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ENHANCEMENTS OF THERMAL PERFORMANCE FACTOR IN TURBULENT FLOW THROUGH A TUBE FITTED WITH HELICAL SCREW LOUVERED ROD INSERTS

P.Rathnakumar[1], Madan D[2] and Ravi Kulkarni H[3]
[1]Professor, Department of Mechanical Engineering, Navodaya Institute of Technology, Raichur, Karnataka, Pin code-584 103 India
[2]Professor, Department of Mechanical Engineering, Sri Indu College of Engineering & Technology, Hyderabad, Telangana Pin code- 501510 India
[3]Assistant Professor, Department of Mechanical Engineering, Navodaya Institute of Technology, Raichur, Karnataka, Pin code-584 103 India
Corresponding Author Email: rathnakumar1972@gmail.com

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ABSTRACT- The aim of this study is to investigate the enhancement of thermal performance factor and characteristics in tube fitted with helical screw louvered rod inserts using water and carbon nanotubes (CNT)/Water nanofluids with constant heat flux under turbulent flow condition. Nanofluids of 0.1%, 0.2% and 0.5% volume fraction were prepared by a two step method. In the experiments, the swirling flow was introduced by using helical screw louvered rod inserts arrangements (forward and backward) inside the inner test tube with different twist ratios, Y = 1.78, 2.44 and 3.0. The Reynolds number varied from 10,000 to 27,500. The experimental results revealed that the increase in heat transfer rate of the helical screw louvered rod inserts was found to be strongly influenced by tape-induced swirl or vortex motion. The heat transfer increased with an increase in the volume concentration. Thermal performance analysis based on the constant pumping power criteria showed that helical louvered rod tape inserts with forward arrangement led to better thermal performance than that with backward arrangement.

Keywords: Carbon nanotube Nanofluid, Helical louvered rod inserts, Thermal conductivity, Viscosity, Nusselt number, Friction factor

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A	Cross sectional area (m^2)	*k*	Thermal conductivity (W/m K)
S	Surface area (m^2)	*Nu*	Nusselt number, hD/k
D	Test section diameter (m)	*T*	Temperature (^oC)
L	Test section length (m)	*v*	Fluid velocity (m/s)
V	Voltage (V)	*Q*	Heat input (W)
I	Current (A)	*q*	Actual heat flux (W/m^2)
m	Mass flow rate (kg/s)	*P*	pitch
Re	Reynolds number, 4m/πμD	*Y*	Twist ratio
Pr	Prandtl number, μcp/k	*FWD*	forward
cp	Specific heat (J/kg K)	*BWD*	backward
f	Friction factor	**Greek Symbols**	
h	Convective heat transfer coefficient (W/m^2K)	*Δp*	Pressure drop (Pa)
		μ	Dynamic viscosity (kg/m^2 s)
		ρ	Density (kg./m^3)
		φ	Volume concentration (%)

I. INTRODUCTION

Carbon nanotubes are mixed with working fluid due to their extremely high thermal conductivity in the longitudinal (axial) direction. Base fluids mostly used in the preparation of nanofluids are the common working fluids of heat transfer applications; such as, water, ethylene glycol and engine oil. In order to improve the stability of nanoparticles inside the base fluid, some additives are added to the mixture in small amounts. Smith Eiamsa-ard et al.[1] measured the heat transfer and friction characteristics employing louvered strips inserted in a concentric tube heat exchanger. The louvered strip was inserted into the tube to generate turbulent flow which helped to increase the heat transfer rate of the tube. The flow rate of the tube was in the range of Reynolds number between 6000 and 42,000. The turbulent flow devices consisted of (1) the louvered strips with forward or backward arrangements, and (2) the louvered strip with various inclined angles (θ=15°, 25° and 30°), inserted in the inner tube of the heat exchanger. The increases in average Nusselt number and friction loss for the inclined forward louvered strip is more while compared to those for the backward louvered strip over the plain tube, respectively.

A.W.Fan et al.[2] investigated the characteristics of heat transfer, flow resistance, and overall thermo-hydraulic performance of turbulent airflow in a circular tube fitted with louvered strip inserts through numerical simulation. The value of performance evaluation criterion (PEC) lied in the range of 1.60–2.05, which demonstrated that the louvered strip insert had a very good overall thermo-hydraulic performance. Comparatively steady and good overall thermo-hydraulic performance can be obtained at a moderate slant angle together with a small pitch.

Aiwu Fan et al.[3] investigated the heat transfer rate, flow resistance, and overall thermo-hydraulic performance of turbulent flow in a circular tube fitted with the conical strip inserts. The value of performance evaluation criterion (PEC) lied in the range of 1.67 to 2.06, which demonstrated that the conical strip insert had a very good thermo-hydraulic performance. P.Sivashanmugam and Suresh et al.[4] conducted an experimental investigation on turbulent heat transfer and friction factor characteristics of water through a circular tube fitted with full-length helical screw inserts of different twist ratios, and increasing and decreasing order of twist ratio. S. Suresh et al.[5] investigated the convective heat transfer and friction factor characteristics of the plain and helically dimpled tube under turbulent flow with constant heat flux using CuO/water nanofluid as working fluid. The effect of the inclusion of nanoparticles on heat transfer enhancement, thermal conductivity, viscosity, and pressure loss in the turbulent flow region were investigated.

N. Kannadasan et al.[6]compared the heat transfer and pressure drop characteristics of CuO/water nanofluids in a helically coiled heat exchanger held in horizontal and vertical positions. The experimental results showed that there was not much difference between horizontal and vertical arrangements in the enhancement of convective heat transfer coefficient and friction factors of nanofluids compared to that of water. The objective of the present study is to investigate the turbulent forced convective flow in a tube having helical louvered rod inserts with different arrangements (forward and backward) by using CNT/water nanofluids and Reynolds number in the range of 10,000 to 27,500. The results of inserts such as Thermal performance factor (PEC) for turbulent flow using CNT/water nanofluids of 0.1%,0.2% and 0.5% volume fractions in a circular tube fitted with helical louvered rod inserts are reported.

II. EXPERIMENTAL DETAILS

The schematic diagram of the experimental set up is shown in Fig.1. The experimental set up consists of a pump, heat exchanger, test section, calming section and a fluid reservoir. A plastic container of seven liters capacity is used as the fluid reservoir. Test and calming sections are made of straight copper tube with the dimensions of 1000 mm long, 10 mm ID and 12 mm OD. Uniform heating is provided by ceramic beads coated electrical SWG Nichrome heating wire of resistance 120 Ω wound on the test section. A thick insulation is provided over the electrical winding using glass wool to minimize heat loss. The terminals of the Nichrome wire are attached to an auto-transformer, by which heat flux can be varied by varying noted using the digital display units.

A differential U-tube manometer is fitted across the test section to measure the pressure drop. The fluid after passing through the heated test section flows through a riser section and then through the cooling unit which is an air cooled heat exchanger and finally it is collected in the reservoir. A centrifugal pump is used to circulate the fluid through the circuit. The flow rate of the fluid varies using two rotameter of rating 50 – 1500 lph for turbulent flows respectively. The twist ratio 'Y' is defined 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 experimental work, three helical louvered rod inserts with twist ratios 1.78, 2.44 and 3 for both forward and backward arrangements are used as depicted in Fig.2

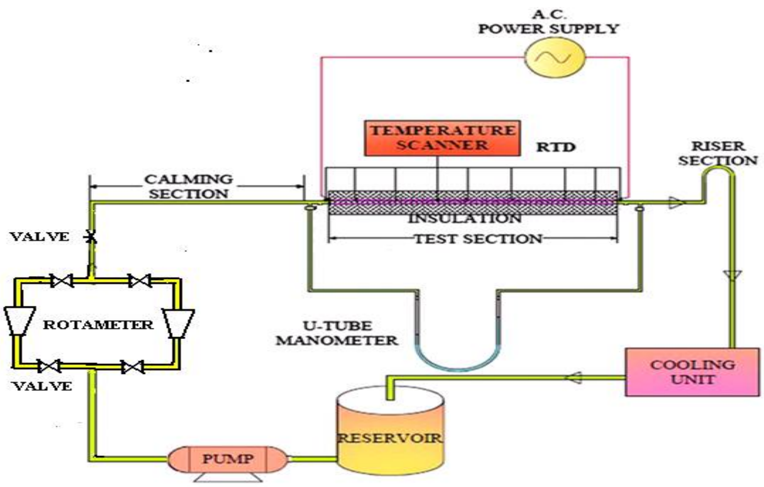
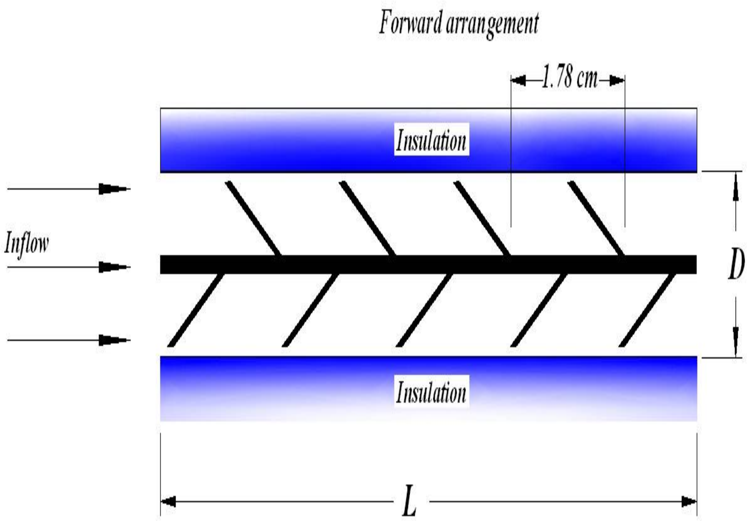


Fig.1. Schematic diagram of the experimental set up



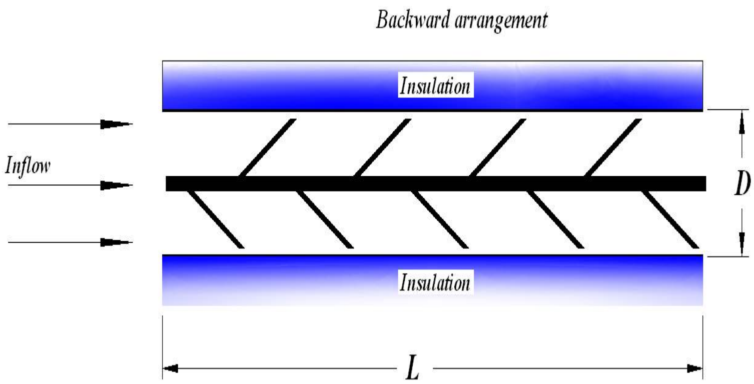


Fig.2. Helical louvered rod with forward and backward arrangements

III. DATA REDUCTION

The performance evaluation analysis for the same pumping power for turbulent flow is given by the following correlation

$$\eta = \frac{\dfrac{Nu}{Nu_{pt}}}{\left(\dfrac{f}{f_{pt}}\right)^{\frac{1}{3}}} \quad (1)$$

Where numerator is the ratio of the Nusselt number using insert for the plain tube and the denominator is the ratio of the friction factor using insert for the plain tube.

IV. RESULTS AND DISCUSSION

4.1 Effect of Thermal performance analysis in CNT/Water Nanofluids

The thermal performance factor for the forward helical louvered rod tape at various twist ratios 1.78, 2.44 and 3.0 using CNT/water nanofluid under turbulent flow calculated from the Equation (2) are presented in figure 3

$$\eta = 1.11\mathrm{Re}^{0.0055}\left(\frac{P}{D}\right)^{-0.066}(1+\phi)^{5.76} \quad (2)$$

The thermal performance factor of backward helical louvered rod is arrived from the Equation (3) for turbulent flow using CNT/water nanofluid.

$$\eta = 1.13\mathrm{Re}^{0.0066}\left(\frac{P}{D}\right)^{-0.102}(1+\phi)^{13.86} \quad (3)$$

The thermal performance of forward and backward arrangements helical louvered rod inserts in turbulent flow of water and CNT/water nanofluids is evaluated in terms of thermal performance factor for constant pumping power condition. Figs.3 and 4 present the comparison of thermal performance factor with respect to Reynolds number at different twist ratios for water and CNT/Water nanofluid of 0.1, 0.2 and 0.5% of volume fraction concentrations. It is evident that the thermal performance factor at Reynolds number increases as the twist ratio decreases. This is because of the stronger turbulence/swirl flow generated by the helical louvered rod insert in the case of insert with the smallest twist ratio. Also, the thermal performance factor is found to be decreasing with increase in Reynolds number. This is because of the increase in pressure loss as Reynolds number increases. The value of the thermal performance factor must be greater than unity for a net energy gain in the system. It is noted that the thermal performance factor using CNT nanofluid is higher than the corresponding value using water for all twist ratios involved in this study.

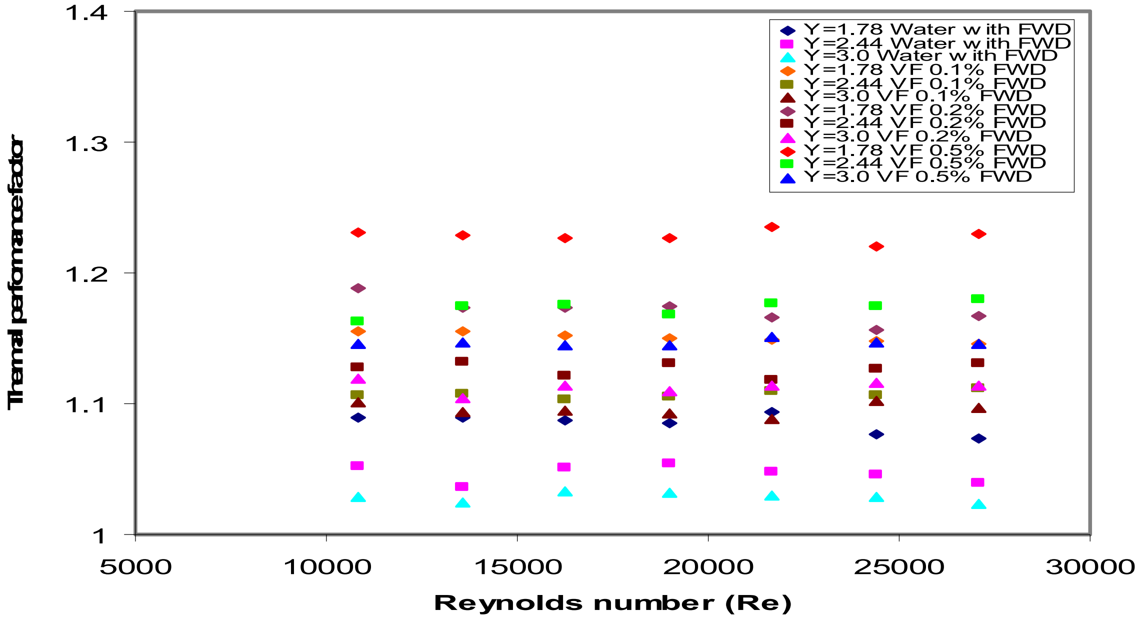


Fig. 3. Comparison of thermal performance factor with respect to Reynolds number at different twist ratios for water and 0.1%, 0.2% and 0.5% nanofluid for FWD

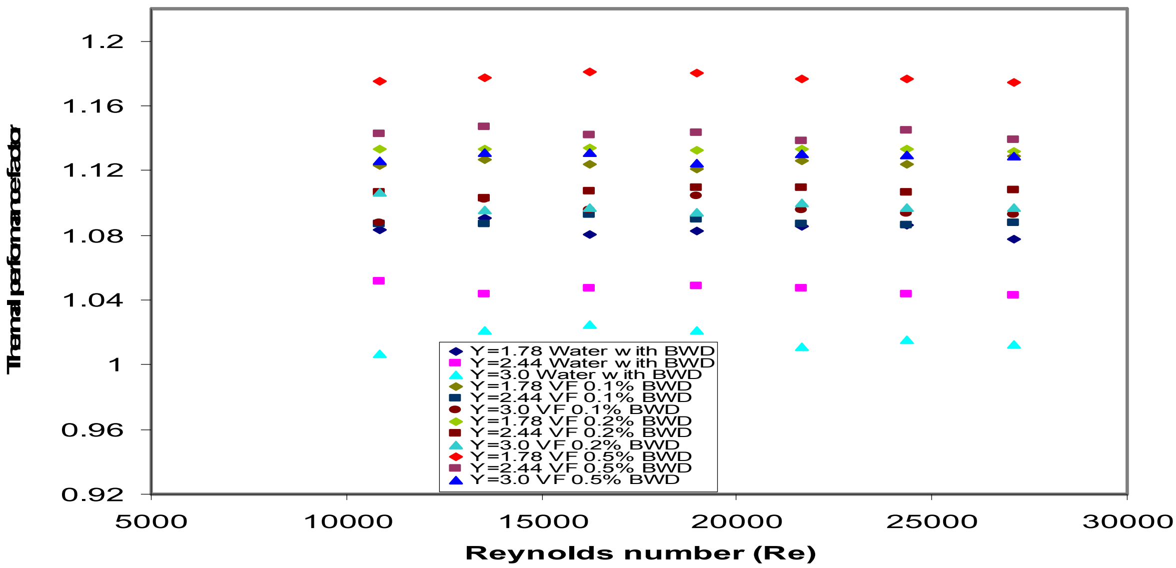


Fig. 4. Comparison of thermal performance factor with respect to Reynolds number at different twist ratios for water and 0.1%, 0.2% and 0.5% nanofluid for BWD

The maximum thermal performance factor value of 1.235 is found with the use of nanofluid of 0.5% of volume fraction of concentration with twist ratio of 1.78 in forward arrangements. When used with backward helical louvered rod insert with CNTs nanofluid of 0.5% volume concentration, the maximum thermal performance factor are 1.181 for Y = 1.78. The experimental results show that helical louvered rod insert tape gives better thermal performance when used with forward arrangements than with backward arrangements.

V.CONCLUSIONS

In the present experimental study, Thermal performance factor enhancements of helical screw louvered rod inserts in turbulent flow of water and CNT nanofluids were investigated. The helical louvered rod inserts with twist ratios Y = 1.78, 2.44 and 3 were used in the experimental study using water and 0.1%, 0.2% and 0.5% volume concentration of CNT/water nanofluid.

- The maximum thermal performance factor value of 1.235 is found with the use of nanofluid of 0.5% volume fraction of concentration with twist ratio of 1.78 in forward arrangements. When used with backward helical louvered rod insert with CNT nanofluid of 0.5% volume concentration, the maximum thermal performance factor is 1.181 for Y = 1.78. The experimental results show that helical louvered rod insert tape gives better thermal performance when used with forward arrangements than with backward arrangements.

REFERENCES

1. Smith Eiamsa-ard, Somsak Pethkool, Chinaruk Thianpong, Pongjet Promvonge, "Turbulent flow heat transfer and pressure loss in a double pipe heat exchanger with louvered strip inserts," International Communications in Heat and Mass Transfer,Vol.35, 2008,pp.120-129.
2. A.W. Fan, J.J. Deng, A. Nakayama, W.Liu, "Parametric study on turbulent heat Transfer and flow characteristics in a circular tube fitted with louvered strip inserts," International Journal of Heat and Mass Transfer, Vol.55, 2012, pp.5205-5213.
3. Aiwu Fan, Junjie Deng, Jian Guo, Wei Liu, "A numerical study on thermo-hydraulic characteristics of turbulent flow in a circular tube fitted with conical strip inserts," Applied Thermal Engineering,Vol. 31, 2011 pp.2819-2828.
4. P.Sivashanmugam and S.Suresh, "Experimental studies on heat transfer and friction factor characteristics of turbulent flow through a circular tube fitted with regularly spaced helical screw-tape inserts," Applied Thermal Engineering, Vol. 27, 2007, pp.1311- 1319.
5. S. Suresh, M. Chandrasekhar, S. Chandra Sekhar, "Experimental studies on heat transfer and friction factor characteristics of CuO/water nanofluid under turbulent flow in a helically dimpled tube," Experimental Thermal and Fluid Science, Vol. 35, 2011, pp.542-549.
6. N. Kannadasan, K. Ramanathan, S. Suresh, "Comparison of heat transfer and pressure drop in horizontal and vertical helically coiled heat exchanger with CuO/water based nanofluids," Experimental Thermal and Fluid Science, Vol. 42, 2012, pp. 64-70.

