Moderate and high magnetization soft magnetic nanoparticles for the fabrication of smart magnetorheological fluids

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Magnetorheological fluids (MRF) fabricated with the adequate carrier liquid and additives and using as magnetic fillers moderate or high magnetization magnetic nanoparticles show a rheological behaviour controlled by the applied external magnetic field. This fact assesses for these "magnetic inks" to be suitable materials to be used for additive manufacturing processes.

Keywords: magnetic nanoparticles; magnetorheological fluids

1. Introduction

Magnetorheological fluids (MRF) are a class of smart materials fabricated with magnetic particles (usually Fe or Fe_3O_4) embedded in a liquid carrier. Thus, the resulting composite mechanical behavior (viscosity, yield stress) can be fully controlled by an external magnetic field that alters the internal structure or disposition of those magnetic fillers. In this work we present results concerning the fabrication of such smart fluids by using moderate (Fe_3O_4, magnetite with different morphologies [1]) and high magnetization (Fe, FeCo alloy [2]) soft magnetic nanoparticles and silicon oil as liquid matrix. The possibility to use these fluidic composites in additive manufacturing processing of multifunctional materials will be also assessed.

2. Results and discussion

MRF have been fabricated by adding mineral oil as carrier liquid (~ 46.4%wt.), magnetic filler (~ 47.1%wt.), oleic acid as surfactant (~ 5.3%wt.) and Aerosil as additive to control the viscosity of the fluid (~ 1.2%wt.). The magnetic nanoparticles have been added in a two steps procedure (50% total amount/each), and further to each step the mixture was dispersed by combining ultrasound (5 minutes) and mechanical (5 minutes) stirrings. Fabricated fluids magnetorheological behaviour has been tested by using an Anton Paar Physica MCR 501 rheometer, and obtained data fitted to the well-known Herschel-Bulkley model: $\tau = \tau_0 + K \cdot \dot{\gamma}^n$, where τ_0 is the yield stress, K is the consistency index, $\dot{\gamma}$ is the shear rate value and n is the pseudo-plasticity index [3].

Our observations clearly indicate that MRF rheology can be taylored to achieve their best performance: the high saturation of Fe and FeCo nanoparticles determines the high yield stress value τ_0, while a reversibility as high as 92% in the magnetorheological behaviour can be achieved in moderate magnetization Fe_3O_4 nanoparticles provided their aggregation is avoided.

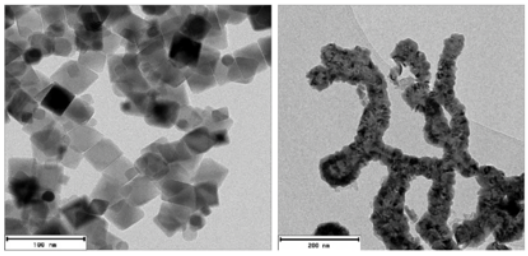

Figure 1: (*left*) Octahedral magnetite nanoparticles and (*right*) FeCo quasi-equiatomic alloy aggregated nanoparticles.

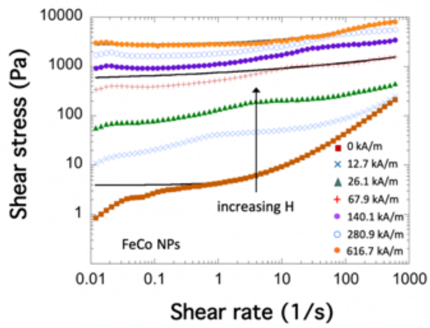

Figure 2: Magnetorheological behaviour observed for the FeCo alloy nanoparticle containing MRF. Black lines are some of the fits to the Herschel-Bulkley model.

These controlled properties open the door for these "magnetic inks" to be suitable materials to be used in Direct Ink Writing (DIW) additive manufacturing processes.

References

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