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Entropy Generation Calculation for Turbulent Fully Developed Forced Flow and Heat Transfer of Nanofluids inside Annuli

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Abstract

This paper analytically investigates the entropy generation of Al_2O_3-water nanofluid flow through annuli with uniform heat flux at the inner wall while the outer wall is insulated. The present study has been done for fully developed and turbulent flow condition and single phase approach is used for the nanofluid modeling and the thermophysical properties of the nanofluid are calculated using available correlations. Control volume approach is selected for calculation of the entropy generation. Total entropy generation is calculated for different values of nanoparticles volume fractions at different geometrical ratios and compared with those of the base fluid. The results for the dependency of entropy generation of the nanofluid on geometrical factors such as L/D_h and D_o/D_i are obtained and compared for different nanoparticles volume fractions. For all of mentioned cases, It has been found that that the irreversibility due to fluid flow (pressure drop) is dominant and adding nanoparticles leads to increased entropy generation.

Keywords: Nanofluid, Entropy generation, Turbulent forced convection, Annulus, Analytical solution

Introduction

Since nanofluids have eminent heat transfer ability, mostly get used in heat exchangers and in recent years have attracted the attention of researchers and different industries. For instance, in transportation industry two of the biggest car factories of the US, GM and Ford, have ongoing nanofluid research projects. Electronics cooling, defense, space, nuclear systems cooling and biomedicine are other nanofluids applications. Electronic devices have resistance and due to passing electronic current, heat gets produced and if the heat produced does not be taken away it definitely would harm the device. Rafati et al. [6] have presented a study on the application of nanofluids in computer cooling systems. They investigated the use of enhanced thermal properties of nanofluids for the cooling of computer microchips. Their nanofluids were combinations of three different volumetric concentrations of silica, alumina and titania suspended in various mixture of deionized water and ethylene glycol. They observed that the largest decrease was for alumina nanofluid, which decreased processor temperature from 49.4C to 43.9C for 1.0% of volumetric concentration and flow rate of 1.0 lpm when compared with the pure base fluid with the same flow rate. They also came to conclusion that there should be a balance between volumetric concentration of nanoparticles and the flow rate to satisfy the economy and power consumption of cooling the system. Ijam and Saidur [7] analyzed a minichannel heat sink with SiC-water nanofluid and TiO_2-water nanofluid turbulent flow as coolants. The results showed that enhancement in thermal conductivity by dispersed SiC in water at 4% volume fraction was 12.44% and by dispersed TiO_2 in water was 9.99% for the same volume fraction. There are aslo examples of nanofluid applications in transportation industry. Leong et al. [8] investigated the performance of an automotive car radiator operated with nanofluids as coolant. It was observed that, about 3.8% of heat transfer enhancement could be achieved with the addition of 2% copper particles in a base fluid at the Reynolds number of 6000 and 5000 for air and coolant, respectively.

Low efficiency of engineering thermal systems which use water, ethylene glycol and etc. as their working fluid has made researchers investigating ways to enhance heat transfer ability of the fluid and so increasing the efficiency. One way of enhancing heat transfer of a fluid is increasing its thermal conductivity. However, there are other ways like changing in geometry of the duct in which the fluid flows or changing thermal boundary conditions, increasing thermal conductivity of the fluid is in more interest of researchers. Since solids have higher thermal conductivity than liquids, adding nano-sized particles known as nanoparticles to the liquid increases its thermal conductivity. Many researches have been carried out to investigate the effective thermal conductivity and dynamic viscosity of nanofluids. For instance, Ghanbarpour et al. [1] investigated the thermal properties and rheological behavior of water based Al_2O_3 nanofluid as a heat transfer fluid both experimentally and theoretically. The result showed that for the nanoparticles mass fraction ranging from 3% to 50% and temperature ranging from 293K to 323K thermal conductivity and viscosity of the nanofluid increase from 1.1% to 87% and from 18.1% to 300%, respectively. Also Xuan and Li [2] presented a study on the thermal conductivity of a nanofluid consisting of copper nanoparticles. The measured data showed that adding 2.5-7.5% copper oxide nanoparticles to the water increases its conductivity by about 24-78%.

There are also many researches conducted on nanofluids heat transfer enhancement. For example, Izadi et al. [3] presented a numerical study on developing laminar forced convection of Al_2O_3-water nanofluid in an annulus using single phase approach. Abu-Nada et al. [4]