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THEORETICAL PERFORMANCE ANALYSIS OF HEAT TRANSFER AUGMENTATION INSIDE FINNED CIRCULAR TUBES WITH TWISTED TAPE INSERTS USING POLYNOMIAL EQUATION

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ABSTRACT

In engineering equipments for heat transfer enhancement twisted tape is a widely used technique. In this paper, the work employs to generate higher-order logic of an efficient representation of cubic polynomial equation and compared with standard twisted tape correlations developed by Manglik & Bergles [1, 2] and also compared with Ansys CFD based four turbulent simulation models such as standard k-ε (transport equations for the turbulence kinetic energy (k) and its dissipation rate (ε)), RNG k-ε (renormalization group), Standard k-ω (transport equations for the turbulence kinetic energy (k) and the specific dissipation rate (ω)) & SST k-ω (shear-stress transport (SST) k-ω) developed by Talakala Dhani Babu [3]. In this work by taking Reynolds number within the range from 2500 to 12500, Finned tube with three different reduced width twisted tapes (RWTT) (width 12, 14 and 16 mm), of twist ratios (y = 2, 3, 4 and 5) were inspected, based on constant flow rate. The simulation results revealed that the predicted thermal performance factor (η) obtained from the Polynomial Equation is in better agreement compared to those from other models. Validation of the studies is performed by comparing with the outcome graphs of Manglik & Bergles (1993) [1,2] and Talakala Dhani Babu (2013) [3] by cubic polynomial equation, graphs generated through MS Excel.

Key words: Polynomial Equation, CFD, Heat transfer enhancement, Twisted tape, Reduced width twisted tape, Thermal performance etc.

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Abbreviations: [7]

Standard k-ε: The standard k-ε model is a semi empirical model based on model transport equations for the turbulence kinetic energy (k) and its dissipation rate (ε).

RNG k-ε: The RNG based k-ε turbulence model is derived from the instantaneous Navier-Stokes equations, using a mathematical technique called "renormalization group" (RNG) methods.

Standard k-ω: The standard k-ω model is an empirical model based on model transport equations for the turbulence kinetic energy (k) and the specific dissipation rate (ω), which can also be thought of as the ratio of ε to k.

SST k-ω: The shear-stress transport (SST) k-ω model is used as effectively blend the robust and accurate formulation of the k-ω model in the near-wall region with the free-stream independence of the k-ε model in the far field.

INTRODUCTION OF HEAT EXCHANGER

A heat exchanger is a device that is used to transfer thermal energy (enthalpy) between two or more fluids, between a solid surface and a fluid, or between solid particulates and a fluid, at different temperatures and in thermal contact. In heat exchangers, there are usually no external heat and work interactions. The subject of heat transfer enhancement has significant interest to develop the compact heat exchangers in order to obtain a high efficiency, low cost, light weight and size as small as possible [5]. The study of improved heat transfer performance is referred to as heat transfer enhancement or augmentation [6].

In this work, twisted tapes are used for heat transfer enhancement. A twisted tape induces the swirl flow of tube side fluid, resulting in higher near wall velocities and mixing of fluids thereby enhancing the heat transfer coefficient. A reasonable flow velocity is required in order to induce effective swirl flow, for that reason twisted tapes are most effective in turbulent flows with limited pressure drop.

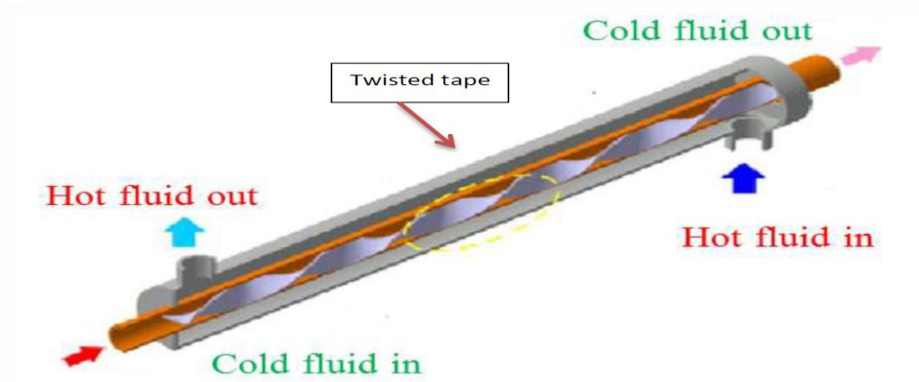

Fig. 1 View of the twisted tape inside a plain tube [3]

Flow friction and heat transfer behavior in a twisted tape swirl generator inserted tube are investigated experimentally [4]. The twisted tapes are inserted separately from the tube wall. The effects of twist ratios, y (H/D = 2, 3, 4, 5) are discussed in the range of Reynolds number from 2500 to 12500 is tested and Higher order Cubic Polynomial Equation is generated and compared with Ansys based simulated model of Talakala Dhani Babu [3].

METHODOLOGY & PROCEDURE

In this work, Higher order Cubic Polynomial Equations & graphs are generated, and those graphs are compared with Ansys based Simulated CFD graphs by Talakala Dhani Babu [3] in relation of Thermal performance factor & Reynolds Number with case study of internal finned tube with twist ratios 2, 3, 4, 5 & widths 12, 14, 16 mm {reduced width twisted tape (RWTT)} Inserts at turbulent region. The following specifications have been taken.

Table 1. Specification for Pipe & Fluid

S.NO	SPECIFICATION TAKEN BY TALAKALA DHANI BABU [3]	SPECIFICATION TAKEN IN THE PRESENT WORK
01	Diameter (D) = 22 mm	Diameter (D) = 22 mm
02	Length (L) = 2200 mm	Length (L) = 2200 mm
03	Density (ρ) = 998.2 kg/m^3	Density (ρ) = 998.2 kg/m^3
04	Specific heat capacity (C_p) = 4182 J/kg K	Specific heat capacity (C_p)= 4182 J/kg K
05	Thermal conductivity = 0.6 W/m K	Thermal conductivity = 0.6 W/m K
06	Viscosity (μ) = 1.003 X 10^{-3} kg/ m s	Viscosity (μ) = 1.003 X 10^{-3} kg/ m s
07	Temperature of Inlet water=25^{0}C(298 K)	Temperature of Inlet water=25^{0}C(298 K)
08	Tube Wall Material =Copper	Tube Wall Material =Copper

Table 2. Specification for Internal Finned Tube with Reduced Width Twisted Tape Inserts

S.NO	SPECIFICATION TAKEN BY TALAKALA DHANI BABU [3]	SPECIFICATION TAKEN IN THE PRESENT WORK
	CASE (INTERNAL FINNED TUBE WITH REDUCED WIDTH (RWTT) TWISTED TAPE INSERTS)	CASE (INTERNAL FINNED TUBE WITH REDUCED WIDTH (RWTT) TWISTED TAPE INSERTS)
09	Reynolds numbers 4000, 6000, 8000 and 10,000 (for turbulent flow)	Reynolds numbers 2500 to 12500 with interval 500 (for turbulent flow)
10	Four different twist ratios, y=2, 3, 4 and 5	Four different twist ratios, y=2, 3, 4 and 5
11	Pitch, H mm 24 to 80 mm	Pitch, H mm 24 to 80 mm
12	Width w mm 12, 14 & 16 mm	Width w mm 12, 14 & 16 mm
13	Thickness (δ) of 1 mm	Thickness (δ) of 1 mm
14	Four longitudinal fins are placed inside the plain tube with equal spacing.	Four longitudinal fins are placed inside the plain tube with equal spacing.
15	Fin thickness is 1 mm and 2 mm height	Fin thickness is 1 mm and 2 mm height
16	Length of the fin same as the circular tube.	Length of the fin same as the circular tube.
17	CFD Software used	Used Polynomial equation developed by M. S. Excel.

There are many types of mathematical equations. Following are mainly used equations.

- EXPONENTIAL EQUATION
- LOGARITHMIC EQUATION
- POLYNOMIAL EQUATION
- POWER EQUATION
- MOVING AVERAGE EQUATION

Out of these equations higher order cubic polynomial equation is applied for present work.

METHODS USED FOR ANALYSIS

- NEWTON'S DIVIDED DIFFERENCE INTERPOLATION METHOD
- TO FIT CUBIC POLYNOMIAL BY LEAST SQUARE METHOD
- COMPUTERIZED METHOD

CUBIC POLYNOMIAL TRENDLINE EQUATION BY MICROSOFT EXCEL

Equation: y = (c3 * x^3) + (c2 * x^2) + (c1 * x^1) + b

c3: =INDEX(LINEST(y,x^{1,2,3}),1)

c2: =INDEX(LINEST(y,x^{1,2,3}),1,2)

c1: =INDEX(LINEST(y,x^{1,2,3}),1,3)

b: =INDEX(LINEST(y,x^{1,2,3}),1,4)

ASSESSMENT OF OUTCOMES

By Using Newton's Divided Interpolation Method

$$Y = 3.5869\text{ E-09 } X3 - 1.795\text{ E-05 } X2 + 0.0309962\ X - 8.698$$

By Using To Fit Cubic Polynomial By Least Square Method

$$y=3.58688148049491\text{E-09 } x3-1.76285901729181\text{ E-05 } x2+0.0280743232411479\ x-6.56081608760692$$

By Using Computerized Method

$$y = 3.586922\text{ E-09 } x3 - 1.7628741377\text{ E-05 } x2 + 0.030354374326029\ x - 8.390764498374300$$

Values of constants of polynomial equations in all the processes are approximately same; therefore, Computerized Method (Microsoft Excel) has been used.

COMPARISON OF THERMAL PERFORMANCE FACTOR (η):

The Thermal Performance factor for different case are compared and shown in Fig.4 at turbulent region. In turbulent region the thermal performance factor increase with Reynolds number increases corresponding tape widths of w = 12 mm, 14 mm, 16 mm.

ANSYS BASED SIMULATED GRAPH GENERATED BY TALAKALA DHANI BABU [3]

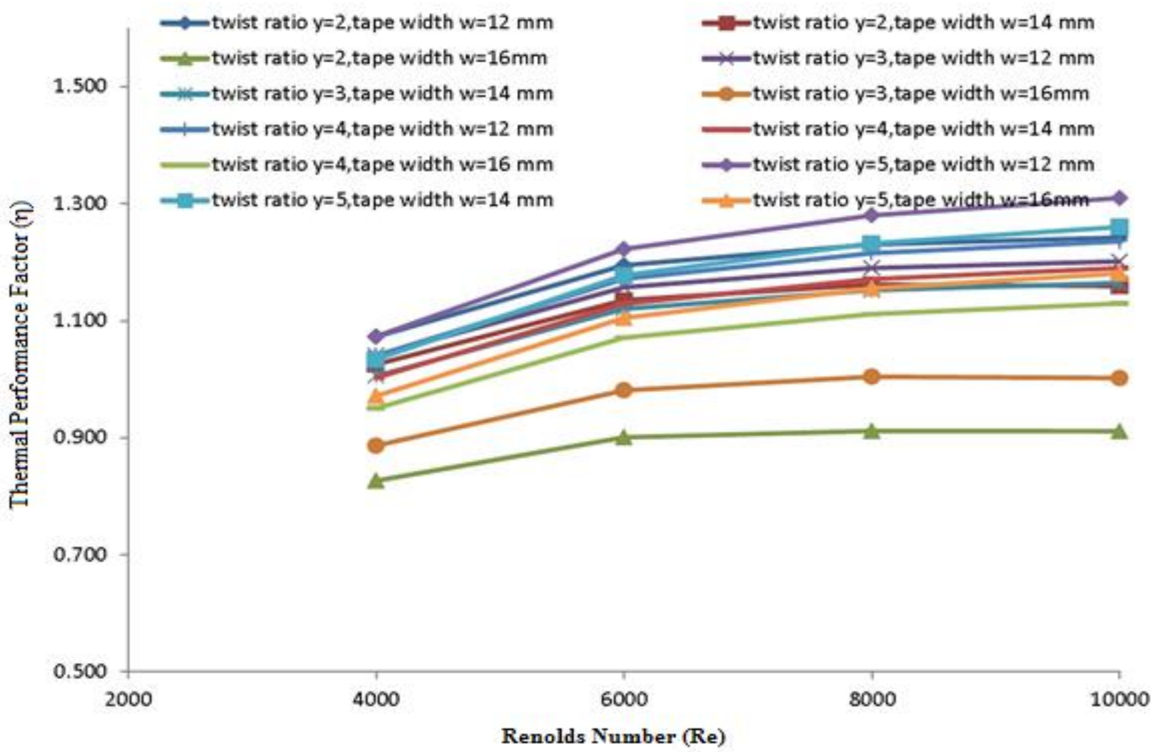

Fig. 4 Graph generated in Relation of η (Thermal Performance Factor) & Re (Reynolds Number) based on Ansys CFD Simulation models by Talakala Dhani Babu [3] to represent thermal performance factor for finned tube with twisted tape RWTT inserts, width, w = 12, 14, 16, twist ratio, y (H/w = 2, 3, 4, 5) at the Turbulent Region.

Ansys based simulated graph is considered in this study and compared & validated with higher order cubic polynomial Equation within these steps.

1. First of all values of x & y has been measured & tabulated from Talakala Dhani Babu Graphs, four values of x & y has been obtained.
2. Then rescale, the obtained measured values of x & y, in terms of Reynolds number (Re) & Thermal performance factor (η).
3. On the basis of these four values of Re & η, polynomial equation has been generated.
4. By using generated polynomial equation, with in turbulent region of 2500 to 12500, the value of η is obtained through difference of 500 Reynolds number.

5. For validation, the obtained values have been compared with available data in literature (Talakala Dhani Babu).

GRAPH GENERATED THROUGH DATA OBTAINED BY POLYNOMIAL EQUATION

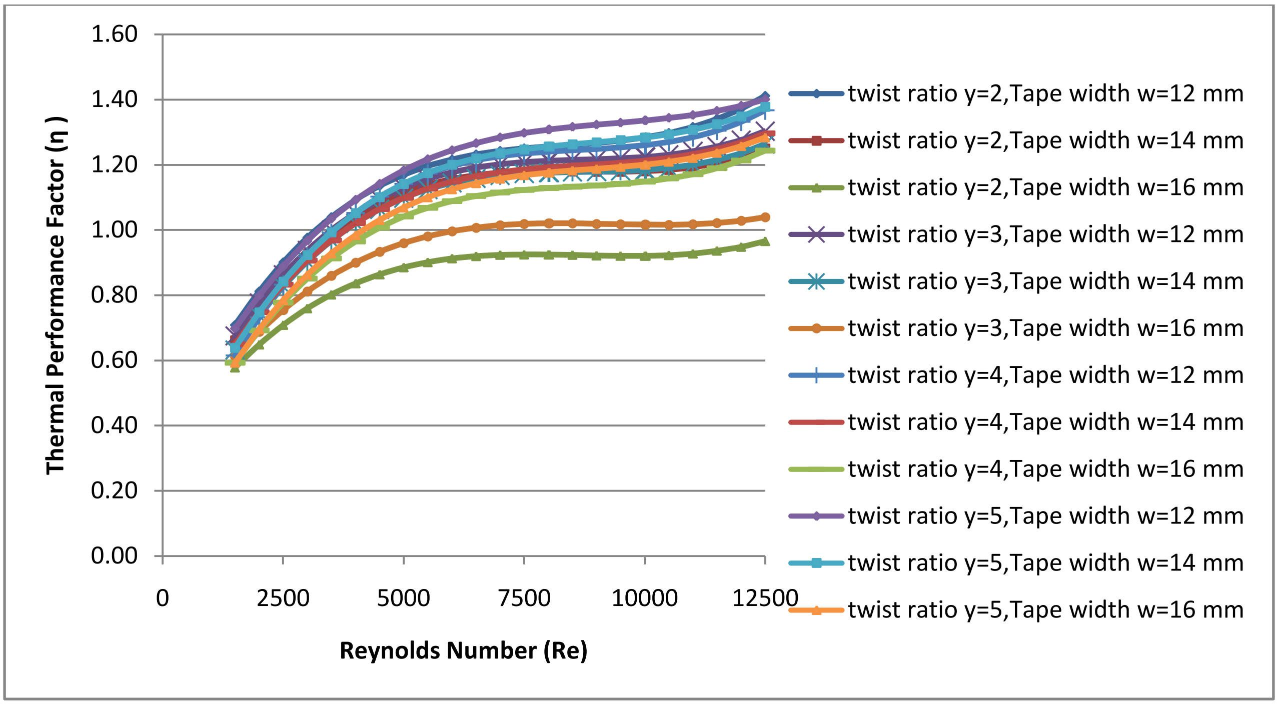

Fig. 5 Comparison of η (Thermal Performance Factor) & Re (Reynolds Number) for w = 12, 14, 16 based on Higher order Cubic Polynomial Equation for internal finned tube with RWTT inserts, twist ratio (y = 2, 3, 4, 5) at the Turbulent Region.

DISCUSSION & CONCLUSION

Polynomial equations for twisted tape can be used safely & results obtained are matched properly with the Talakala Dhani Babu [3] results. It is also concluded that variation of Reynolds number ranging from 2500 to 12500 for turbulent flow has been found justified. From this work it has been concluded that the polynomial equation is better and easy approach for any graph, related analysis of fluid properties as Reynolds Number, Nusselt Number, Friction Factor, Thermal Performance factor etc.

The Polynomial graph results of predicted thermal performance factor (η) are compared with those obtained from Talakala Dhani Babu. It is clearly seen that the predicted thermal performance factor (η) obtained from the Polynomial Equation is in better agreement compared to those from other models. The Polynomial Equation is valid within ± 0.035% error limit with measurements for predicted thermal performance factor (η). Therefore this higher order cubic polynomial equation can be used for further studies analysis of heat transfer enhancement.

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