CFD Analysis of Pin Finned Tube Heat Exchanger using ANSYS CFX

[1]Bhupendra Kumar, [2]Ashwini Bhoi, [3]Sudhir Singh Rajput
[1]Research Scholar, [2]Assistant Professor, [3]Head of Department
[1]Mechanical Engineering,
[1] Raipur Institute Of Technology, Raipur,(Chhatishgarh), India.

*Abstract:*The current research investigates pin finned tube heat exchanger was studied numerically having conventional circular fin and fins with extended members. The numerical analysis is conducted using ANSYS CFX software and CAD model is developed using Creo design software. The Nusselt number and friction factor are evaluated for both design configurations at different air inlet velocities of 5m/s, 7m/s, 9m/s and 11m/s**.** Standard K-epsilon turbulence model is used for CFD analysis which gives reasonably good predictions for fluid flow involving complex geometries. The Nusselt number and friction factor are determined for different Reynolds number for both design configurations. The CFD analysis has shown that fins with extended members show augmentation in heat transfer and Nusselt number with incorporation of extended members of pin finned heat exchanger.

Keywords: Pin finned tube, Fins, CFD.

I. INTRODUCTION

The fins are used in heat exchangers as extended surfaces which augment heat transfer characteristics by increasing surface area. Fins are of different geometries like plain, wavy. These geometries can be attached on inner side of flat tubes or circular tubes. Fins may also be used on the high heat transfer coefficient fluid side in a heat exchanger primarily for structural strength or to provide a thorough mixing of a highly-viscous liquid. Fins are attached to the primary surface by brazing, soldering, welding, adhesive bonding or mechanical expansion, or extruded or integrally connected to tubes.

II. LITERATURE REVIEW

Lawson etal. [1] investigated air foil with pin fins by experimental testing for Reynolds number ranging from 4000 to 28000. The findings have shown that pin spacing has significant effect on heat transfer and friction factor for given Reynolds number.

Hafiz et al. [2] conducted experimental testing on pin-fin tubes operated with ethylene glycol at low Reynolds number. The findings have shown that heat transfer augmented with pin height and decreased circumferential pin spacing

Sahrayet.al. [3] conducted experimental and numerical analysis on pin-fin heat sinks under free convection. The effect of fin density and fin height are investigated with respect to heat transfer augmentation and findings have shown that fin height has significant effect on heat transfer characteristics.

U. V. Awasarmolet. al.[4] conducted experimental investigation on solid and permeable fins for heat transfer enhancement by varying inclination angle of fins. The findings have shown that solid fin reached to higher temperature as compared to permeable fins thus heat transfer characteristics are higher in permeable fins.

Yang et.al. [5] conducted numerical analysis on porous pin fin channels with air and water as cold fluids. The effect of Reynolds number, density and pin fin geometry are analyzed. The findings have shown augmentation of heat transfer with usage of porous channels against solid pin fins.

III. PROPOSED WORK

The current research investigates the effect of geometric configuration of round pin fins surrounding tubes on heat dissipation. The CAD model of tube and round pin fins is developed using Creo 2.0 and CFD analysis is conducted using ANSYS CFX software.The CFD analysis is conducted on 2 different design configurations to determine velocity, pressure and temperature characteristics. The first design has tube with circular fins and second design has fins with extended members.

IV. METHODOLOGY

The dimensions of finned tube are taken from literature [6]. Solid pin finned tube and with inner diameter (Di=20 mm), outer diameter (Do= 32 mm), tube length (L=330 mm), fin height (b=10 mm), fin diameter (d=3 mm), longitudinal fin spacing (x=12 mm), angle between fins (y=45°). The CAD model is developed with the dimensions specified above.

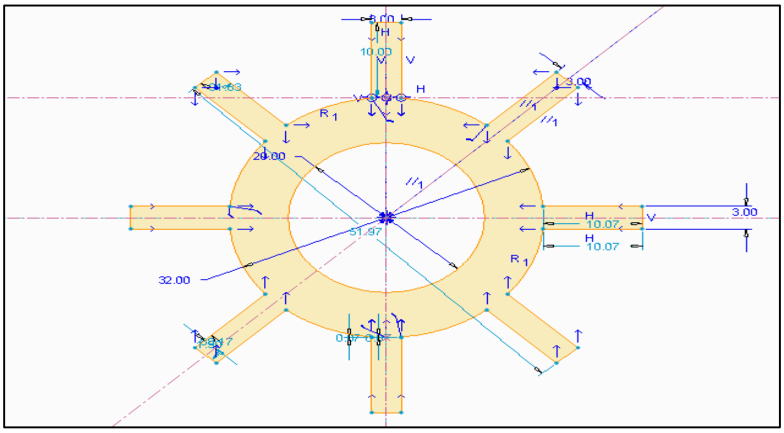

Figure 1: Sketch of finned tube

The sketch of finned tube is developed using Creo 2.0 software as shown in figure 1 above which is sketch based, parametric 3d modelling software. The sketch is extruded to develop finned tube as shown in figure 2 below.

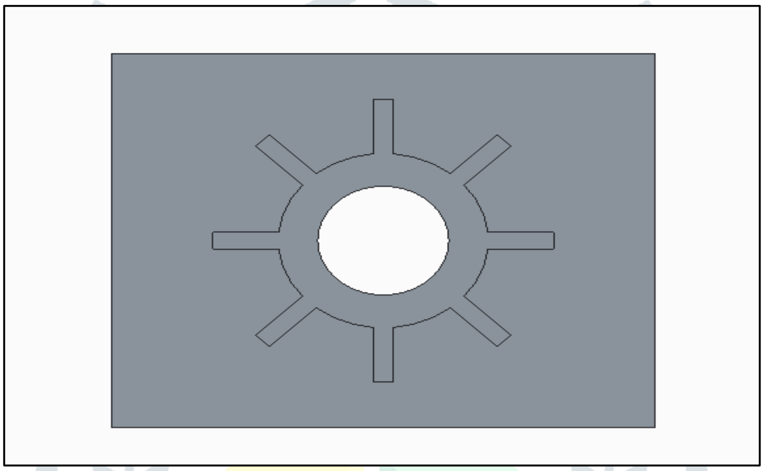

Figure 2: Assembled CAD model of finned tube

The CAD model of finned tube and enclosure is assembled using coincident constraint for surface and making coaxial as shown in figure 2 above. The CAD model developed in Creo 2.0 is imported in ANSYS design modeler. The CAD model is checked for geometric errors like hard edges, swivels etc as shown in figure 3 below.

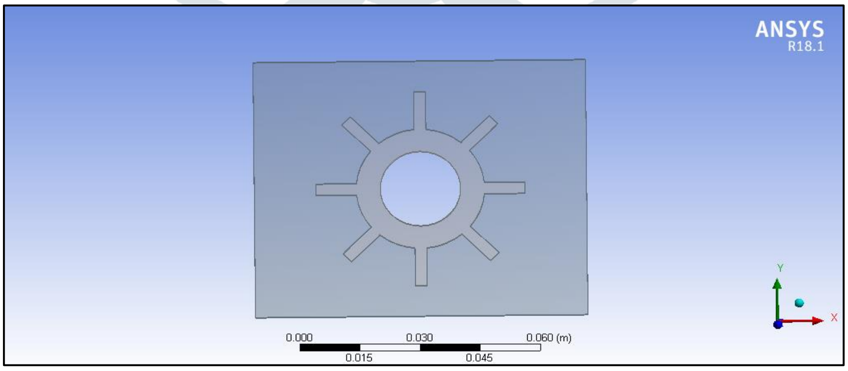

Figure 3: Imported CAD model of solar water heater in ANSYS design modeler

The imported CAD model is checked for geometric errors like hard edges, splines and curvature errors etc. The CAD model is meshed using tetrahedral elements and fine sizing with curvature effects on. The number of elements generated is 9842 and number of nodes generated is 15963.The element shape of hexahedral and partly tetrahedral element is shown in figure 4 below. It consists of 4 nodes connected to each other by tetrahedral shape.

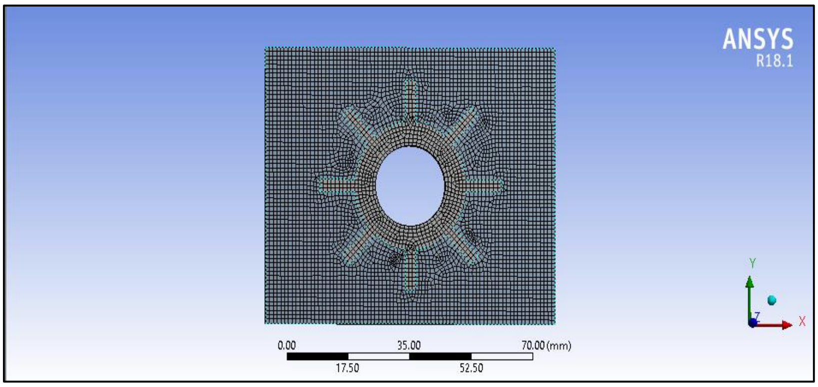

Fig 4: Meshing of solar water heater

The fluid domain is defined with air as material and reference pressure set to 1 atm. Standard k-epsilon turbulence model is set for analysis. The inlet and outlet boundary conditions are defined. The model is applied with air inlet velocities of 5m/s, 7m/s, 9m/s and 11m/s as shown in figure 5 below.

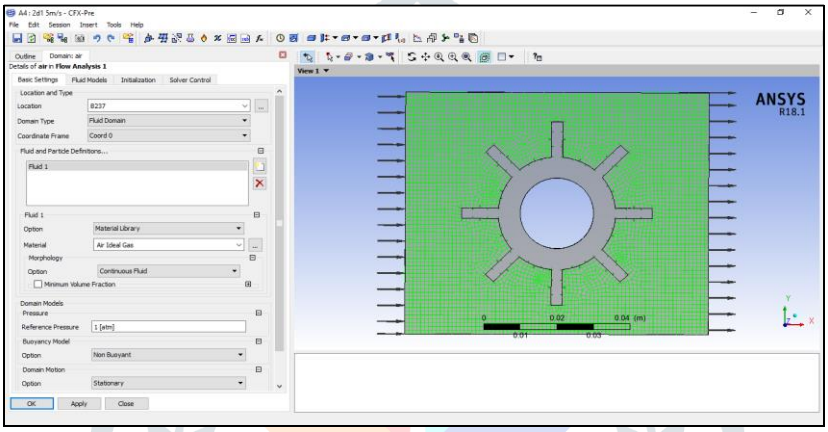

Fig 5: Domain definition for air as highlighted in green color

The solver setting is to RMS residual values of 1e-4 and more than 200 iterations are carried out. Software carries out matrix formulations, multiplications and inversions. Initially element stiffness matrix is formulated, the element stiffness matrix are assembled to form global stiffness matrix. When solver is set to run, the software calculates results at nodes and results are interpolated for entire element edge length.

V. RESULTS AND DISCUSSION

The CFD analysis is conducted on two different design configurations of pin fin tube. The temperature plot and pressure plot are generated to determine the effect of fins on heat transfer characteristics. The 1st design configuration is pin finned tube without extended members and with extended members.

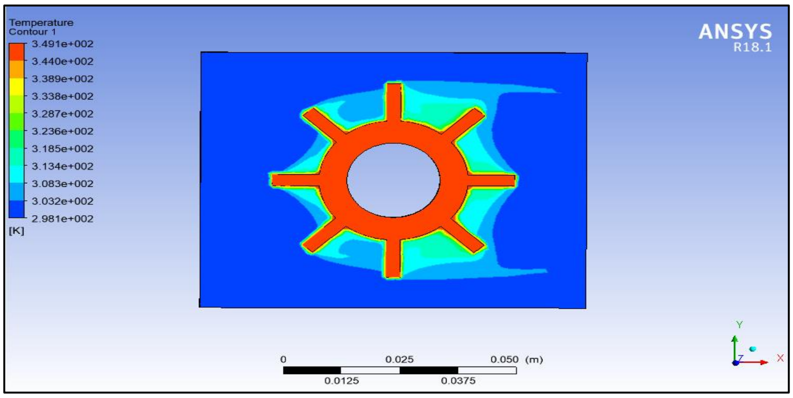

Figure 6: Temperature plot at 7m/s speed with fins without extended geometry

The plot above in figure 6 shows that temperature between fins is higher as shown by light green and dark green colors while region away from fins has lower temperature plot.

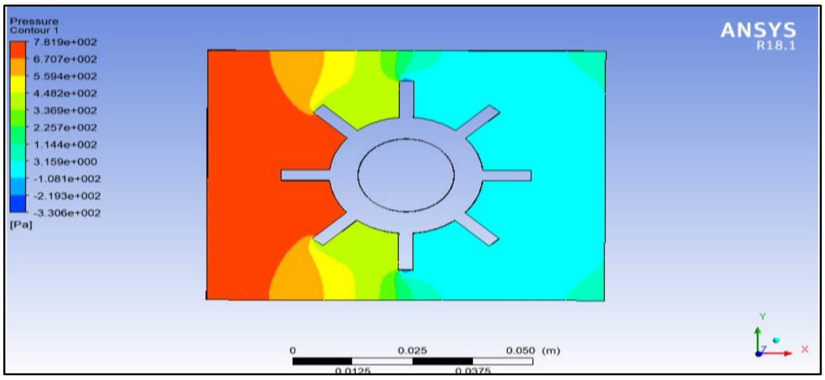

Figure 7: Pressure plot at 7m/s speed without extended geometry

The pressure buildup near tube is 781.9 Pa as shown by red color and dark orange color plot near tube. The pressure on top and bottom ends of tube are low as shown by dark blue color. The pressure near outlet is 3.49Pa.

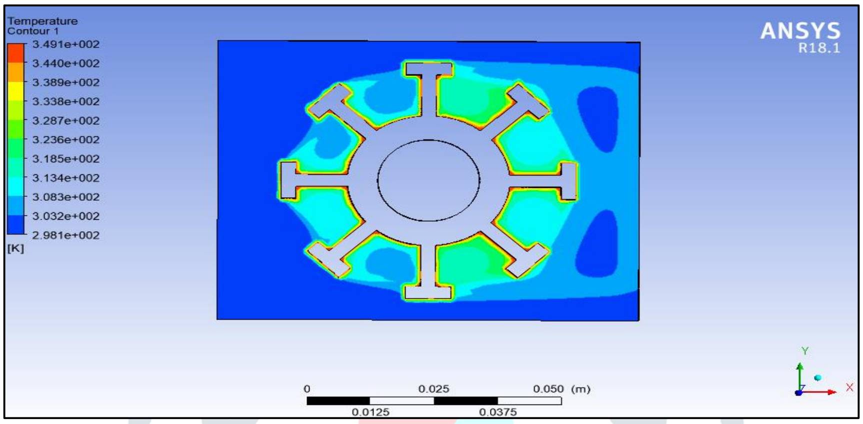

Figure 8: Temperature plot at 7m/s speed with extended geometry

The plot above in figure 8 shows that temperature between fins is higher as shown by light green and dark green colors while region away from fins has lower temperature plot. The extended geometry of rectangular shape has also helped to increase heat transfer rate.

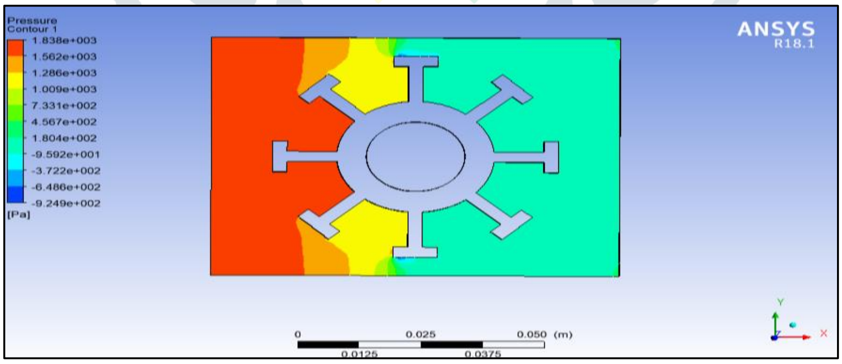

Figure 9: Pressure plot at 7m/s speed with extended geometry

The pressure buildup near tube is 1838 Pa as shown by red color and dark orange color plot near tube. The pressure on top and bottom ends of tube are low as shown by dark blue color. The pressure near outlet is 180.4Pa.The wall heat transfer coefficient and pressure drop are determined from CFD simulation at different Reynolds numbers.

Table 1: Results of finned tube without extended geometry

Reynolds Number	Heat Transfer Coefficient(h) (W/m^2K)	Nusselt Number (Nu)	Pressure Difference	Friction factor
1255.54	32.06	4.76	373.99	0.297
1757.7	41.39	6.12	725.89	0.294
2259.9	50.51	7.47	1196.34	0.293
2762.1	59.52	8.8	1792.66	0.281

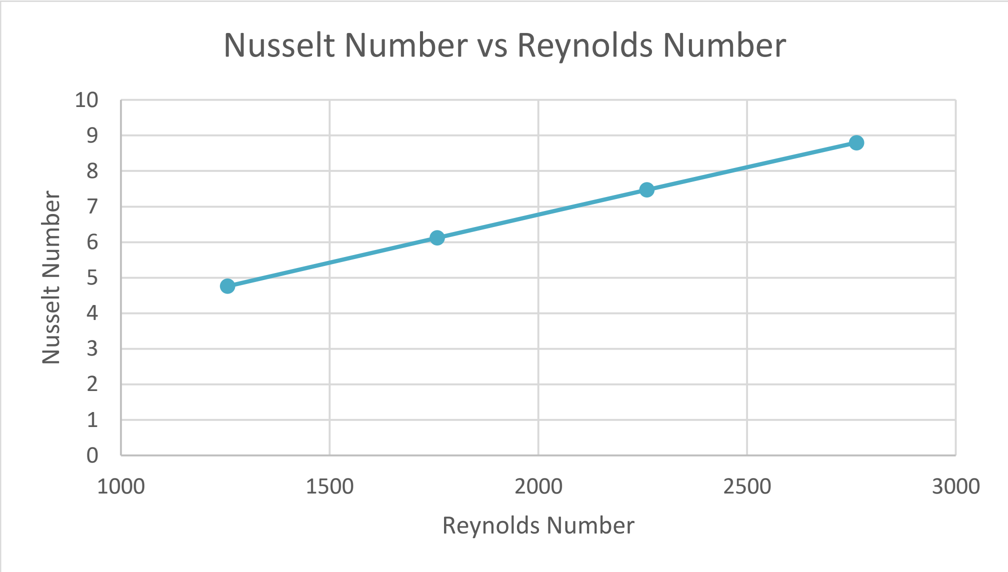

Figure 10: Nusselt Number vs Reynolds number for finned tube without extended geometry

The graph between Nusselt number and Reynolds number clearly shows an increase of heat transfer rate with increase in air speed as shown in figure 10 above. The highest value of Nusselt number is observed for Nusselt number 2762.

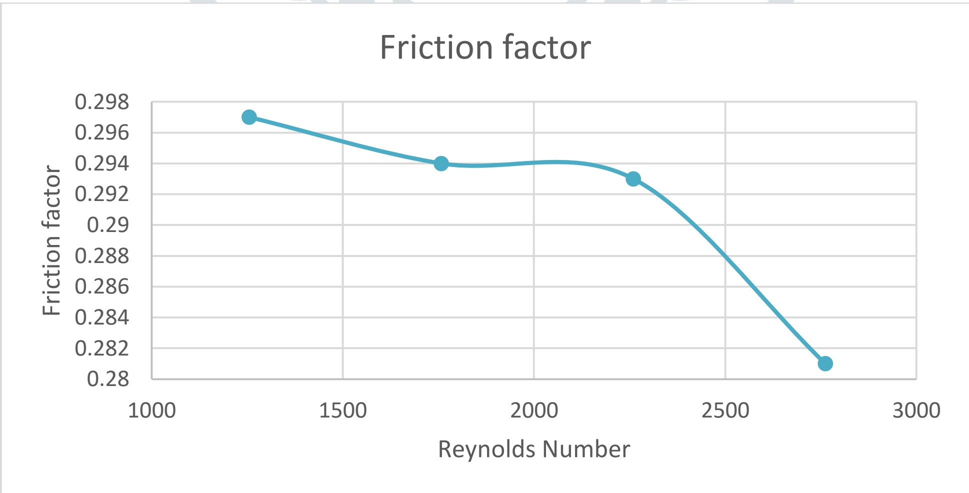

Figure 11: Friction factor vs Reynolds number for finned tube without extended geometry

The graph between friction factor and Reynolds number is shown in figure 11 above. The friction factor decreases with increase in Reynolds number. The minimum friction factor is observed for Reynolds number 2762.

Nusselt number

Nu=hD/k

Nu = 37.67*.00388/.0261 = 32.06

Where h is heat transfer coefficient

D is hydraulic diameter

K is thermal conductivity

Friction factor for rectangular duct is given by

$$F= 2\Delta P D_h / 4\rho L_f V^2$$

Where,

ΔP is pressure drop

D_h is hydraulic diameter = .00388m

L_f is length of duct = .082m

V is velocity of fluid flowing

P is density of fluid = 1.185Kg/m^3

Table 2: Results of finned tube with extended geometry

Reynolds Number	Heat Transfer Coefficient(h) (W/m^{2}K)	Nusselt Number (Nu)	Pressure Difference	Friction factor
1255.54	37.67	5.59	888.35	0.707
1757.7	48.34	7.18	1752.13	0.711
2259.9	58.63	8.71	2948.32	0.724
2762.1	68.89	10.19	4532.69	0.745

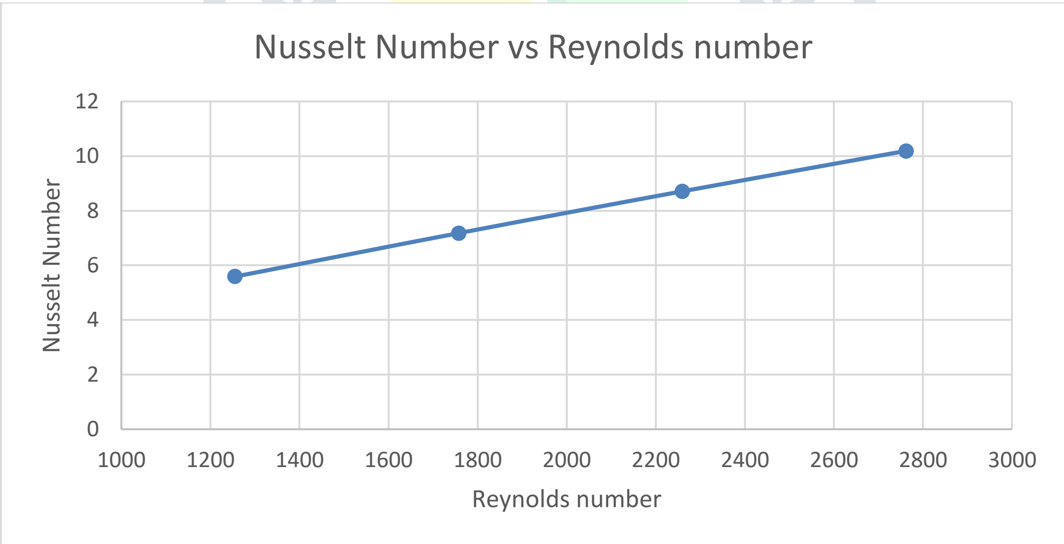

Figure 12: Nusselt Number vs Reynolds number for finned tube with extended geometry

The graph between Nusselt number and Reynolds number clearly shows an increase of heat transfer rate with increase in air speed as shown in figure 12 above. The highest value of Nusselt number is observed for Nusselt number 2762.

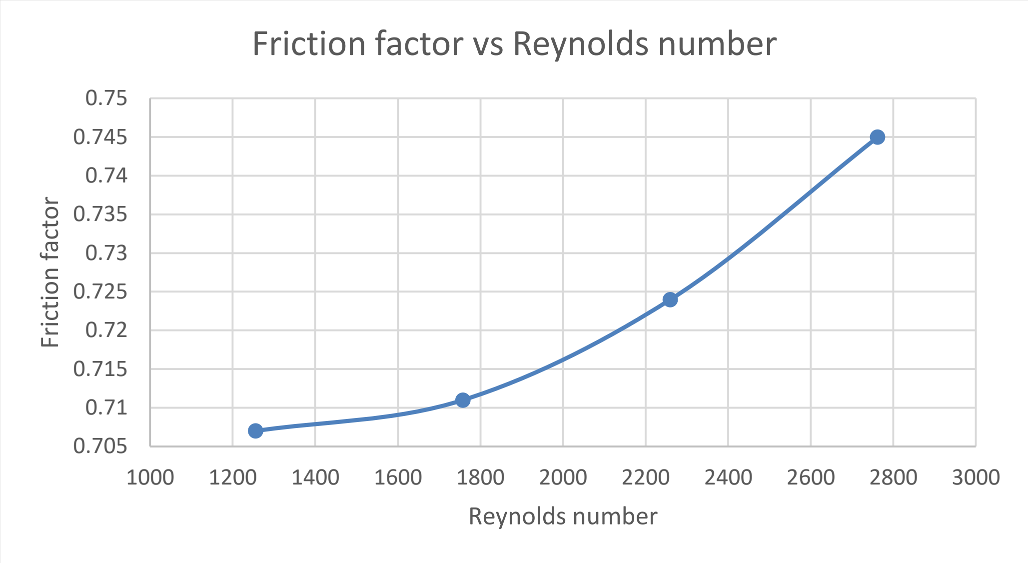

Figure 13: Friction factor vs Reynolds number for finned tube with extended geometry

The graph between friction factor and Reynolds number is shown in figure 13 above. The friction factor increases with increase in Reynolds number. The curve shows linear variation after Reynolds number 1700. As the flow changes to turbulent the friction factor shows drastic increase for extended geometry shape.

VI. CONCLUSION

The heat transfer rate and friction factor of finned tube are analyzed using ANSYS CFX software. Standard k-epsilon turbulence model is used for analysis. The heat transfer rate and friction factor are largely determined by geometrical shape and fluid flow velocity magnitude. The detailed conclusion are as follows:

1. The heat transfer rate and Nusselt increases with increase in Reynolds number for both designs.
2. The friction factor decreases with increase in Reynolds number for finned tube without extended members.
3. The friction factor increases with increase in Reynolds number for finned tube with extended members.
4. Standard K-epsilon turbulence model gives reasonably good predictions for fluid flow involving complex geometries.
5. The heat transfer rate for finned tube with extended geometries has higher heat transfer rate as compared to finned tube without extended members.
6. The higher friction factor for finned tube with extended geometry can be attributed to increased pressure drop and higher magnitude of turbulence kinetic energy associated with swirl flow.
7. The Nusselt number values obtained for finned tube with extended geometry has shown higher magnitude for each Reynolds number as compared to finned tube without extended geometry.

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