foaming and sample loss are eliminated when compared to Probe type sonication.

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