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An Insight on Viscoelastic-Viscoplastic Behaviour of Stearate-Based Nanofluids

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Extended Abstract

Nanofluids have been extensively studied in the literature for at least two decades, however the understanding of the mechanism involving the modification of their physical properties remains uncomplete. These colloidal suspensions usually exhibit complex rheological behaviour, requiring a careful analysis of their rheological characteristics. This work is focused on the different rheological behaviour of two nanofluids families based on PureTemp8 (PT8), a commercial isooctyl stearate. Nanofluids were elaborated dispersing magnesium oxide nanoparticles (MgO/PT8) and graphene nanoparticles (GnP/PT8) at different mass fractions. Their design, stability and thermophysical properties were studied in a previous work [1].

The rheological analysis was performed in an Anton Paar Physica MCR 101. A cone and plane geometrical configuration with 50 mm diameter and 1º cone was used, keeping a constant gap of 0.102 mm. The temperature was controlled by means of a Peltier system in the plate and a Peltier hood, holding a constant temperature of 283.15 K during all the tests. Firstly, flow curves were carried out, consisting in non-linear viscoelastic tests to measure the relationship between the viscosity and the shear stress. In these experiments, the shear rate was varied in a range from 0.1 to 10000 s^{-1}. After, linear viscoelastic oscillatory tests were performed, determining the store (G') and loss (G'') moduli. The linear viscoelastic regime (LVR) of the PT8-based nanofluids was determined with strain sweeps at constant frequency of 10 $rad \cdot s^{-1}$, amplitudes ranging from 0.01 to 1000%. Frequency sweeps were then carried out within the LVR, angular frequency ranging from 600 to 0.1 $rad \cdot s^{-1}$. All experiments were replicated three times, with uncertainties in torque and temperature of 1% and 0.06 K, respectively.

The flow curves show that the base fluid is Newtonian, while nanofluids reveal pseudoplastic behaviour. The shear-thinning non-Newtonian behaviour of MgO/PT8 nanofluids is different than GnP/PT8 due to the presence of yield stress in the former. Thus, MgO/PT8 show viscoplastic behaviour (solid-like when stationary) whereas GnP/PT8 viscoelastic (liquid-like when stationary). The observed shear-thinning behaviour is due to the structural modifications and rearrangements of the nanoparticles: at rest, the Brownian movement and the van der Waals forces contribute to agglomerate the nanomaterials, leading to high viscosities; while shearing provokes their reorientation and breakage, reducing the viscosity.

Oscillatory tests provided insights into the analysis of the viscoelasticity of the nanofluids. The LVR, determined by strain sweeps, identified the critical strain where the structure of the nanofluids become losing strength. Comparing both nanofluid families, MgO/PT8 evidences stronger structure than GnP/PT8 due to the spherical shape of MgO nanoparticles, allowing the formation of a gel-like structure. Contrarily, the sheet shape of GnP prevents the accommodation of the molecules of the base fluids around them. Moreover, the induced strong gel network on MgO/PT8 is due to the formation of large not compact fractal agglomerates caused by the presence of long-range attraction forces.

References

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