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Analytical Investigation of Heat Transfer Enhancement In Micro Tube Using Hybrid Nanofluids

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ABSTRACT

The heat transfer enhancement in micro tube using different types of nanofluids such as Al_2O_3(Aluminium oxide), SiO_2(Silicon oxide) and Hybrid fluid (i.e.) mixing (Al_2O_{3}+SiO_2) with nanosized particle size 30nm and are mixed at different volume fractions ranged from 0.5% to 1% using water (H_2O) which is a base fluid, is investigated analytically covering Reynolds number ranging between 90 to 800. As Hybridity boosts the temperature distribution as well as the heat transfer rate of the fluids. Distilled pure water is used as a base fluid. Properties such as thermal conductivity, specific heat, density and viscosity for the nanofluids are calculated numerically. CFD Analysis is done on the Micro tube (MT) with 0.01cm diameter and 20cm length in this investigation to obtain the values of heat transfer coefficient, heat transfer rate, pressure drop, temperature distribution, heat flux, Nusselt number for each individual nanofluids, from which better fluids can be determined for improving heat transfer. The micro tube material is copper. Model of the micro tube is done in Creo and CFD analysis is done in ANSYS.

Keywords: Nanofluid, overall heat transfer coefficient, mass flow rate, CFD.

INTRODUCTION

1.1 MICROTUBE

Micro heat exchangers, Micro-scale heat exchangers, or micro structured heat exchangers are heat exchangers in which (at least one) fluid flows in lateral confinements with typical dimensions below 1mm. The most typical such confinement are microchannels, which are channels with a hydraulic diameter below 1 mm. Microchannel heat exchangers can be made from metal, ceramic. Microchannel heat exchangers can be used for many applications including: High-performance aircraft gas turbine engines, Heat pumps, Air conditioning

1.4 NANOFLUIDS

Nanofluids are a new class of fluids engineered by dispersing nanometer-sized materials (nanoparticles, nanofibers, nanotubes, nanowires, nanorods, nanosheet, or droplets) in base fluids. In other words, nanofluids are nanoscale colloidal suspensions containing condensed nanomaterials. They are two-phase systems with one phase (solid phase) in another (liquid phase).

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Nanofluids have been found to possess enhanced thermophysical properties such as thermal conductivity, thermal diffusivity, viscosity, and convective heat transfer coefficients compared to those of base fluids like oil or water. It has demonstrated great potential applications in many fields. In recent years, nanofluids have attracted more and more attention. The main driving force for nanofluids research lies in a wide range of applications.

By hybridization of two or more different nanoparticles are increases the thermal conductivity of new composite nanoparticle is formed is knows as hybrid nanoparticle. The nanofluid shows better performance than the conventional fluid. When nanofluid used as heat transfer medium hybrid nanofluid shows better thermal conductivity than the mono. **Some of the applications of nanofluids are:** Heat Transfer Intensification, Electronic Applications, Transportation, Industrial Cooling Applications, Heating Buildings and Reducing Pollution, Nuclear Systems Cooling, Space and Defense, Mass Transfer Enhancement, Energy Applications, Energy Storage, Solar Absorption, Biomedical Application, Mechanical Applications.

LITERATURE REVIEW

N.S.M. Sahid [4], presented an experimental investigation on properties and stability of hybrid nanofluids (TiO2 and ZnO) in water-ethylene glycol mixture. Hybrid nanofluids with different volume concentration up to 0.1-1.5% were prepared with 21nm particle size of TiO_2 and 10-30nm ZnO nanoparticle. The nanoparticle was suspended in various ratio of TiO_2: ZnO including 70:30, 80:20 and 90:10 by volume percent. The measurements of viscosity were performed using Brookfield LVDV III Ultra Rheometer for hybrid nanofluid temperature of 50 to 70^{0}C, while the measurements of thermal conductivity were performed using KD2 PRO thermal conductivity. Viscosity and thermal conductivity of hybrid nanofluids were perceived to impact by hybrid nanofluids concentration, temperature and water Ethelene glycol as base fluid strongly.

Tanzila Hayat [6], Nanofluids are of great importance to researchers as they have significant uses industrially due to their high heat transfer rates. Recently, a new class of nanofluid, “hybrid nanofluid” is being used to further enhance the heat transfer rate. This new model in 3D is employed to examine the impact of thermal radiation, heat generation and chemical reaction over stretching sheet in the presence of rotation. It is concluded from the current research that even in the presence of radiation, heat generation and chemical reaction the heat transfer rate of Hybrid nanofluid is higher than the simple nanofluid.

CALCULATIONS AND PROPERTIES OF NANOFLUIDS

The properties of nanofluids such as Al_2O_3 and SiO_2, and hybrid nanofluid Al_2O_3+ SiO_2 with 70:30 ratio with nanoparticle size 30 nm, and volume fraction 1% using water as base fluids are calculated numerically.

4.2 FORMULAS FOR PROPERTIES OF NANOFLUIDS

1. **Density of nanofluid**

$$\rho_{nf} = (1 - \phi_p)\, \rho_{bf} + \rho_p \phi_p$$

ρ_{nf} = Density of nanofluid, ϕ_p = Volume fraction of nanofluid, ρ_p = Density of nanoparticle, ρ_{bf} = = Density of base fluid

2. **Specific heat of nanofluid**

$$C_{pnf} = \frac{(1 - \phi)\, \rho bf\, Cpbf + \phi p\, (Cp)p\, \rho p}{\rho nf}$$

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C_{pnf} = Specific heat of nanofluid, C_{pbf} = Specific heat of base fluid, $(C_p)_p$ = Specific heat of nanoparticle

3. **Thermal Conductivity of nanofluid**

$$K_{nf} = K_{bf} * \left[\frac{Kp+2Kbf-2\phi\,(Kbf-Kp)}{Kp+2Kbf+\phi\,(Kbf+Kp)} \right]$$

K_{nf} = Thermal conductivity of nanofluid, K_{bf} = Thermal conductivity of base fluid, K_p = Thermal conductivity of nanoparticle

4. **Viscosity of nanofluid**

$$\mu_{nf} = (1+2.5\phi)\, \mu_{bf}$$

μ_{nf} = Viscosity of nanofluid, μ_{bf} = Viscosity of base fluid

MODELING AND ANALYSIS OF MICROTUBE

The Microtube (MT) with 0.01 cm diameter and 20 cm length is modeled in Creo 6.0.

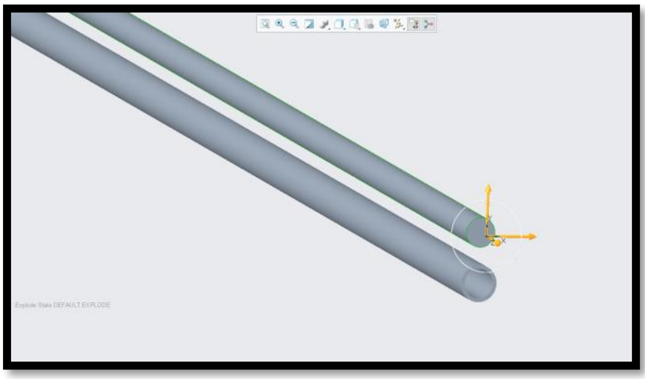

Fig 5.3: Exploded view of assembly of microtube and fluid region

5.1 CFD ANALYSIS

CFD analysis is performed on the microtube using Fluid Flow (Fluent) in ANSYS. The results observed are heat transfer coefficient, heat transfer rate, pressure drop, heat flux, Nusselt number. The analyses are carried out using a commercial CFD solver, ANSYS Fluent. The solver is based on finite volume method with second order discretization. The convergence criteria for continuity, momentum and other parameters were set to 10^{-3}, while the convergence of energy equation was set to 10^{-6}. In most cases, the momentum and other residuals were less than 10^{-5} and the highest residual found was $7*10^{-4}$.

5.2 BOUNDARY CONDITIONS

The velocity of fluid (air) is taken as inlet which is varied due to the variation in Reynold's number 90-800. A no slip boundary condition was assigned for the non-porous wall surfaces. Laminar flow is considered and a constant heat flux (100 W/m^2) is applied on the channel wall. A uniform mass flow inlet and a constant inlet temperature were assigned at the channel inlet. At the exit, pressure was specified.

5.3 FLUID - WATER + Al_2O_3 FOR NANOFLUIDS WITH VOLUME FRACTION 1% WITH Re =800

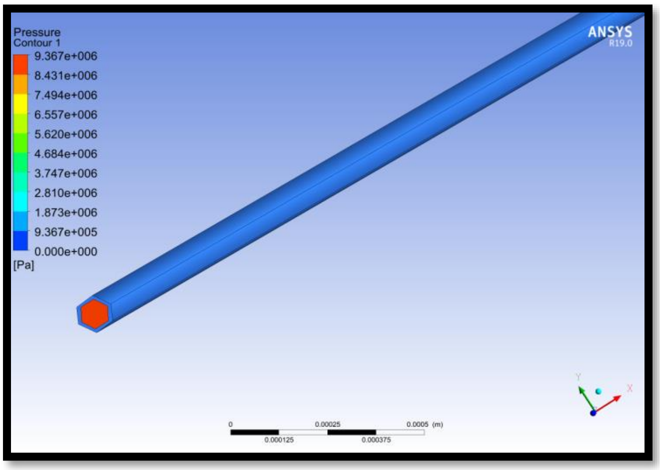

Fig 5.14: Pressure on microtube at Reynolds number 800 using Water + Al_2O_3 at volume fraction 1%

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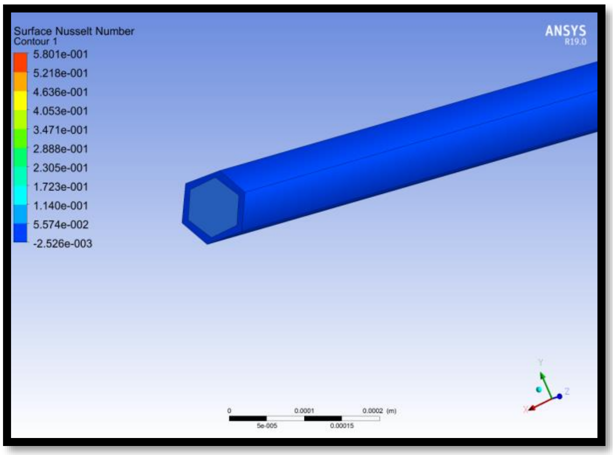

Fig 5.16: Nusselt number on microtube at Reynolds number 800 using Water + Al_2O_3 at volume fraction 1%

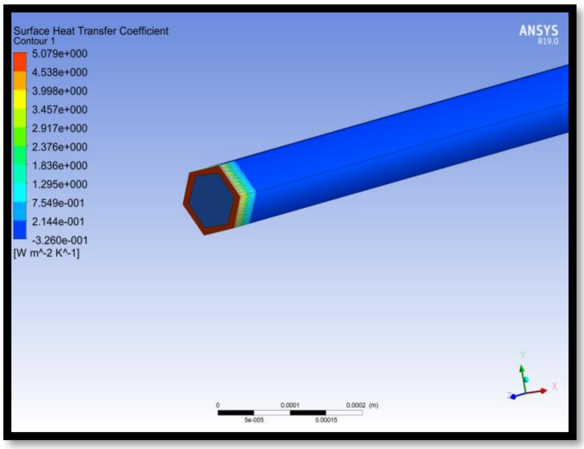

Fig 5.18: Heat transfer coefficient on microtube at Reynolds number 800 using Water + Al_2O_3 at volume fraction 1%

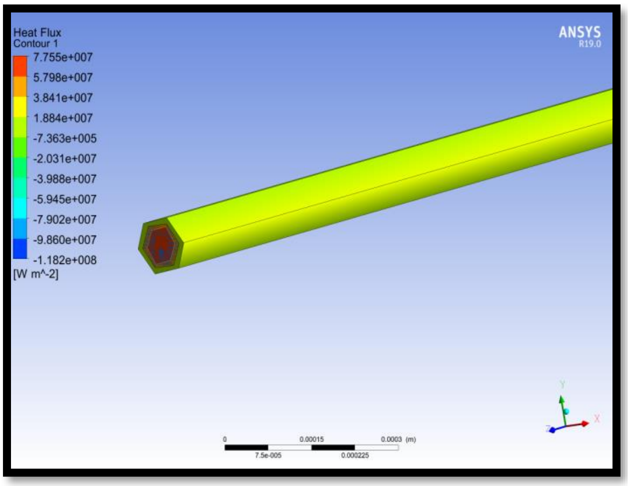

Fig 5.20: Heat Flux on microtube at Reynolds number 800 using Water + Al_2O_3 at volume fraction 1%

RESULTS AND DISCUSSIONS

6.1 RESULTS TABLES AND GRAPHS FOR COMPARISON BETWEEN DIFFERENT NANOFLUIDS FOR DIFFERENT VOLUME FRACTIONS AT DIFFERENT REYNOLDS NUMBER

Table 6.1: Comparison of CFD Results for different nanofluids at Re = 800 at volume fraction 1%

Fluids	Pressure (Pa)	Nusselt Number	Heat Transfer Coefficient (W/m^2K)	Heat Flux (W/m^2)
Water + Al_2O_3	9.36743 e^6	0.58011	5.07876	7.75524e^7
Water + SiO_2	9.61846 e^6	0.583244	5.07923	7.93686e^7
Water + Hybrid	9.721 e^6	0.5806	5.079	7.8115e^7

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Table 6.2: Comparison of CFD Results for different nanofluids at Re = 500 at volume fraction 0.5%

Fluids	Pressure (Pa)	Nusselt Number	Heat Transfer Coefficient (W/m^2K)	Heat Flux (W/m^2)
Water + Al_2O_3	9.356 e^6	0.5816	5.079	7.848 e^7
Water + SiO_2	9.435 e^6	0.5826	5.079	7.903 e^7
Water + Hybrid	9.543 e^6	0.5811	5.079	7.884 e^7

By observing the results, the pressure is decreasing, Nusselt number, heat transfer coefficient and heat flux are increasing by decreasing the volume fraction (i.e) for 0.5% volume fraction. The Nusselt number, heat transfer coefficient and heat flux are more when nanofluid SiO_2 is used.

Table 6.3: Comparison of CFD Results for different nanofluids at Re = 1000 at volume fraction 1%

Fluids	Pressure (Pa)	Nusselt Number	Heat Transfer Coefficient (W/m^2K)	Heat Flux (W/m^2)
Water + Al_2O_3	1.172 e^7	0.5786	5.078	9.692 e^7
Water + SiO_2	1.203 e^7	0.581771	5.07896	9.916 e^7
Water + Hybrid	1.217 e^7	0.579088	5.07855	9.77 e^7

Table 6.4: Comparison of CFD Results for different nanofluids at Re = 1000 at volume fraction 0.5%

Fluids	Pressure (Pa)	Nusselt Number	Heat Transfer Coefficient (W/m^2K)	Heat Flux (W/m^2)
Water + Al_2O_3	1.17e^7	0.5801	5.079	9.808 e^7
Water + SiO_2	1.181 e7	0.5812	5.079	9.879 e^7
Water + Hybrid	1.194 e7	0.5796	5.079	9.853 e^7

By observing the results, the pressure is decreasing, Nusselt number, heat transfer coefficient and heat flux are increasing by decreasing the volume fraction (i.e) for 0.5% volume fraction. The Nusselt number, heat transfer coefficient and heat flux are more when nanofluid SiO_2 is used.

CONCLUSION

By observing the results, it can be concluded that the pressure is decreasing, Nusselt number, heat transfer coefficient and heat flux are increasing by decreasing the volume fraction (i.e.) for 0.5% volume fraction. The Nusselt number, heat transfer coefficient and heat flux are more when nanofluid SiO_2 is used. The Nusselt number is more for Reynolds number 800, the heat transfer coefficient and heat flux are more for Reynolds number 1000.

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