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The micro-tube heat transfer and fluid flow of water based Al_2O_3 nanofluid with viscous dissipation ☆

Dorin Lelea *, Catalin Nisulescu

University Politehnica Timisoara, Faculty of Mechanical Engineering, Department of Thermal Machines and Transportation, B-dul Mihai Viteazu nr. 1, 300222 Timisoara, Romania

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ABSTRACT

The numerical modeling of the conjugate heat transfer and fluid flow of Al_2O_3/water nanofluid through the micro-tube was presented in the paper. The laminar flow regime was considered along with viscous dissipation effect. The diameter ratio of the micro-tube was $D_i/D_o = 0.1/0.3$ mm with a tube length $L = 100$ mm. The heat transfer rate was fixed to $Q = 0.5$ W with three different Br = 0.1, 0.5 and 1. The water based Al_2O_3 nanofluid was considered with various volume concentrations of Al_2O_3 particles $\phi = 1, 4, 6, 9\%$ and two diameters of the particles $D_p = 10$ nm and 47 nm. The analysis was performed on the results for local heat transfer coefficient.

1. Introduction

The recent technological developments and advances in devices that ensure the comfort of everyday life increases the importance of microchannel heat transfer and fluid flow. The cooling of the VLSI devices, biomedical applications, micro-heat-exchangers are some of the examples where the fundamentals of the microchannel heat transfer and fluid flow are essential for a proper design of these devices. Moreover, the nanofluids that were first introduced by Choi [1], gained the interest in the recent years due to their cooling capabilities.

Yang et al.[2] investigated experimentally the laminar heat transfer and fluid flow of graphite nanofluids in horizontal tubes. The experimental results show that the nanoparticles increase the heat transfer coefficient of the fluid system in laminar flow, but the increase is much less than that predicted by current correlation based on static thermal conductivity measurements.

Experimental research on developing laminar and turbulent heat transfer of water-based FMWNT nanofluid in a uniformly heated horizontal tube was made by Amrollahi et al.[3]. The experimental results indicate that the convective heat transfer coefficient of these nanofluids increases by up to 33–40% at a concentration of 0.25 wt.% compared with that of pure water both in laminar and turbulent regime.

The experimental research on heat transfer of Al_2O_3/propanol nanofluid was made by Sommers and Yerkes [4]. The heat transfer coefficient enhancement was observed for $Re_D < 3000$ with the pressure drop increasing from 400% to 600% for the 1 wt% Al_2O_3/propanol nanofluid.

Rea et al.[5] analyzed experimentally the laminar convective heat transfer of alumina–water and zirconia–water nanofluids. The data expressed in form of dimensionless numbers (Nu and x+), show good agreement with the predictions of the traditional models/correlations for laminar flow. This suggests that the nanofluids behave as homogeneous mixtures.

Developing heat transfer of Al_2O_3/water nanofluids in annulus was studied numerically in Izadi et al.[6] with single phase approach adopted for nanofluid modeling. It was concluded that the effect of nanoparticle concentration on the nanofluid bulk temperature is significant.

The experimental research on heat transfer of Al_2O_3/water nanofluid in tubes was analyzed by Wen and Ding [7] and Anoop et al.[8]. The results showed considerable enhancement of convective heat transfer using the nanofluids, particularly significant in the entrance region. Heris et al.[9] analyzed numerically laminar-flow convective heat transfer of nanofluid in a circular tube with constant wall temperature boundary condition. The numerical results indicate that addition of nanoparticles to base liquid produces considerable enhancement of heat transfer. Also decreasing nanoparticles size at a specific concentration increases heat transfer coefficients.

The comparison of different approach for numerical modeling on heat transfer of nanofluids was presented by Lotfi et al.[10] and Fard et al.[11]. It was found that two-phase models are more precise than one-phase model.

The turbulent heat transfer of CuO/water nanofluids inside circular tubes was investigated experimentally by Fotukian and Esfahany [12], while natural convection of Al_2O_3–water nanofluid was analyzed by Nada [13]. In the latter case the single-phase approach was employed with Chon et al.[20] model for thermal conductivity and correlation based on Nguyen et al.[22] experimental results for effective viscosity.

The liquid cooling of electronics with nanofluids was investigated by Nguyen et al.[14]. It was found that for a particular particle volume

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* Corresponding author.
E-mail address: ldorin@mec.upt.ro (D. Lelea).

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