Abstract

The theoretical and experimental study was conducted to investigate the heat transfer and flow of nanofluids through a horizontal and an inclined circular tube heated by an axial uniform heat flux. This study was done in thermally and hydrodynamically fully developed region with laminar flow. Three types of nanofluids are used through this work, Al (25nm) – distilled water, Al_2O_3 (30nm) – distilled water and CuO (50nm) – distilled water.

The theoretical study includes the construction of the single phase model from the governing equations of heat transfer and flow through a horizontal and an inclined tube from the basic governing equations (continuity, energy and the momentum equations in the polar three – dimensional coordinate). The governing equations are transformed to a dimensionless formula include volume fraction, Prandtl number, Reynolds number and Rayleigh number. These equations were numerically solved by the finite difference methods using the alternating direction implicit method (ADI) and Gauss elimination technique.

The results based on the fact that the secondary flow created by natural convection has significant effects on the heat transfer process, reveal an increase in the Nussult number values as the heat flux increases and as the angle of inclination moves from the vertical to the horizontal position. The results showed that, the average rate of the heat transfer increases significantly with increases of the particle volume fraction and Rayleigh number. Also, the type of nanofluid is a key factor for the heat transfer enhancement, where the high values are obtained when using Al, Al_2O_3, and CuO nanoparticles, respectively.

The experimental study includes construction of experimental test rig which consists of Pyrex tubes of 4 mm diameter. It is fixed horizontally and heated by tungsten wire and supplied with tank for collection the nanofluid, pump, pressure gauges, flow meter and thermocouples. The range of Reynolds number are chosen (100 – 900) , heat flux ranging between (588– 7910W/m^2) which cover a wide range of Rayleigh number between (1×10^3– 4×10^6) and concentrations from (0.25 – 2.5 vol %). The pressure drop, wall temperature, flow rate, heat flux and temperature of nanofluids flowing through a uniform heated circular tube in the fully developed laminar flow regime were measured. Moreover the properties

of the nanofluid, density, viscosity, specific heat and thermal conductivity were measured practically. The values of Nusselt number ratio (NuR) were evaluated to be (45%, 31%, 25%) for the three nanofluids (Al, Al_2O_3,CuO) – distilled water respectively, with the uniform heat flux and (36%, 27%, 22%) constant wall temperature .

It should be noted that the enhancement of heat transfer greatly depend on volume fraction, nanoparticles type, nanoparticles size, flow regime. Nanofluids that contain metal nanoparticles shows more enhancement than oxide nanofluids. Correlation for average Nusselt number with Rayleigh number and nanofluid concentration were obtained for each type of the used nanofluid. General correlation were also obtained for the three types of nanofluids. The comparison of the present numerical and experimental results with the works of other researchers is done, and show good agreement. The difference between theoretical and experimental results in the present work is ±9 % for average Nusselt number.