Heat Transfer Enhancement Using Nanofluids in a Chaotic Configuration

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Abstract
In this study, the problem of laminar flows of nanofluids in a chaotic configuration has been numerically investigated. Results, as obtained for water-Al_2O_3 mixture, show an enhancement of heat transfer rate due to the presence of nanoparticles in the base fluid. However, inclusion of particles in the flow increases friction factor and pressure drop. The effects of Reynolds number(Re=50,100,200 and 350) and concentration of nanoparticles (Φ=0, 2, 4 and 6) on Nusselt number (Nu) and pressure drop parameter (f×Re) have evaluated. The results show a 0-34% increase in average Nusselt number and 0-3.5% increase in pressure drop as particle concentration increases from 0 to 6%. Finally, thermal-hydraulic performance (η) was evaluated and it was seen that the best performance can be obtained for Φ=6%.

Keywords: nanofluid, chaotic configuration, particle concentration, thermal- hydraulic performance.

Introduction

The use of metallic particles in base fluid is one approach to improve heat transfer rate. In recent years, the advances in manufacturing technology have caused the production of nanoparticles. Many researchers experimentally showed nanofluids have higher thermal conductivity than those of the base fluids and a lot of correlations have obtained. Wang and Mujumdar [1] have summarized some these correlations. The enhancement of heat transfer characteristics using nanofluids instead of conventional fluids inside tubes in heat exchanger have been reported in different experimental and numerical investigations. For an example Farajollahi et al.[2] experimentally investigated the heat transfer performance Al_2O_3-water and TiO_2-water nanofluids in a shell and tube heat exchanger. Akbarinia and Laur[3] reported the results of their numerical studies on laminar mixed convection heat transfer in a circular curved tube with a nanofluid consisting of water and 1vol.% Al_2O_3.They used two phase mixture model and control volume technique to study flow field .These authors investigated the effects of diameter of particles on hydrodynamic and thermal parameters. They found that increasing the solid particles diameter decrease Nusselt number and secondary flow.

The heat transfer and fluid flow characteristics in chaotic configurations have been investigated by many researchers due to their high thermal performance. when the fluid present pathlines that do not conform to the laminar regime, such fluid present chaotic advection[4]. A clear example that shows how to generate chaotic advection in three dimensional flow presented by Hosseinalipour et al.[5]. Archarya et al. [6] examined chaotic mixing in a chaotic coil and showed the chaotic coil has a 6-8% higher heat transfer coefficient in comparison with a simple one.

In the present paper, the flow and heat transfer characteristics of laminar flow in a chaotic coil for base fluid (distilled water) and a nanofluid that is composed of distilled water and Al_2O_3 nanoparticles are numerically investigated.

Studied geometry

A schematic diagram of studied chaotic configuration is shown in figure1.The chaotic configuration is a coil. Each period of this coil is included of three 90^o bends with circular cross-section which each bend is placed in different coordinate plane. The studied coil consists of 3 periods (i.e. 12 bends).

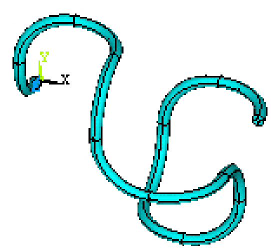

Figure 1: Chaotic coil configuration.

Governing equation and nanofluid properties

In present work, the nanofluid is considered incompressible with constant physical properties. The compression work and viscous dissipation terms were considered negligible in the energy equation. Under such assumptions, the general governing equations written are as the followings:

Conservation of mass:

$$div(V) = 0 \tag{1}$$

Conservation of momentum: