Heat Transfer Enhancements for a Nano Fluid by Turbulent Flow

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Abstract

The purpose of this work is to study the heat transfer and pressure drop characteristics in tube fitted with helical screw louvered rod addition using water and carbon nanotubes (i.e. CNT) with continuous heat flux in turbulent flow condition. Nano fluids 0.1%, 0.2% & 0.5% with volume fraction were prepared. In the work, the swirling flow was presented by using helical screw louvered rod inserts arrangements (forward) inside the inner test tube through numerous ratio of twist, \( Y = 1.78, 2.44 \) and \( 3.0 \). The Reynolds number differs from 10,000 to 27,500. The work carried out results showed rise in rate of heat transfer of the helical screw louvered rod inserts creates a strong influence on a tape-induced swirl or vortex motion. The heat transfer goes on increasing with a change in the volume concentration. Subsequently, an observed correlation for the friction factor and Nusselt number onward helical louvered rod inserts were established and fitted with the investigational data.

Keywords: Carbon Nanotube Nano-fluid, Friction Factor, Helical Louvered Rod Inserts, Nusselt Number; Thermal Conductivity, Viscosity

1. Introduction

The current massive developments in nanotechnology, nano sized particle which are carrying highest buoyant capacity. By way of a significance, by using nano-particles as a base liquid for cultivating thermal conductivity can be formed by impress of overhanging recently3-4. Nano particle interruption with base fluid is called nano fluid. Among the various available nanoparticles, carbon nanotubes (CNTs) which react to the maximum thermal conductivity are shaped by rolling-up a graphene sheet and its properties differ depend upon rolling angle and radius mixture. The main features of the tubes include their elastic modules, tensile strength and excellent electrical and thermal conductivities. When neither dispersant nor surfactant is present, carbon nanotubes (CNTs) take a hydrophobic surface which is prone to accumulation and precipitation in water.

Carbon nanotubes were often used as their tremendously thermal conductivity in the axial direction. Commonly used in the research of nano fluids are base fluids and were used as main fluids for heat transfer. Some additives were simulated.

A.W. Fan et al.\(^5\) conducted numerical simulation of turbulent airflow in a circular tube fitted with louvered strip inserted by knowing its heat transfer, flow resistance, and overall thermo-hydraulic performance. The value of PEC lied in the range of 1.60–2.05, which showed that the good thermal properties of a strip louvered inserts.

B. Farajollahi et al.\(^6\) calculated the performance of heat transfer and compared behaviour between two nanofluids using shell and tube heat exchanger under turbulent flow condition, addition of nanoparticles to the base fluid produces significant improvement of performance of heat transfer.

Amirhossein Zamzamian et al.\(^7\) examined results of convective coefficient of heat transfer in turbulent flow by using a heat exchanger of plate and double pipe type and found that the 2% to 50% increase in convective coefficient of heat transfer of the nano fluids on comparing with the fluid of base.

Bayram Sahin et al.\(^8\) examined the characteristics of
Al₂O₃–water nano-fluid inside a circular tube and under constant heat flux state examined effects of the Reynolds number and volume fraction. Found that increase in the heat transfer and particle volume concentrations of 2 and 4%.

Bhuiya et al. studied the characteristics of heat transfer by using double helical tape inserts under turbulent flow. The above parameters were examined with different helix angle with using of helical tape tabulators.

Suresh et al. conducted the experiment on the different tubes under turbulent flow with continuous heat flux by means of CuO/water nano-fluid. Measured the friction factor and heat transfer performance and results showed that there is an increment of 2–10% of pressure drop when compared with plain tube.

A.A. Abbasian Arani et al. conducted the experiment with different volume concentration of nano-particle effect on pressure drop and convective heat transfer for an average diameter of nano-particles. The results revealed that the maximum thermal characteristics for the various range of volume concentrations and Reynolds number found to be the nano fluids particle with 20 nm diameter size.

Zan Wu et al. examined performances of water and alumina/water nano fluids for convective heat transfer and pressure drop with variable mass portions. The experimental heat transfer data under laminar flow using fabricated tubes. The thermal performance of water and nano-fluids for flow of turbulent type can be correlated by using Seban and McLaughlin.

Adnan M. Hussein et al. found that the significant enhancement of heat transfers and hydrodynamic flow for additives of solid nanoparticles to liquids. In this study, experiment was conducted for different nanoparticles are isolated using water as a fluid of base. Simulation concluded that the thermal characteristics were studied along with Reynolds number as effort and were as Nusselt number and friction factor as productivity limitations.

P. Sivashanmugam and Suresh et al. conducted experiments on different twist ratios for the turbulent performance of friction factor and heat transfer for water through a round tube fixed with long helical screw and showed that decreases in ratio of twist along show that there is increases in friction factor and heat transfer.

L. Syam Sundar et al. examined turbulent friction factor and convective heat transfer performance in Al₂O₃ nanofluid for different aspect ratios of circular tube fitted with longitudinal strip inserted. For different particle volume concentration and Reynolds number the experiments were conducted for water and nano-fluid.

L. Suresh et al. measured the different twist ratio for performance of friction factor and heat transfer under turbulent condition a round tube fixed with evenly spaced fabricated tape inserts.

M.H. Kayhani et al. studied the behaviour of Titanium Oxide with water as a nanofluid through a consistently heated horizontal round tube along with different parameters under turbulent condition. The spherical Titanium Oxide nano-particles with a regular diameter were changed by a novel biochemical treatment and different nanofluid volume concentrations of 0.1 to 2.0% is formed.

N. Kannadasan et al. compared the CuO/water nanofluids performance of pressure drop and heat transfer in a fabricated heat exchanger leaning in different positions. For 0.1% and 0.2% volume concentrations the turbulent flow the experiments were conducted by using water and copper oxide with water as nano-fluid. The outcomes relieved that variation in friction factors and convective coefficient of heat transfer of nano-fluids for different type when compared to that of water is not varied so much.

The determination of the current work is to examine the forced convective turbulent flow in a tube taking helical louvered rod inserts with forward preparations by using CNT/water nanofluids and for the Reynolds number of different range (10,000 to 27,500). The work carried out for on inserts turbulent flow using CNT/water nanofluids of different percentage along with volume fractions in a round tube fixed with helical louvered rod inserts are stated such as friction factor and Nusselt number.

2. Experimental Work

2.1 Formulation of Nanofluids

Water and CNT nano fluid are two working fluids is used for present work. The aim behind this is that CNT nanoparticles have good thermal conductivity standards. Enhancement of coolant can be obtained by inspection of carbon nano tubes elements and it begins due to its much more thermal conductivity. Its range of CNTs can be intended by numerous resources. Three different volume of (0.1, 0.2 & 0.5%) of carbon nano tube nano-fluids were got ready by using Di-ionized water as fluid...
of base. Different-walled Carbon nanotube elements with surfactants were clubbed along with the Di-ionized water using a vibrator of ultrasonic type. The nanoparticles will become further steady and to endure additional discrete in water by using vibrator of ultrasonic type. Sonication is used for 1 hour constantly to become an further steady and often discrete nano-particle suspension. It is found that there is formation of foam by using a surfactant of Sodium dodecyl benzene sulfonate during primary experimentation and Gum Arabic (Acacia) surfactant is used to rectified problem.

2.2 Experimental Work Carried Out
The circuit of the experimental work is shown below, using calibrated RTDs the fluid and wall temperatures were tested and the output is found in Figure 1. The experimental work carried contains a pump, heat exchanger, test section, calming section with a fluid reservoir. A seven litres volume of plastic container is used as the fluid reservoir. Straight copper tube made with test and calming sections through the lengths of 1 meter, 0.01 m Inner Diameter and 0.012 m Outer Diameter. Uniform heating is provided by using Nichrome heating electrical wire with SWG coated with ceramic beads along with resistance of 120 Ω coiled on the test section. By using glass wool heat lost is minimized by providing a thick insulation over the electrical winding. The varying heat flux can be obtained by connecting the ends of the heating coil wire to an auto-transformer and which can be noted by using the digital display units.

The pressure drop is measured by using U-tube manometer of differential type fitted along the test section. After passing through the test section heat is carried along the fluid and flows towards the riser section, then is pass through cooling unit were air cooled heat exchanger is used as a for cooling and collected in the reservoir. Centrifugal pump is used to control the fluid circulation. Two rotameter of rating in the range of 50 – 1500 lph are used to measure the flow rate of fluid under turbulent flows condition. The ratio of twist ‘Y’ is shown as the ratio of length of one twist (linear distance of 360° rotation) to diameter of the twist. (Pitch, P/diameter, D). In the present work, three helical louvered rod inserts with different ratio of twist 1.78, 2.44 and 3 for forward arrangements are used as depicted in Figure 2.

3. Results and Discussion
3.1 Experimental Work Validation
Present work outcomes in terms of friction factor and Nusselt number for heat transfer and friction features for a plain tube. Experimentation were carried for water in pure form in a tube of plain type with different Reynolds number range up to 27,500. Comparison were done based on the investigational results for the completely established flow of turbulent along with the correlations were compared with review of literature. Comparison is done on plain tube obtained from the friction factor and Nusselt number along with the correlations of equation 2 and 1 shown below respectively.

Dittus-Boelter equation (1930) correlation,

$$\frac{Nu}{Re^{0.8} Pr^{0.4}} = 0.023$$

Pethukov equation (1970) correlation,
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\[ Nu = \left( \frac{f}{8} \right) \frac{\text{Re Pr}}{1.07 + 12.7 \left( \frac{f}{8} \right)^{0.5} \left( \text{Pr}^{0.67} - 1 \right)} \]  \quad (2)

Figure 3. Investigational data and observed correlation of the tube of plain type for Nusselt number were compared.

Figure 3. Indicates that the difference projected from the investigational Nusselt number and observed Nusselt number from equation of Dittus-Boelter along through Reynolds number for plain tube and found the experimental data of Nusselt number valued varies from \(\pm7\%\) and \(\pm14\%\) of theoretical values calculated using Dittus-Boelter and Pethukov equation (1970) correlation.

Equations (3) gives the correlation between Plain tube experimental correlations for friction factor with Blassius correlations

\[ f = 0.316/\text{Re}^{0.25} \]  \quad (3)

Pethukov (1970) correlations,

\[ f = (1.82 \log_{10} \text{Re} - 1.64)^{-2} \]  \quad (4)

Figure 4 indicates the difference of Reynolds number with friction factor. The data in the table indicates that for a plain tube the Blassius and Pethukov correlations discrepancy of less than \(\pm8\%\) and \(\pm9.5\%\).

3.2 Influence of Heat Transfer Using CNT/Water Nanofluids

Figure 5 show that with change in Nusselt number along with Reynolds number and also falling ratio of twist for 3.0, 2.44 and 1.78 of forward arrangements helical louvered rods using test fluid as water and 0.1, 0.2 and 0.5\% fraction of CNT/Water nano-fluids. This endorses the helical louvered rod has improvement in heat transfer than that of water and plain tube. Found that the twist ratios of 1.78, 2.44 and 3 were 17.02\%, 11.2\% and 9\% respectively which indicated the improvement for forward arrangements Nusselt number for water, when compared to plain tube. Moreover, using helical louvered rod inserts the smaller pitch (i.e, \(y = 1.78\)), the more convective heat transfer rate of nano-fluids was obtained as related to water. Flow of swirl induced the instability nearby the tube wall and increase the resident period of the liquid in the tube. The hydrodynamic and thermal boundary layer accordingly resulted in development of the convective heat transfer remained efficient redevelopment by fluid mixing with the good instability strength of the fluid near to the tube wall related through the helical louvered rod insert.

Increased in convective heat transfer is found by using carbon nanotube nanoparticles. Result showed that there is an improvement in thermal conductivity (K) of the
nano-fluid which is compared with di-ionized fluid, the improvement of convective heat transfer performed to be main parameter. A different mechanism was commonly mentioned in the literature for the enhancement of conductivity.

One can see that, a moderately minor pitch had a greatly influence on heat transfer improvement, it was noticeably demonstrated by different twist ratios in the Fig.5. However, with increase in the pitch growth was not so significant. Throughout the nano-fluid with fabricate inserts, the improvement in Nusselt numbers was effortlessly related to Nusselt number was found by means of tube of plain type, water and CNT nano-fluid (Figure 5). Average improvements of Nusselt number along with ratios of twist were shown below for forward arrangements.

a) 3, 2.44 and 1.78 were 17.5%, 19.4% and 24.10% for 0.1% fraction.

b) 0.2% fraction 19.7%, 22.8% and 27.8% were found.

c) 24.1%, 26.7% and 31.2% for a fraction of 0.5%.

Figure 5. Deviation of Reynolds with Nusselt number at varying ratios of twist for water and 0.1%, 0.2% and 0.5% nanofluid for FWD.

3.3 Influence of Pressure Drop Using Water Nano fluids/ CNT

It is found that with lowering ratio of twist there is an increment in friction factor. Figure 6 depict the deviations of friction factor against Reynolds number for forward arrangements helical louvered rod inserts of varying pitches using test of Deionized water and 0.1%, 0.2% and 0.5% fraction of CNT/water nano-fluids. The percentage of friction factor for water with ratios of twist 1.78, 2.44 and 3 were 23%, 16.43% and 14.02% respectively for forward arrangements, when compared to plain tube. One can observe that, using helical louvered rod inserts of the friction factor was greater than that of water and tube of plain type. Friction factor was found to be decreasing with increasing of Reynolds numbers. The typical standards of friction factors of CNT/water nano-fluid with 0.5% volume fraction concentration for the forward helical louvered rod inserts with different ratios of twist is 1.78, 2.44 and 3 obtained in the range of 38.8%, 34.3% and 32.4% and compared to the friction factor in the case tube of plain type.

Reynolds number for a friction factor will be increased with the decreased P/D ratio and reached the maximum for Y=1.78 of 0.5% volume concentration of nano fluids. It is found from the Figure 6 that the friction factor for Y=2.44 and 3.0 were less when compared with Y=1.78. This was due to a smaller amount of contact surface area of the louvered rod inserts twist ratio of Y= 2.44 and 3.0, found higher friction factor for bigger contact surface areas and geometry. Occurrence of fabricated inserts reduced allowed areas of flow will lead to a higher swirl speed flow. This led to extensively improved friction among the inner tube wall along with inserts core rod surface.

Figure 6. Deviation of Friction factor with Reynolds number for varying ratios of twist for water and 0.1%, 0.2% and 0.5 % nanofluid for FWD.

3.4 Empirical Associations for Nusselt Number and Friction Factor in FWD

The outcomes of Nusselt number and friction factor for CNT nano-fluids through tube fixed along with fabricated
inserts has been associated in the below equations using the least squares regression analysis.

\[ Nu = 0.01Re^{0.899}Pr^{0.4}(\frac{P}{D})^{-0.15}(1+\phi)^{29.31} \]  
(5)

\[ f = 1.118Re^{-0.323}(\frac{P}{D})^{-0.217}(1+\phi)^{35.28} \]  
(6)

Figure 7. Evaluations of experimental and predicted Nusselt number for the tube with regularly full length helical screw inserts tape with FWD configurations.

Figure 8. Evaluations of friction factor for different experimental and predicted values for the tube with regularly full length helical screw inserts tape with FWD configurations.

The projected standards of friction factor from Equation (6) and Nusselt number from Equation (5) were related along with the investigated standards and obtainable from Figure 7 and 8. The observed associations proposed were matching with the experimental values with ±5.06% for Nusselt number and ±3.94% for friction factor respectively.

4. Conclusions

Present work showed that heat transfer enhancements of fabricated inserts in turbulent flow of water and CNT nano-fluids were investigated. The helical louvered rod inserts with different ratios of twist that is \( Y = 1.78, 2.44 \) and \( 3 \) were used for result by considering water and 0.1%, 0.2% and 0.5% fraction of volume of CNT/water nano-fluid.

- The experimental results show that a forward louvered rod insert arrangement gives enriched improvement in heat transfer than tube of plain type.
- Friction factor is witnessed to reduce with rise of Reynolds numbers. Typical values of friction factors of CNT/water nano-fluid is 0.5% volume fraction for the forward helical louvered rod inserts with different ratios of twist is 1.78, 2.44 and 3 were establish to be 38.8%, 34.3% and 32.4% associated along with the friction factor in tube of plain type.
- The experiential associations for the friction factor, Nusselt number for forward helical louvered rod inserts are established and fixed with the experimental data.

5. References

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**Nomenclature**

| A | Cross sectional area (m²) |
| S | Surface area (m²) |
| D | Test section diameter (m) |
| L | Test section length (m) |
| V | Voltage (V) |
| I | Current (A) |
| m | Mass flow rate (kg/s) |
| Re | Reynolds number, 4m/πμD |
| Pr | Prandtl number, μc_p/κ |
| c_p | Specific heat (J/kg K) |
| f | Friction factor |
| h | Convective heat transfer coefficient (W/m²K) |
| k | Thermal conductivity (W/m K) |
| Nu | Nusselt number, hD/k |
| T | Temperature (°C) |
| v | Fluid velocity (m/s) |
| Q | Heat input (W) |
| q | Actual heat flux (W/m²) |
| P | pitch |
| Y | Twist ratio |
| FWD | Forward |

| Greek Symbols |
| Δp | Pressure drop (Pa) |
| μ | Dynamic viscosity (kg/m² s) |
| ρ | Density (kg/m³) |
| φ | Volume concentration (%) |

| Subscripts |
| in | inlet |
| nf | nanofluid |
| out | outlet |
| pt | plain tube |
| s | solid phase |
| t | theoretical |
| w | wall |
| lph | liter per hour |