



## Effect of Al<sub>2</sub>O<sub>3</sub> nanoparticles on laminar, transient and turbulent flow of isopropyl alcohol

A. Nikulin<sup>a,\*</sup>, A.S. Moita<sup>a</sup>, A.L.N. Moreira<sup>a</sup>, S.M.S. Murshed<sup>a,b</sup>, A. Humnic<sup>c</sup>, Y. Grosu<sup>d</sup>, A. Faik<sup>d</sup>, J. Nieto-Maestre<sup>e</sup>, O. Khliyeva<sup>f</sup>

<sup>a</sup>Instituto Superior Técnico, Universidade de Lisboa, Center for Innovation, Technology and Policy Research, IN+, Av. Rovisco Pais 1, 1049-001 Lisboa, Portugal

<sup>b</sup>Centro de Química Estrutural, Faculdade de Ciências, Universidade de Lisboa, Campo Grande, 1749-016 Lisboa, Portugal

<sup>c</sup>Transilvania University of Brasov, Mechanical Engineering Department, 29, Bulevardul Eroilor, 500036 Brasov, Romania

<sup>d</sup>CIC Energigune, Albert Einstein 48, Mirano, Alava 01510, Spain

<sup>e</sup>Material and Processes Energy Unit, Tecnalia Research and Innovation, Mikeletegi Pasealekua, 2, 20009 San Sebastián, Gipúzcoa, Spain

<sup>f</sup>Odessa National Academy of Food Technologies, Institute of Refrigeration, Cryotechnology and Eco-Energy, 1/3 Dvoryn'skaya Str., 65082 Odessa, Ukraine

### Highlights

- Single-phase flow of isopropanol/Al<sub>2</sub>O<sub>3</sub> nanofluid was studied.
- Viscosity of nanofluid exhibit non-linear trend vs. temperature.
- Dependence of the friction factor vs. *Re* is the same for nanofluid as for base fluid.
- Effect of nanoparticles on heat transfer depends on criteria selected for analysis.
- The onset of laminar-turbulent transition is affected by nanoparticles.

### Abstract

The laminar, transient and turbulent heat transfer and hydrodynamic of a new nanofluid isopropanol/Al<sub>2</sub>O<sub>3</sub> is investigated in a closed flow loop with a horizontal mini-channel test section (3.5 mm inner diameter) under uniform heat flux conditions. The experiments performed at various inlet temperatures (15, 25, 35 °C), mass flow rates (from 0.00076 to 0.041 kg/s) and nanoparticle concentrations (0.387, 0.992, 3.12, 4.71 mass%). We found that despite the pressure drop increases with Reynolds number and nanoparticles mass fraction the dependence of friction factor for the isopropanol/Al<sub>2</sub>O<sub>3</sub> nanofluid remains the same as for the base fluid. The heat transfer performance of isopropanol/Al<sub>2</sub>O<sub>3</sub> nanofluid was evaluated in two ways (*i*) depending on the Reynolds number and (*ii*) product of the mass flow rate and specific heat capacity. The first approach indicates to significant enhancement of the heat transfer coefficient with addition of nanoparticles in all range of experimental parameters. The second approach shows no effect of nanoparticles on the heat transfer coefficient in laminar flow and its deterioration in transient and turbulent flows. Both effects of nanoparticles on the heat transfer are attributed to change in intensity of the turbulence in nanofluids compared to the base fluids. Finally, an influence of nanoparticles on the start of laminar-turbulent transition was examined.