EVIDENCE OF ECONOMIC IMPACT OF QUALITY MEASUREMENTS

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Background: Some time ago we discussed in several papers [1-3] the state of art in measuring the thermophysical properties of ionic liquids, and a main conclusion was drawn that the current state of the measurement of thermophysical properties of ionic liquids is far from being comparable to those actually found for molecular liquids, possibly explained by incorrect sample handling and method of measurement characterization. There [3] a faith was stressed that we can obtain most of the properties of the ionic liquids with the same level of accuracy now found for molecular liquids, if all end users of instrumentation interiorize that the "game" is different, that the structure and properties of ionic liquids (including high temperature ionic liquids or molten salts) are also different, a fact not yet accommodated in many commercial instruments.

The impact of wrong (inaccurate) data on chemical process design can be very significant [4,5], incurring in capital investment costs of processing equipment and additionally in running costs.

Heat transfer equipment using Ionanofluids was analyzed to obtain the impact of inaccurate data of viscosity, thermal conductivity, density and heat capacity of the heat transfer fluid in the heat transfer area and cost of equipment. Ionanofluids were used as potential property enhancers of base ionic liquids properties.

Experimental and Simulation:

Experimental Methodology. The thermal conductivity of a set of calibrants (water, toluene, glycerine, mixture of water-glycerine and an aqueous solution of NaCl) was measured and a calibration constant was determined to account for the deviation of the device (KD2 Pro, Decagon Devices). The next step was to measure the pure ionic liquids. Finally, the IoNanofluids were manufactured with MWCNT's and their thermal conductivity was measured.

Simulation Methodology. In order to estimate the heat transfer area (A_0) of a shell and tube heat exchanger, the Sieder and Tate correlation was used as it accounts for heat transfer coefficients and the physical properties of the fluid and its flow:

$$\frac{h_i D_i}{\lambda} = 0{,}027\,\mathrm{Re}^{0,8}\,\mathrm{Pr}^{\frac{1}{3}}\left(\frac{\eta}{\eta_w}\right)^{0,14} \quad (1)$$

$$\frac{h_o D_e}{\lambda} = 0{,}36\,\mathrm{Re}^{0{,}55}\,\mathrm{Pr}^{\frac{1}{3}}\left(\frac{\eta}{\eta_w}\right)^{0{,}14} \quad (2)$$

From the inner heat transfer coefficient (h_i) and from the heat transfer coefficient relative to outside of the tubes (h_o) we can obtain the value of the overall heat transfer coefficient (U_o)

$$\frac{1}{U_o} = \frac{D_o}{h_i D_i} + \frac{1}{h_o} + R \quad (3)$$

Knowing the heat transfer rate (Q) and the mean logarithm temperature difference between the inlet and outlet stream temperatures of the two fluids, we can obtain the value of A_o:

$$Q = U_o A_o (\Delta T)_{lm} \quad (4)$$

Being A_o a function of heat capacity (C_P), thermal conductivity (λ), density (ρ) and viscosity (η), values of these thermophysical properties are needed to use the correlation. While thermal conductivity has been measured, ILThermo can provide the missing data for pure ionic liquids. However, in the case of IoNanofluids, only the thermal conductivity has been measured and there are no references from which we can obtain values for the remainder properties. Therefore, some assumptions had to be made in order to get acceptable values for C_P, ρ, and η. Having quantified the enhancement of λ due to the addition of MWCNT's, it was assumed that the enhancement variations (E_X) were the following:

$$E_\lambda = E_\eta \qquad E_{Cp} = 1{,}5;\ 2;\ 5\ \% \qquad E_\rho = 0 \quad (5)$$

Hence, the values of the thermophysical properties were available to perform the simulation. The simulation was accomplished considering a temperature of 313 K.

Results:

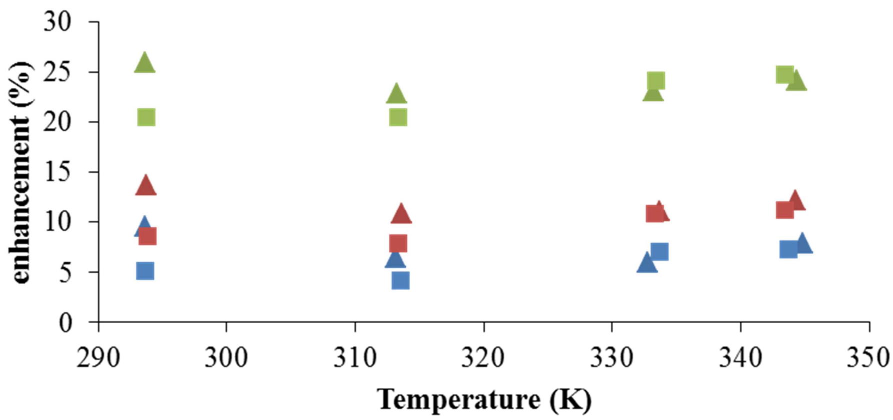

Figure 1. Thermal conductivity enhancement of IoNanofluids as a function of temperature. ▲, [C4mim][NTf2]; ■, [C2mim][EtSO4]; ▲, ■, 0,5% w/w MWCNT's; ▲, ■, 1% w/w MWCNT's; ▲, ■, 3% w/w MWCNT's.

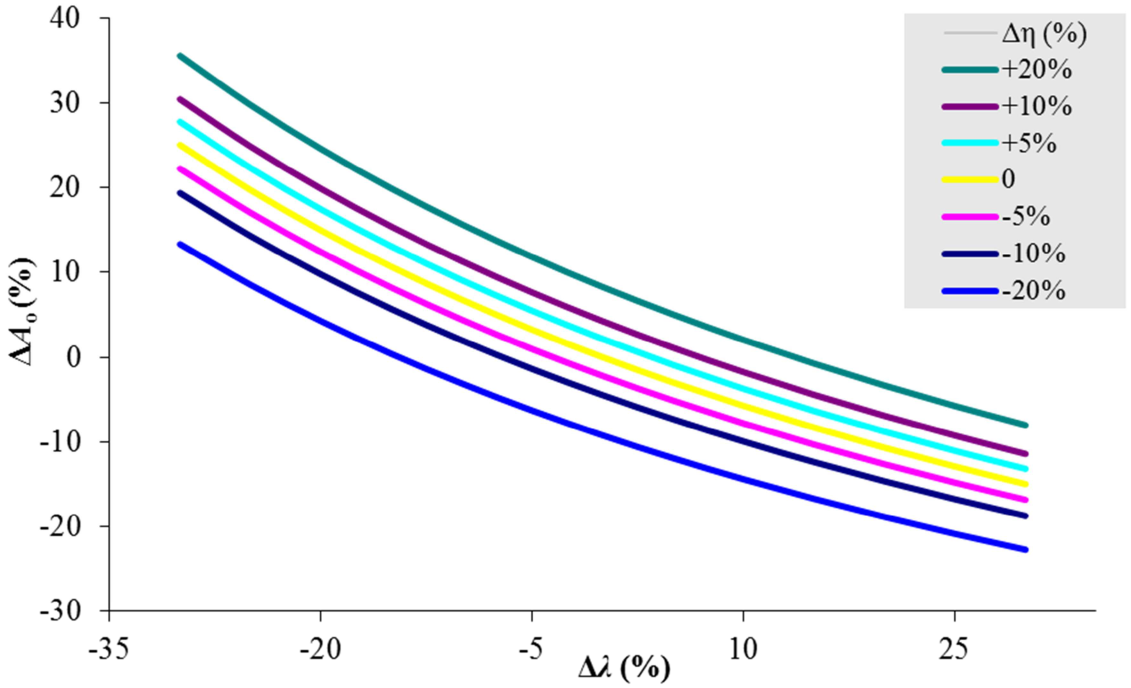

Figure 2. ΔA_o *vs* $\Delta\lambda$ *vs* $\Delta\eta$ for $[C_4mim][NTf_2]$.

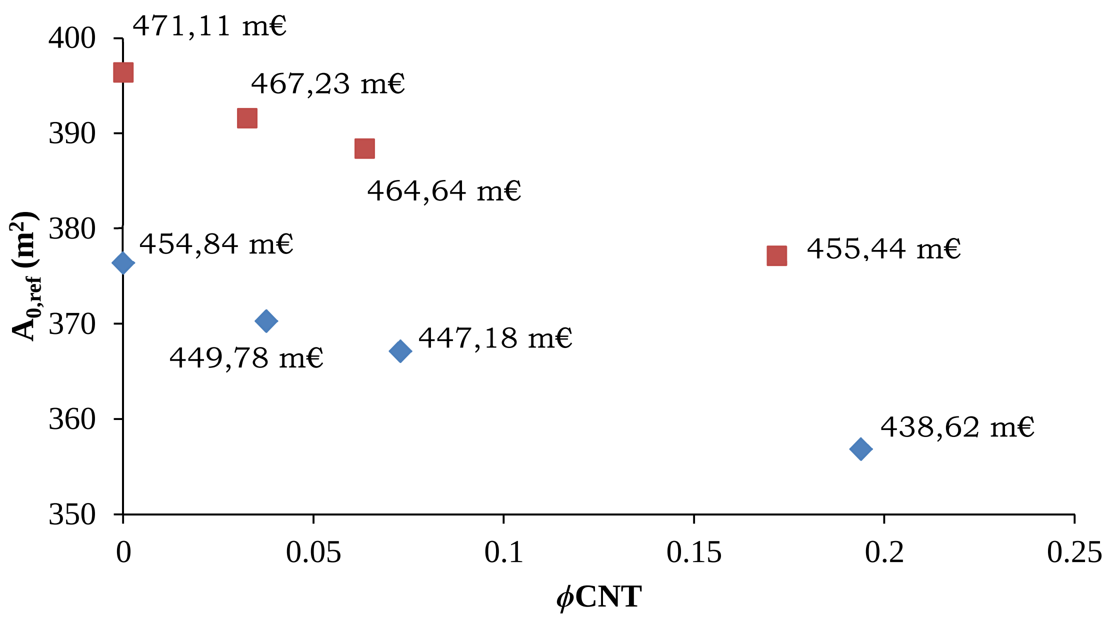

Figure3. ΔA_o *vs* ϕ_{CNT} of ionic liquids and IoNanofluids. ♦, fluids based on $[C_4mim][NTf_2]$; ■, fluids based on $[C_2mim][EtSO_4]$. Close to each data point is the cost of the heat exchanger.

Discussion and Conclusions: The enhancement of thermal conductivity dispersing MWCNT's on these ionic liquids is obvious, leading up to a 26% increase of this property relatively to the pure fluids.

The results of the simulation study show that IoNanofluids represent a strong and viable possibility regarding the substitution of the currently commercialized fluids since the values of A_0 are close to those obtained for commercial fluids [5]. Being known as designer solvents, there is a vast extent of ionic liquids and as such, it "simply" remains to find the ideal combination between ionic liquid and nanomaterial to obtain the ideal heat transfer fluid. However, further study and property measurement is needed to verify the results obtained in the simulation section.

The influence of the uncertainty of thermophysical properties is self-explanatory. The results presented illustrate the importance of rigorous data on the thermophysical properties of a heat transfer fluid to avoid ill-designed units that would have to be modified or considered unusable, either economically harmful. The most cautious approach consists on the rigorous and valid measurement of the properties needed to support an accurate unit design and a more efficient choice of operational variables.

References:

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