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Experimental Study of Stability of Deionized Water Based Copper Oxide Nanofluid and Achievement to the Optimal Stability Conditions

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ABSTRACT

In this study, the stability of deionized water based copper oxide nanofluid with weight concentration of 0.1 % is investigated experimentally. The experiments are designed to investigate the influence of rotational speed and dispersion time of nanoparticles in the base fluid, ultrasonic waving time, type and concentration of surfactants and pH on the nanofluid stability and achieve to an optimal stability condition. The results are statistically analyzed using Taguchi method by implementing Qualitek-4 software. Furthermore, nanofluid stability is evaluated by investigation of sedimentation photographs also, zeta potential method. The results showed that using sodium dodecyl sulphate with weight concentration of 0.1 %, ultrasonic waving by ultrasonic probe device for an hour and changing the pH to 10.72, provide the best conditions for dispersing copper oxide nanoparticles in deionized water. In this condition, prepared nanofluid is maintained its stability with no trace of sedimentation of nanoparticles for forty days at least.

KEYWORDS:

Nanofluid, Ultrasonic Waving, pH, Taguchi Method, Zeta Potential.

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1- INTRODUCTION

Nanofluids are suspensions of solid nanoparticles which are made of mixing the nanoparticles in various liquids such as water, thermal oils or ethylene glycol. One of the most important issues in this case is nanofluid stability. Because, on the one hand, particles tends to settle due to the difference in density and on the other hand, it tends to join together and form agglomerations due to van der waals forces between particles. This may affect the properties and applications of nanofluids.

In most of the researches use ultrasonic waving, adding surfactants and changing the pH methods to stabilize distribution of nanoparticles in the base fluid. One of the important parameters in Ultrasonic waving method is waving time. Some of the researchers, reported an optimal waving time [1]. In some works, researchers concentrated on the other parameters. Tajik et al. [2], studied the effect of the ultrasonic waves quality on stability of the aqueous suspensions of TiO_2 and Al_2O_3 .

The effect of type and concentration of the surfactants on nanofluid stability also, examined as an important parameter. Karthik et al. [3], studied the stability of NaAl/water nanofluid and showed that stronger attraction of sodium dodecyl sulphate as surfactant resulted in better stability. The effect of changing the pH on nanofluid stability also, examined as a key parameter recently. Sahooli et al. [4], studied thermal properties of CuO/ethylene glycol nanofluid and showed that the sample with pH=7.8 was more stable than the others.

In this paper, the effects of rotational speed and dispersion time of nanoparticle in base fluid, ultrasonic waving time, type and concentration of surfactants and pH on nanofluid stability using Taguchi method by implementing Qualitek-4 software are investigated experimentally.

2- METHODOLOGY AND RESULTS

We prepared nanofluids from CuO nanoparticles (40nm) With weight concentration of 0.1 % and deionized water as base fluid. Also, SDS and PVP selected as surfactants. In the first step, four factors in four levels selected, including, rotational speed (A), dispersion time of nanoparticle in base fluid (B), ultrasonic waving time (C) and surfactant concentration (D) by using Taguchi method to design experiments. According to factors and levels, the L-16 orthogonal array was used. Sedimentation height of nanoparticles is measured after

7 days as experiment responses. In the next step, the effect of changing pH on nanofluid stability investigated by using NaOH and HCL solutions to adjust pH in range of 2-12. In the final step, zeta potential analysis were experimentally carried out.

2- 1- OPTIMUM VALUE OF FACTORS

According to predictions performed by using average factor effect method and selecting “smaller is better” as experiment quality characteristic, the optimum value of level for A, B, C and D factors is specified at 700 rpm, 90 min, 60 min and 0.1 wt%, in A group (SDS as surfactant) and at 700 rpm, 150 min, 60 min and 0.3 wt%, in B group (PVP as surfactant).

2- 2- INFLUENCE OF EACH FACTOR IN RESPONSE

Results demonstrated that the A, B, C and D factors have 4, 27, 41 and 28 percent contribution in the response in A group and have 5, 21, 42 and 32 percent contribution in the response in B group, respectively. Low percentage error estimated by variance analysis (0.3-0.4) showed the results can be reliable.

3- pH EFFECT ON NANOFLUID STABILITY

Acidity value of nanofluids which had the best stability condition (A and B groups) in previous steps, was changed in range of 2-12. Then, zeta potential of nanoparticles surface measured for each of sample. Results of these tests can be seen in Figure 1.

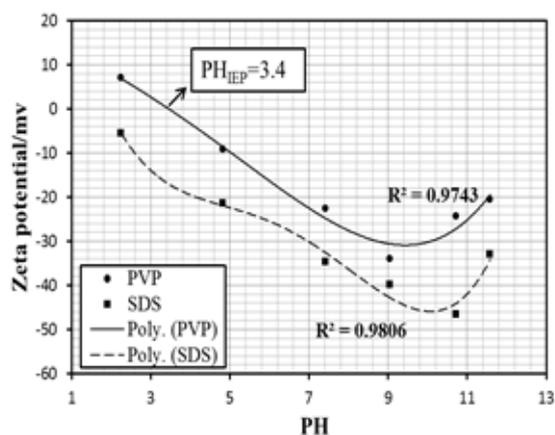


Figure 1. Effect of pH on zeta potential of CuO/deionized water nanofluid with SDS and PVP surfactants. concentration of cuo is 0.1 % (mass fraction)

Trend lines in Figure 1, represent polynomial-degree 4 as best curve to fit experimental data in both groups (A and B). According to the zeta potential values of CuO powders, pH=10.72 and pH=9.05 can be

selected as an operating pH for A and B groups, respectively. Because, in these pH, the absolute values of zeta potential for CuO nanofluids with two kinds of surfactants are higher, $\zeta_{CuO} (SDS) = -46.6$ mV and $\zeta_{CuO} (PVP) = -34$ mV. The regression analysis predicted optimum pH be 10.20 and 9.40 for A and B groups, as shown in Figure 2. It can be seen that the CuO particles are negatively charged by adding SDS surfactant. It may be due to absorption sulphate anions, hydrophobic group, or due to dissociation acid group on nanoparticles surface. As pH increases, the hydroxide anions concentration increases. Therefore, net negative charge of powder surface increases and leads to zeta potential of the particle surface enhancement, So the electrostatic repulsion force between particles become sufficient to prevent attraction and collision between particles caused by the Brownian motion. At pH=10.72, zeta potential become even higher; the electrostatic repulsion force between particles is stronger, so the dispersion stability of CuO nanoparticles is the best. As pH value continues to further increase, the concentration of NaOH in the system increases, which causes lowering the zeta potential of the particle surface and electrostatic repulsion force, and the nanofluid exhibits a poor stability.

PVP is a non-ionic surfactant and there is no ionization in base fluid. When pH has a low value (pH=2.24), hydroxide ions are insufficient and nanoparticle surface has excessive positive charge. Therefore, zeta potential of nanoparticle surface is positive first. As pH increases, due to forming the hydrogen bonding between oxygen molecules in carbonyl group of PVP surfactant (C=O) and hydrogen molecules in deionized water, hydroxide ions can be balanced with hydrogen ions in nanoparticle external surface completely. This equilibrium causes net charge of nanoparticle surface be zero actually and it leads to zeta potential of nanoparticle surface be zero (pH IEP=3.4). As pH value continues to further increases, hydroxide anions concentration become more and more. Therefore, zeta potential of nanoparticle surface become more negative. At pH > 9.05, excessive concentration of hydroxide anions leads to compressing the electrical double layer and decreasing the dispersion stability of nanofluid. Final optimum conditions of nanofluid stability are represented in Table 1.

According to the results represented in Table 1, the stability duration of nanofluids investigated. Results demonstrated that the stability duration for optimum nanofluids in A and B groups is 40 and 30 days, respectively.

Table 1. Final optimum conditions of nanofluid stability with 0.1% (mass concentration)

Tests	Factors				pH
	A (rpm)	B (min)	C (min)	D (wt%)	
Group A	700	90	60	0.1	10.72
Group B	700	150	60	0.3	9.05

4- CONCLUSIONS

In this paper, the stability of deionized water based copper oxide nanofluid investigated experimentally. The results have been statistically analyzed using Taguchi method. The major conclusions are as follows:

- 1- Ultrasonic waving time has maximum effect in nanofluid stability (about 42 percent), while the rotational speed of nanoparticles in base fluid has minimum effect in nanofluid stability (about 5 %).
- 2- Interaction between rotational speed and dispersion time of nanoparticles in base fluid factors, has maximum effect in sedimentation height of nanoparticles.
- 3- The optimum ultrasonic waving time is found to be 60 minutes.
- 4- The optimum dispersion time of nanoparticles in base fluid (SDS and deionized water) is found to be 90 minutes.
- 5- Optimum value of pH is 10.20 and 9.40 for A and B groups, respectively. Furthermore, nanofluid in pH=3.4 (B group), has an unstable condition (isoelectric point).
- 6- CuO/deionized water nanofluid at optimum conditions of stability can be stabilized up to 40 and 30 days for A and B groups, respectively.

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