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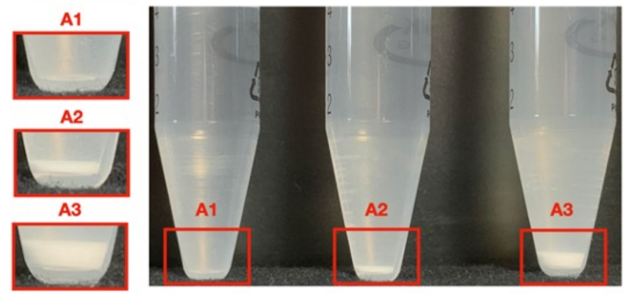
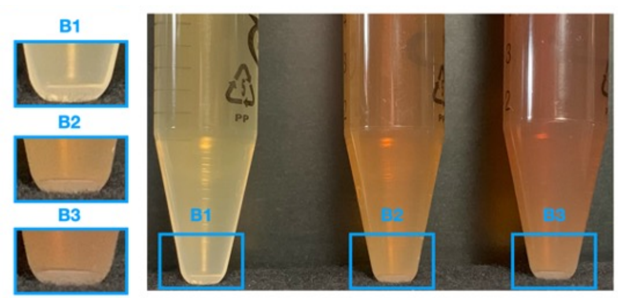
INL International Iberian Nanotechnology Laboratory
CINAMIL Military Academy Research Center
IN+ Center for Innovation, Technology and Policy Research
Técnico Lisboa
U.Porto FEUP Faculdade de Engenharia Universidade do Porto

Experimental studies of the sedimentation, stability and thermal conductivity of two different nanofluids

Al_2O_3 nanofluid
Versus
Fe_3O_4@PAA nanofluid



Poor stability



High stability

METRICS Mechanical Engineering and Resource Sustainability Center
IN+ Center for Innovation, Technology and Policy Research
CEFT

Abstract

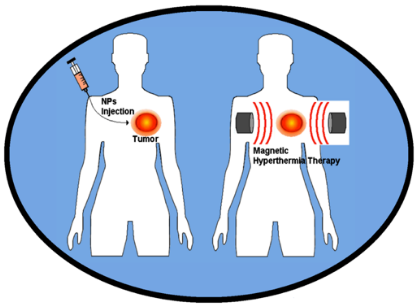
Fluids containing nanometer-sized particles (nanofluids, NFs), are potential candidates to improve the performance and efficiency of several thermal devices at micro and macro scale levels. However, the problem of sedimentation and instability of these colloidal dispersions, has been the biggest obstacle for industrial scale applications. In this work, two different NFs were tested using distilled water (DI-Water) as the base fluid. The first is a traditional NF formed by Al_2O_3 nanoparticles (NPs) and the second is a novel NF formed by poly (acrylic acid)-coated iron oxide NPs (Fe_3O_4@PAA), obtained through a hydrothermal synthesis process. The main objective of this study was to evaluate the colloidal stability of these NFs over time using different volume fractions and compare it with DI-Water. Results involving sedimentation studies and zeta potential measurements showed that the proposed Fe_3O_4@PAA NF presents a higher colloidal stability compared to that of the Al_2O_3 NF. Additionally, thermal conductivity measurements were performed in both Fe_3O_4@PAA and Al_2O_3 NFs at different NP concentrations, using the transient plane source technique. Results showed higher thermal conductivity values for the Fe_3O_4@PAA NFs compared to those of Al_2O_3 NFs. However, a linear enhancement of thermal conductivity with increasing NPs concentration was observed for the Al_2O_3 NF over the whole range of NP concentrations tested, whereas two different regimes were observed for the Fe_3O_4@PAA NF.

Keywords: Nanofluids; zeta potential; stability; thermal conductivity.

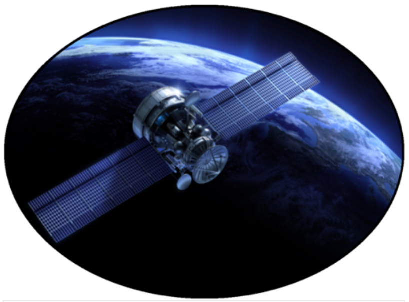
Introduction

- Nanofluids (NFs) has been frequently used to augment the heat transfer capacity of a fluid by studying their thermophysical properties and stability.

- The NFs are being used in different fields of engineering, ranging from nanomedicine to renewable energies (Gonçalves et *al*. 2021).

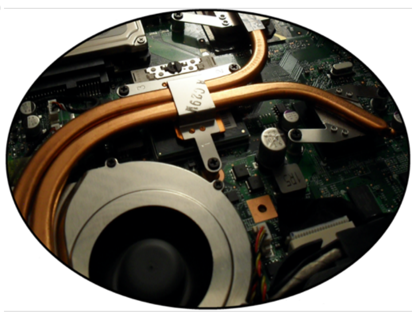


Medicine

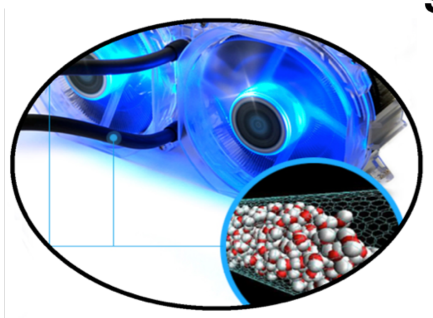


Space

Solar energy



Heat pipes



CPU Cooler

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Materials and methods

Nanoparticles characteristics

Table 1. Physical properties of the nanoparticles.

	Al_2O_3	Fe_3O_4
Physical property	Commercial	Synthesized by hydrothermal method
Size (nm)	<50	5.0±1.1
color	white	dark brown
ρ (kg/m^3)	3900	5170
c_p (J/kgK)	779	670
k (W/mK)	36	6

Nanofluids preparation

- The samples of Al_2O_3 were prepared by means of the two-step method, Haddad et al. (2014);

- The samples of Fe_3O_4@PAA were obtained through a hydrothermal synthesis process described by Kolen'ko et al. (2014).

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Materials and methods

Nanofluids concentrations evaluated

Table 2. Nanoparticles concentrations

Concentrations [w/v %]	
Alumina (Al_2O_3)	**Iron oxide (Fe_3O_4@PAA)**
-	0.001
-	0.005
0.01	0.01
-	0.03
0.05	0.05
0.1	0.1

Meaning of Zeta Potential

Table 3. Stability behavior of the colloid mixture based on zeta potential value (Kumar et al. 2017)

Zeta Potential [mV]	**Stability behavior**
0 to ±5	Rapid coagulation or flocculation
±10 to ±30	Incipient instability
±30 to ±40	Moderate stability
±40 to ±60	Good stability
> 61	Excellent stability

Materials and methods

Measurements of the thermal conductivity and zeta potential

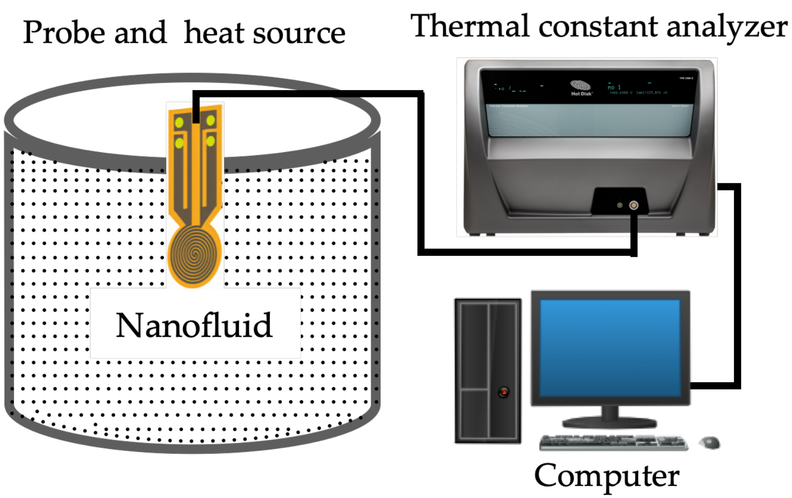

Fig.1.**Transient plane source method**

The thermal conductivity of NFs were measured using a TPS 2500S thermal constants analyzer (Hot Disk®).

The zeta potential were measured by Zetasizer DLS

Fig.2. Zetasizer DLS

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Results and Discussion

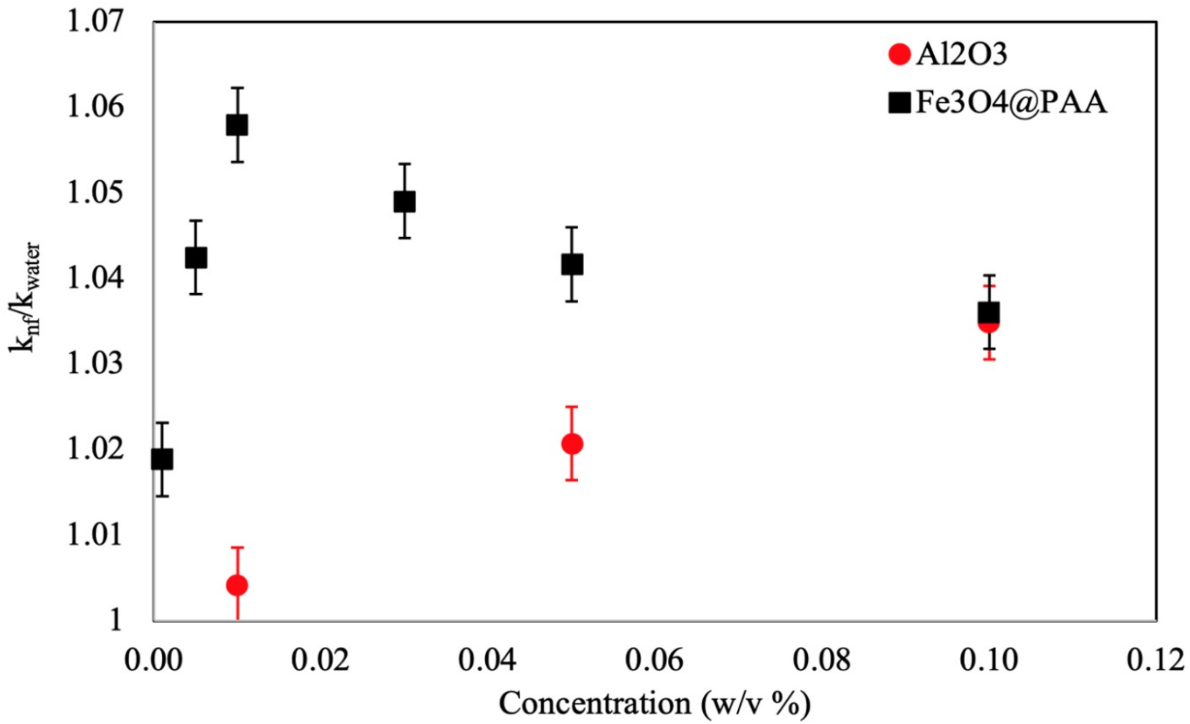

Fig.3. Comparison between the ratio the thermal conductivity of the Al_2O_3 and Fe_3O_4@PAA NFs and the thermal conductivity from DI-Water at 22 °C in function of the nanoparticles concentration.

- The main advantage of the proposed Fe_3O_4@PAA NFs is that it has a high thermal conductivity using a smaller amount of NPs when compared to the traditional Al_2O_3 NFs.

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Results and Discussion

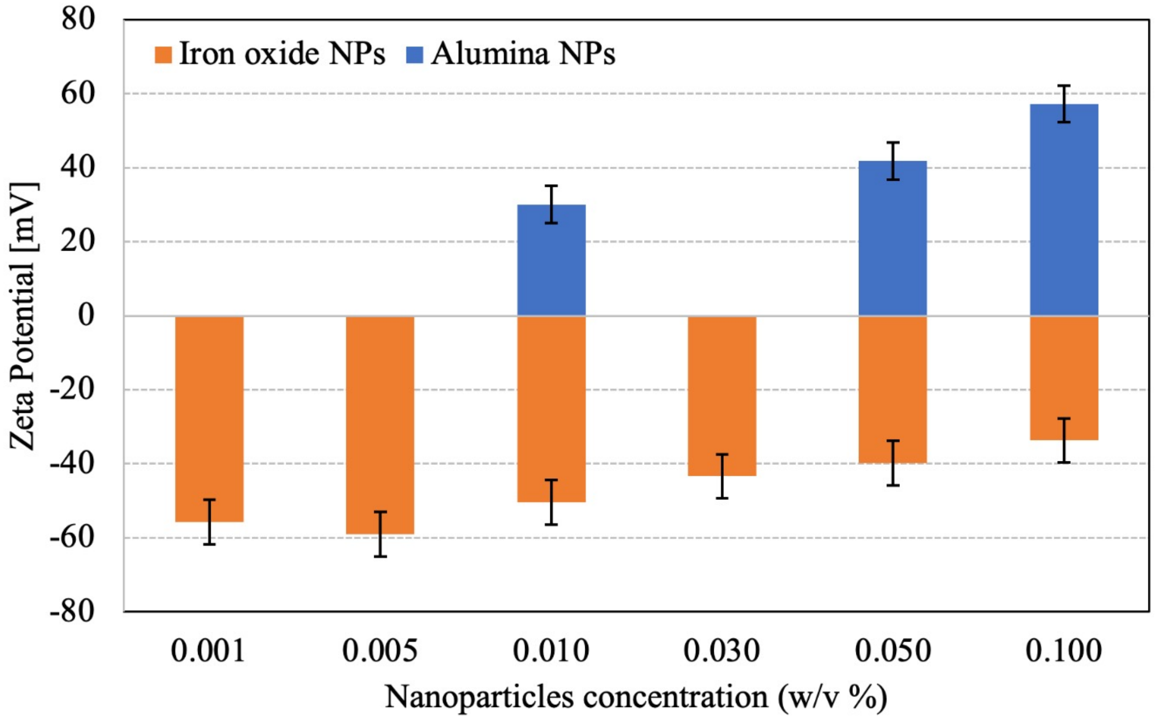

Fig.4. Zeta potential as function of nanoparticles concentration.

- Comparing Fig.4 with Table.3 the results indicating that all iron oxides NPs present zeta potential values into the range of ±40 to ±60 which means a good stability.
- Although, the results for alumina NPs show stability behavior between moderate and good, unlike the iron oxide NFs, the NFs had to be submitted to an ultrasonic bath of 2 consecutive hours before the beginning of the measurements.

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Results and Discussion

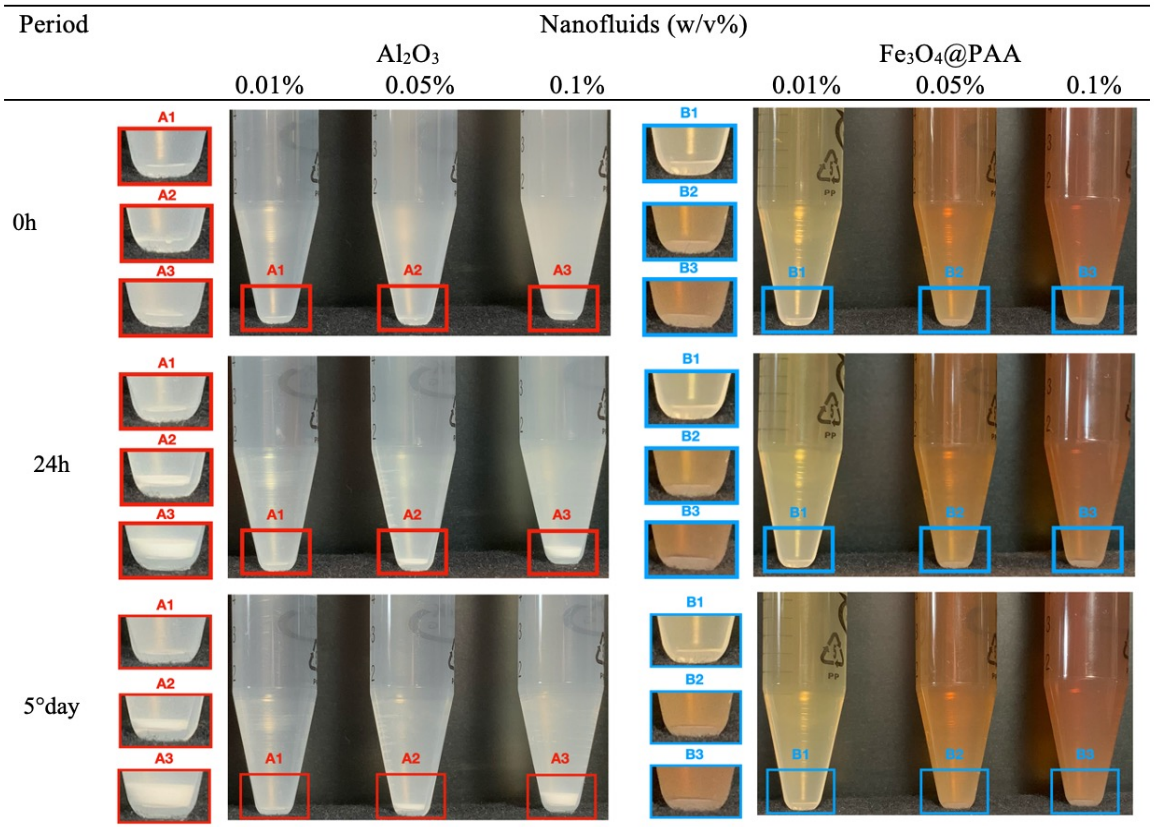

Fig.5.Qualitative analysis of NFs in function of time after preparation for three different concentrations. At left are Al_2O_3 NFs and at right are the Fe_3O_4@PAA NFs.

- For these results, it is possible to conclude that the proposed Fe_3O_4@PAA NF is more much colloidal and stable than the Al_2O_3 NF.

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Conclusions

- The synthesis process used to produce these nanoparticles allowed to develop a NF with an extremely high stability and free of sedimentation, when compared with commercial Al_2O_3 NFs;

- The thermal conductivity ratio increases with the increase of NPs concentration for all the tested NFs;

- The thermal conductivity of Fe_3O_4@PAA/water NF has shown a limit maximum of grow with concentration, reaching the maximum value at 0.01 w/v%, after that, a reduction in the thermal conductivity was observed. Similar behavior was obtained by other studies when surfactants were added to the NFs;

- The magnitude of the zeta potential indicated the good stability for all Fe_3O_4@PAA NF and better values was obtained for low concentrations of nanoparticles;

- The zeta potential for Al_2O_3 NF also presented good stability, however, the measured values were obtained immediately after 2 hours in an ultrasonic bath, after that, it is not possible guarantee the stability of the mixture.

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