DENSITY OF AQUEOUS ALUMINA (15 NM) NANOFLUIDS AT DIFFERENT TEMPERATURES

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Introduction

At nanometric scale the materials presents properties distinctively different from those in the bulk. The literature has shown that the main factors involved in the behavior of their thermophysical properties are the size, morphology and content of nanoparticles, the purity of the base fluid and also the possibility addition of surfactants. From a fundamental standpoint, it is discussed whether the positive values of ρ/ρ_W , fig. 1, can be considered greater than what would be expected. From an applied standpoint isobaric thermal expansivity is calculated at all temperatures and their values are compared with that of the base fluid, figures 2 and 3. The figure 4 show that $\Delta\rho \neq 0$, i. e., these nanofluids do not follow an ideal behavior and therefore the equation of Pak and Cho. The effect of concentration and temperature on the nanolayer thickness is observable in fig. 5. Figure 6 shows the calculated values of nanolayer density with density of the bulk nanoparticles and base fluid.

The results presented in this work were obtained without the addition of surfactants in order not to mask the effect of the nanoparticles and highlight the importance of the other factors mentioned above on the density behavior.

Methods

In this work the density of nanoparticles of the metal oxide of Al_2O_3 (15 nm) in water is studied at fourteen concentrations (up to 2% in volume) and at six temperatures (from 293.15 K to 343.15 K). The spherical nanoparticles were provided by mkNANO at 99.5% pure, with a density of 3.7gcm^{-3}. The aqueous alumina nanofluids were homogenized by using intensive ultrasound vibration from a Bandelin Sonopuls HD2200 apparatus equipped with a titanium flat tip TT 13 of 13 mm diameter during 60 min at 10% of maximum power.

The measure of the density was carried out using a conical-shaped pycnometer calibrated with Milli-Q water. To ensure a uniform temperature of the sample, the pycnometer was maintained immersed 10 minutes in a PolyScience 9102A12E circular bath. The uncertainty in the temperature was of 0.01K. Several weighings of the pycnometer were made under the same conditions until a concordant value was obtained between them. A Mettler AT-201 balance with an uncertainty of ± 0.0001 g was used.

For this study density and isobaric thermal expansivity and density, thickness and molar mass of the nanolayer is calculated at all temperatures and their values are compared with that of the base fluid.

Results

Following the procedure proposed in [1] the thickness, density and molar mass of the interfacial nanolayer around nanofluid particles are predicted.

Enhancement of density, ρ/ρ_W

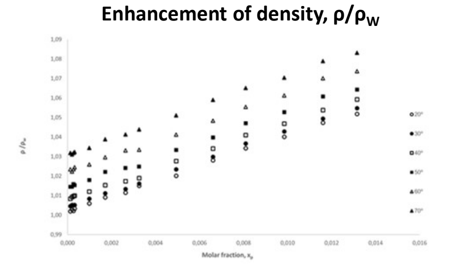

Fig. 1. Enhancement of density, ρ/ρ_w , for [Al_2O_3 (15 nm) water based nanofluid] as function of molar fraction, x_p , at different temperatures ○:20 ºC; ●:30 ºC ; □:40 ºC; ■:50 ºC; △:60 ºC;▲:70 ºC.

Isobaric thermal expansivity, α

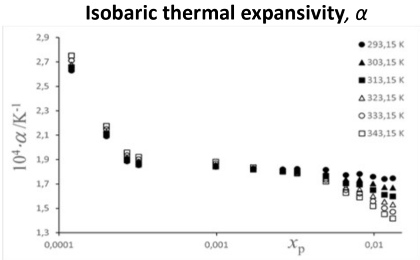

Fig. 2. Isobaric thermal expansivity, α, for Al_2O_3 (15 nm) water based nanofluid, as function of molar fraction, x_p , at different temperatures ●:293,15 K; ▲:303,15 K ; ■:313,15 K; △:323,15 K; ○:333,15 K; □:343,15 K.

Ratio α/α_w

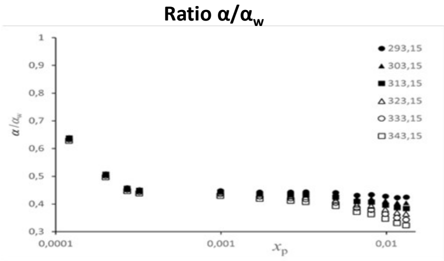

Fig. 3. Ratio α/α_w, for Al_2O_3 (15 nm) water based nanofluid, as function of molar fraction, x_p , at different temperatures ●:293,15 K; ▲:303,15 K ; ■:313,15 K; △:323,15 K; ○:333,15 K; □:343,15 K.

Density Deviation, $\Delta\rho$

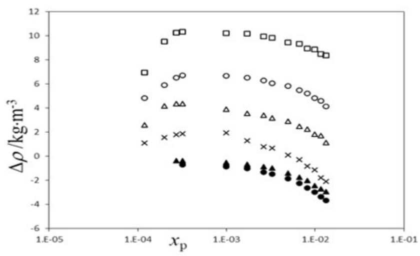

Fig. 4. Density deviation, Δρ, for [Al_2O_3 (15 nm) water based nanofluid] as function of molar fraction, x_p , at different temperatures ●:20 ºC; ▲:30 ºC; x:40 ºC; △:50 ºC; ○:60 ºC; □:70 ºC.

Nanolayer thickness, t

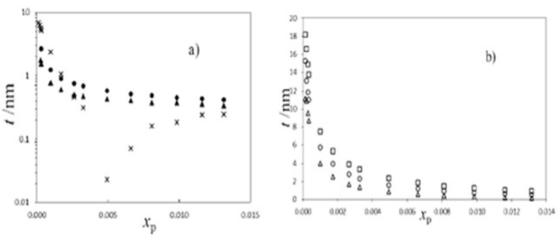

Fig. 5. Nanolayer thickness, *t*, for [Al_2O_3 (15 nm) water based nanofluid] as function of molar fraction, x_p , at different temperatures a) ●:293,15K; ▲:303,15K; x:313,15K; b) △:323,15; ○:333,15K; □:343,15K.

Nanolayer density, ρnl

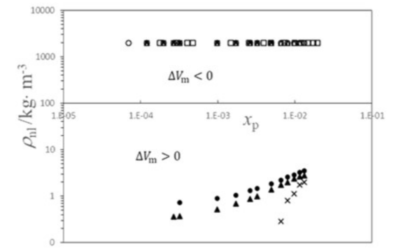

Fig. 6. Nanolayer density, ρ_{nl}, for [Al_2O_3 (15 nm) water based nanofluid] as function of molar fraction, x_p , at different temperatures ●:20 ºC; ▲:30 ºC; x:40 ºC; △:50 ºC; ○:60 ºC; □:70 ºC.

Conclusions

- The density ratio are greater than one, either as function of molar fraction or as function of temperature.
- To lower concentrations, the isobaric thermal expansivity increases with temperature, however for higher concentrations there is a decrease in the coefficient of expansion.
- Also, for ratio of the isobaric thermal expansivity we can verify the effect of concentration, since for the same temperature there is a decrease in the coefficient of expansion.
- The results obtained for the density deviation from the ideality do not support the Pak and Cho's equation [2], except as an approximation, [1].
- The behavior of the systems that present $\Delta Vm < 0$ can be summarized as follows: a) nanolayer density decreases with temperature and tends to remain unchanged with nanoparticle concentration; b) nanolayer density value is between those of the bulk nanoparticles and base fluid; c) the nanolayer thickness increases with temperature and decreases with nanoparticle concentration.
- For $\Delta Vm > 0$ the following different behavior was found: a) nanolayer density increases with nanoparticle concentration and decreases with temperature; b) nanolayer density is very small when is compared to that of the bulk nanoparticles or base fluid; c) the nanolayer thickness decreases both with temperature and with nanoparticle concentration.

References

[1]. T. P. Iglesias, A. Queirós, V. Salgueiriño, M. F. Coelho, An approach to characterize the nanolayer for a nanofluid: thickness, density and molar mass, ECTP2023 – 22nd European Conference on Thermophysical Properties, September 10-13, 2023.
[2]. B. C. Pak, Y. I. Cho, Exp. Heat Transf. vol.11 (1998) pp. 151-170.

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