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Effect of Particle Loading on the Stability of the Water Based Iron-Oxide Nanofluids

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Abstract

Dispersion stability is a crucial challenge for a nanofluid to obtained a uniform dispersion. The main aim of this research is to develop stability monitoring approach by experimental investigation of ultra violet-visible (UV-vis) absorbance of deionized water (DW) based ironoxide (maghemite: MH) nanoparticles dispersed nanofluids (MH/DW). Five different samples were prepared with increasing the loading of MH nanoparticles varied from 0.065 to 0.157 mg/ml in DW. Primarily digital photographs were captured to observed the sedimentation of MH/DW the nanofluids. A method was developed to monitor the quantitative stability of relative concentrations of MH/DW nanofluids. Optical absorbance measurements were conducted using UV-vis absorbance spectroscopy by varying the light wavelength from 200 to 800 nm. Photographs of MH/DW nanofluids after preparation of ~ 25 days shown uniform and there was no precipitation was visible in the suspensions. For a certain loading of MH particle, with the increasing wavelength absorbance was found to be increased. Absorbance peaks were created at wavelength of ~ 360 nm and then decreased monotonically with the increasing wavelength. The relative concentration of the MH/DW nanofluids was declined when increase the precipitation concentration with time due to slight agglomeration. After ~ 600 hours, the minimum and maximum precipitation rates were found ~ 0.27 and ~ 2.5 % for MH/DW

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nanofluid with the MH concentration of 0.065 and 0.157 mg/ml respectively. Amount of MH nanoparticle loading affects the rate of sedimentations of the produced MH/DW nanofluids.

Keywords: *Stability, iron oxide, absorbance, relative concentration and nanofluid.*

INTRODUCTION

Suspension of iron oxide nanoparticles in a liquid is called 'magnetic fluid'. Nano-sized magnetic particles have already been known for their unique combination of high magnetization and super-magnetic behaviours [1]. Iron oxides, such as, magnetite and maghemite have attracted extensive interest due to their magnetic properties and potential applications in many fields. The primary advantage of the water-based maghemite nanofluids is that maghemite nanoparticles are inherently chemically more stable than magnetite nanoparticles [2]. In the maghemite nanofluids, the surface charge and the distribution of maghemite nanoparticles play an important role in colloidal stability [2].

Until now stability is a crucial technical challenge to prepare a homogeneous dispersion because of the strong van der Waals interactions among the nanoparticles which always lead to the generation of aggregates. Sometimes sedimentation, clogging and aggregation phenomenon are the main cause for the stability of suspension which results in hampering of valuable properties of the suspension such as TC and viscosity. There are some physical or chemical approaches such as surfactant addition, modification of particles surface or application of strong forces on the aggregated nanoparticles, use of ultrasonic cleaner for sonication to disperse the nanoparticles into the water, which are implemented to achieve the stable nanofluids where, suspended particles will scatter and disperse well into the base fluid medium [3].

Even though, suspension stability of a nanofluid is an important concern for its application, there are inadequate studies on assessing the suspension stability of the nanofluids. There are some tools and techniques which are able to classify the relative stability of the nano-suspension. Such as, to observe the sedimentation in nanofluids photo capturing is used as a primary technique. Some researchers have used electron Microscopy tools like TEM and SEM to investigate the stability of the nanofluids by distinguishing the size, shape and distribution of nanoparticles. However, it is not a highly recommended technique to monitor the stability of the nanofluids because of the consumption of longer time and qualitative accuracy of the stability results [4]. Some other techniques included in this list are Ultra Violet-Visible (UV-Vis)

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spectrophotometer, light scattering, zeta potential, sedimentation balance or three omega method. Among these, the most widely used approach is UV-Vis spectrophotometer to estimate the rate or percentage of sedimentation of the nano-suspension [4-6].

Water-based magnetic nanofluids are a special category of polar magnetic nanofluids [7]. Although iron or iron oxide nanoparticles containing water-based magnetic nanofluids have widespread applications, however, there are only a few reports in the literature concerning the measurement of its stability [2, 8]. A systematic stability investigation of water-based iron oxide nanofluids are not commonly investigated. Thus the objective of this research his to develop a systemic suspension stability investigation approach for the effect of particle loading with the aid of absorbance measurement of the suspension.

METHODOLOGY

PREPARATION OF MAGHEMITE DISPERSION IN DW

In the explanation of results, Maghemite (γ-Fe_2O_3) is expressed in the short form 'MH' and deionized water is denoted as 'DW'. Filler and based fluid will be conveyed as 'filler/base fluid' throughout the thesis. Five different nanofluid samples were prepared by increasing 20 % mass concentration of MH in DW. Concentrations of the samples varied from 0.065 to 0.157 mg/ml. These five samples are expressed as S1-MH/DW, S2-MH/DW, S3-MH/DW, S4-MH/DW and S5-MH/DW for the concentrations of 0.065, 0.079, 0.101, 0.126 and 0.157 mg/ml respectively.

STABILITY MONITORING OF NANOFLUIDS

- Photograph Capturing: To observe the sedimentation of produced MH/DW nanofluid samples photo capturing was used as a primary technique. Some amount of the suspension was put aside after preparation to capture photos using digital camera after a certain time. By comparing these photos of nanofluids, apparent sedimentation of the suspension was observed.
- Relative stability estimation by UV-vis Spectroscopy: The stability of the as produced MH/DW nanofluids samples were monitored quantitatively with the aid of optical absorbance measurements using UV-vis absorbance spectroscopy, since at a particular wavelength; absorbance depends on the amount of nanoparticles loading in the nanofluid.

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The Beer-Lambert Law (A = αlc) provides a linear relationship between absorbance of light and the properties of a material through which light is passing. A is the absorbance, α is the absorption coefficient (ml $mg^{-1}m^{-1}$), l (m) the distance that light travel through material and c is the concentration (mg ml^{-1}) of absorbing types in the material. Beer-Lambert Law shows that at fixed concentration optical path and absorptivity, the absorbency is relative to the percentage amount of the particles inside the suspension.

On the first step, just after the preparation of each type of nanofluid, samples were scanned in UV-Vis spectrometer (Thermo Scientific, Multiskan GO, Version-1.00.40. 96-grid transparent micro-plates) at room temperature while each measurement was repeated three times to attain a better accuracy. The wavelength ranges of light varied from 200 to 800 nm. Peak absorbance was identified for every sample to a certain wavelength. Then, the standard graph was fit for each type of sample with sample concentrations (C_o) against their corresponding peak absorbance' as the concentration of suspension has a linear relation with absorbance. On the last step, the relative stability of the prepared nanofluids was quantified interns of percentage sedimentation with increasing sedimentation time. Through that, UV-Vis spectrometer scanning was conducted on the supernatant of each sample in about 5 days (120 hours) interval for 25 days (600 hours). Supernatant concentration (C) of the samples was estimated for the corresponding absorbance. The relative concentrations (C/C_o) of the samples were plotted against time.

RESULTS AND DISCUSSIONS

STABILITY INVESTIGATION OF MH/DW NANOFLUIDS

- Stability Monitoring by Physical Appearance of MH/DW Nanofluids

Figure 1 shows the digital photographs of synthesized MH nanoparticles dispersion in DW base fluid medium. It shows a uniform distribution. This suspension was remained stable for about 3-4 months without any visible agglomeration and sedimentation. Digital photographs of this suspension are taken after 5 min and ~ 25 days and ~120 days of preparation. It is apparent that the suspension is almost unchanged within these durations.

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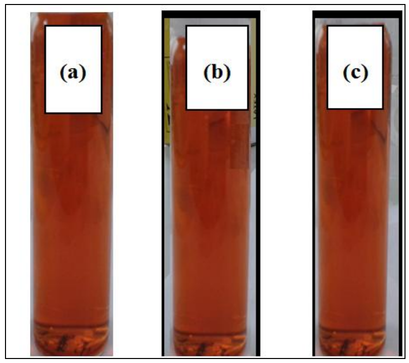

Figure 1. Photographs of synthesized MH nanoparticles dispersion in DW (MH/DW): (a) ~5 min and (b) ~25 days and (c) ~120 days.

- Stability monitoring of MH/DW nanofluids by UV-vis spectroscopy

Figure 2(a) shows the absorbance of MH/DW nanofluids for different amount of MH loading with the variation of wavelengths. The peak absorbance of MH/DW nanofluid samples appears at the wavelength of ~ 360 nm. For a certain concentration the UV-vis spectrum of this MH/DW nanofluid is featureless with a monotonic decrease in absorbance with increasing wavelength. Moreover, the absorbance of MH/DW nanofluids increases with the increasing amount of MH nanoparticles in DW; it should be known that the increasing amount of dispersed MH nanoparticles will increase the absorbance that refers to the better nanofluid dispersion.

Figure 2(b) shows the relationships between MH nanoparticle concentrations of MH/DW nanofluids samples and obtained corresponding peak absorbance's. There is a good linear relationship between the absorbance and the concentration of MH is perceived, which satisfies Beer's Law and indicates that MH nanoparticles were dispersed well in the DW base fluid.

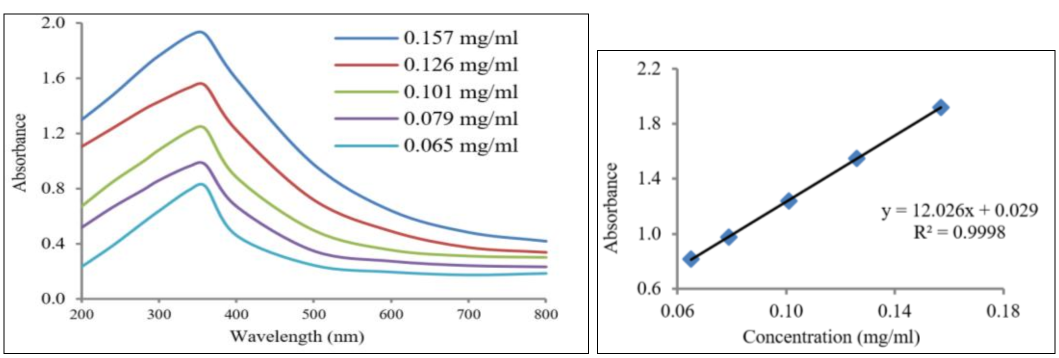

Figure 2. (a) UV-vis spectrum of MH/DW nanofluids samples at different concentrations and wavelength; (b) Linear relationship between light absorption and concentration of MH nanoparticle in DW suspension at wavelength of ~ 360 nm.

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Using the linear relationship (as shown in Figure 2(b)), the relative stability of MH/DW nanofluids at a different concentration as a function of sedimentation time are shown in Figure 3. From the results, it is observed that, the relative concentration of the MH/DW nanofluid samples is decreased due to the slight agglomeration by the increasing precipitation concentration. Higher MH nanoparticle concentration leads to more sedimentation. The gravitational force on the nanoparticles has an effect on the nanofluid [9]. It is seen that within 120 hours (~5 days), concentration decreased by ~ 0.14, ~ 0.16, ~ 0.56, ~ 0.80 and ~ 1.17 % for the samples with the MH nanoparticle concentration of 0.065, 0.079, 0.101, 0.126 and 0.157 mg/ml respectively. The rate of sedimentation after 600 hours (~25 days) is shown different among these five samples as different concentrations are imposed. After this period of time, the lowest precipitation rate appears, ~ 0.27 % for the sample with the MH concentration of 0.065 mg/ml, while maximum precipitation rate is found ~ 2.5 % for MH/DW sample with the concentration of 0.157 mg/ml. These results show that different concentrations affect the rate of sedimentation as well as properties.

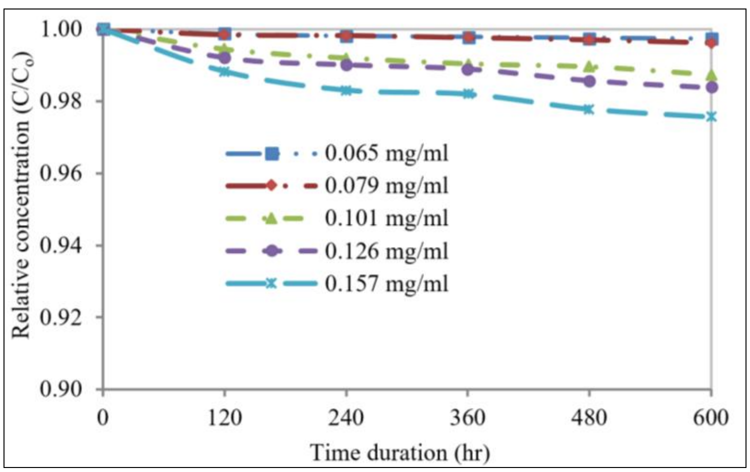

Figure 3. Relative supernatant concentrations of MH/DW nanofluids as a function of sedimentation time.

CONCLUSIONS

A systematic stability analysis approach has been successfully developed to monitor the quantitative stability of relative concentrations of MH/DW nanofluids. It is seen in the digital photographs of the suspensions that the suspensions are almost unchanged without any visible sedimentation within ~120 days of preparation. For a certain loading of MH particle, with the increasing wavelength absorbance was found to be increased than peaks created at the

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wavelength of ~ 360 nm and then decreased monotonically with the increasing wavelengths. All MH/DW nanofluids samples exposed very good stability against sedimentation within the 25 days (~ 600 hours) of investigation period. Very marginal percentage of sedimentation were observed for the samples. After ~ 600 hours' period the lowest and maximum precipitation rates were noted to ~ 0.27 and ~ 2.5 % for the MH/DW nanofluid samples for the MH concentration of 0.065 and 0.157 mg/ml respectively. The relative concentration of the MH/DW nanofluids was declined when increase the precipitation concentration with time due to slight agglomeration.

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