Design & Analysis of Twisted Tape Twist Ratio Performance of Heat Exchanger

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***Abstract*— Nowadays, heat exchanger becomes the prominent application for sensible cooling and sensible heating applications. Heat exchanger size is the critical criteria due to availability various heat transfer augmentation techniques. Twist tape inserts is the one of the heat transfer augmentation techniques. In this work deals with the design of twisted tube heat exchanger using design calculations. Then Computational fluid dynamics analysis will be carried out on plain double pipe heat exchanger and its thermal performance parameters like surface heat transfer coefficient, surface Nusselt number, pressure drop and thermal resistance will be estimated for various Reynolds number . The same analysis will be carried over same heat exchanger with twist tape insert with various twist ratios. Twist ratio is the ratio of length of one twist to diameter of inner tube. Finally, the he thermal performance parameters like surface heat transfer coefficient, surface Nusselt number, pressure drop and thermal resistance will be compared and validated with available correlations in the literature for various Reynolds number. To carry out this analysis same type fluid will be used in the both the tubes and heat exchanger material will be considered as Aluminum. All this CFD analysis will be carried out with Ansys CFX 14.0 and it will be carried out by using k - ε turbulence model and Governing equations are solved by adopting a control volume-based finite-Volume method with a high resolution scheme on an orthogonal non-uniform staggered grid and the pressure based terms of momentum equations are solved by the computational fluid dynamics.**

Index Terms— *Ansys; CFD; heat exchanger; mass flow rate.*

I. INTRODUCTION

Heat transfer augmentation techniques are widely used in areas like heat recovery process, air conditioning and refrigeration systems as well as chemical reactors. The heat transfer as well as pressure drop characteristics of turbulent flow in a tube fitted with trapezoidal cut twisted tape insert have been discussed by Murugesan[8]. Passive and active methods of heat transfer augmentation techniques have been discussed in detail by Dewan and he reviewed that passive techniques particularly twisted tape and wire coil insert are the economical heat transfer augmentation tools. Eiasmaard[6] experimentally investigated the heat transfer and friction factor characteristics in the double pipe heat exchanger fitted with full length tape, spaced twisted tape, forward as well as backward arrangement of louvered strips, helical screw tape with and without core rod and developed the correlations for practical applications. The ultimate goal of this work is to study the heat transfer characteristics of double pipe heat exchanger by varying the mass flow rates 3 LPM, 5 LPM, 7 LPM, 9 LPM.

II. ANALYTICAL DETAILS

Inner fluid diameter D_1 = 0.0285 m
Inner solid diameter D_2 = 0.0325 m
Inlet temperature of cold fluid = 30°c
Inlet temperature of hot fluid = 60°c
Thickness of the tube = 0.002m
Mass flow rate of cold water = 10 LPM (constant)
$= 0.17 \frac{kg}{sec}$
Material of construction = copper

III. HEAT EXCHANGER DESIGN PROCEDURE

The heat exchanger design requires the consideration of the factors just outlined. Designers will arrive at exactly the same design for a given set of conditions, as the design process involves many judgments while carrying out the design. Gollin describes the step-by-step design procedure for a heat exchanger. The heat exchanger design procedure includes the following steps:

- Assess the heat transfer mechanisms involved
- Selection of heat exchanger class
- Determination of the construction details and select the surface geometry
- Determination of layout parameters and size, keeping in mind, the constraints imposed by the purchaser/client
- Perform preliminary thermal design(approximate sizing)
- Perform the detailed design
- Check the design
- Optimize the design
- Perform the check for flow-induced vibration in the case of tube and shell heat exchanger, individually finned tube, and bare tube bank compact heat exchangers.
- Perform mechanical design
- Estimation of cost and finalization of design as per trade considerations

IV. DESIGN CALCULATION

Heat transfer of cold fluid $Q = m_c \times c_c \left(T_{c_0} - T_{c_i} \right)$

Heat transfer of hot fluid $Q = m_h \times c_h \left(T_{h_i} - T_{h_o} \right)$

Design overall heat transfer coefficient,

$$\frac{1}{U_c} = \frac{1}{h_c} + \frac{A_c}{A_h} \times \frac{1}{h_h} + \frac{A_c}{k_s} \times \frac{t}{A_s}$$

Heat capacity of hot and cold water,

$$q_{max} = £ \times c_{min} \times (T_{h_i} - T_{c_i})$$

Effectiveness of heat exchanger,

$$£ = \frac{1 - exp[-NTU\,(1+c_r)]}{1+c_r}$$

Number of transfer units,

$$NTU = \frac{A_c U_c}{c_{min}}$$

Log mean temperature difference,

$$\Delta T_{LM} = \frac{(\Delta T_2 - \Delta T_1)}{ln\,(\frac{\Delta T_2}{\Delta T_1})}$$

Heat transfer coefficient for inner wall,

$$h_h = \frac{N_u\, k}{D_h}$$

Nusselt number $N_u = 0.023 \times R_e^{0.8} \times P_r^{0.3}$

V. COMPUTATIONAL FLUID DYNAMICS

Computational fluid dynamics is a branch of fluid dynamics a cost –effective means of simulating flow by the numerical solution of the governing equations. Experimental methods will play key role in validating and exploring the limits of the various approximation for the governing equations, particularly for the wind tunnel and rig tests that will provide cost effective alternative for full scale testing. And the flow governing equations are extremely complicated such a way those analytic solutions cannot be applicable for most practical applications. Computational fluid dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical analysis as well as algorithms to solve and analyze problems that involve fluid flows. Computers are used mainly to perform calculations required to simulate the interactions of liquids and gases with surfaces defined by boundary conditions.

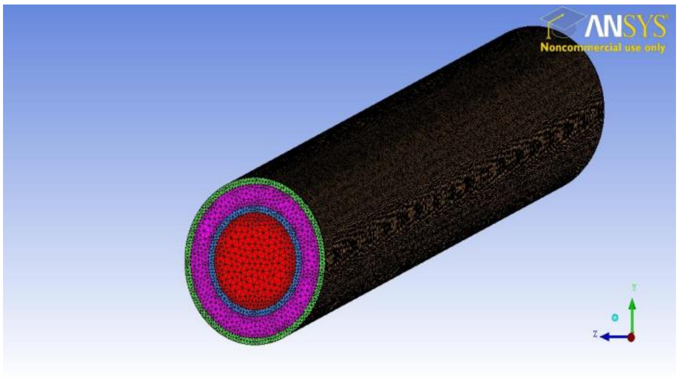

Fig. 1. Isometric view of double pipe heat exchanger

a) Analysis of double pipe heat exchanger:

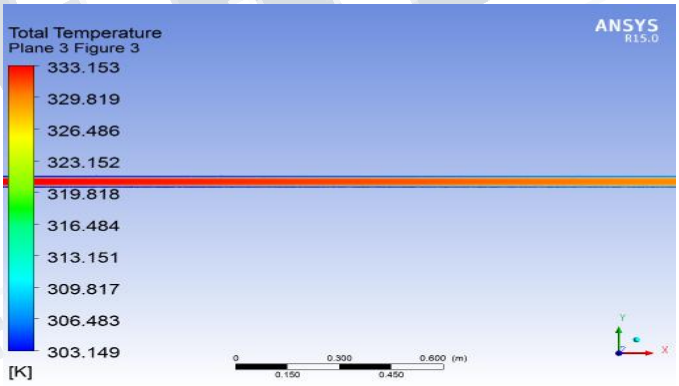

Fig. 2. For 9LPM mass flow rate

b) Analysis of double pipe heat exchanger with twisted tape:

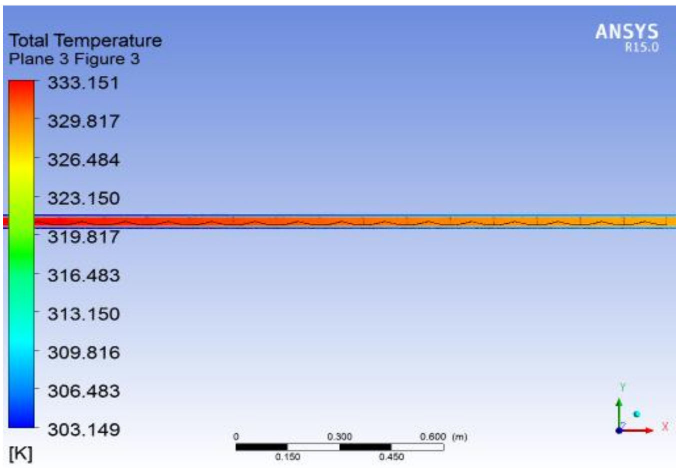

Fig. 3. For 9 LPM mass flow rate and 4.4 twist ratio

c) Analysis result of twisted tape heat exchanger with 4.4 twist ratio:

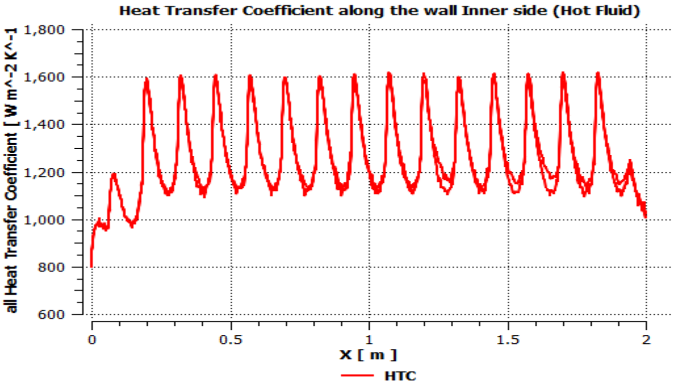

Fig. 4. For 9 LPM mass flow rate and 4.4 twist ratio

VI. RESULTS AND DISCUSSION

In this work I have done design calculation for double pipe heat exchanger. From this I can find Reynolds number, prandl number, Nusselt number, outlet temperature of hot fluid and cold fluid are calculated using heat exchanger design calculations. The calculations are done for various mass flow rate of a hot and cold fluid .Then the modelling and meshing of double tube heat exchanger done using ANSYS-ICEM software. Analysis of double pipe heat exchanger with various mass flow rates was done using ANSYS – CFX. The same type of analysis done for double tube heat exchanger with twisted tape for various twist ratio.

a) Result of double pipe heat exchanger using design calculations:

Mass Flow Rate	Reynolds Number	Nusselt Number	Hot Fluid Outlet Temperature	Cold Fluid Outlet Temperature
LPM			*K*	*K*
3	11642.80	69.72	324.15	305.85
5	8160.34	43.11	325.89	306.77
7	11340.48	56.10	327.15	307.34
9	14641.77	68.82	327.87	307.89

Table. 1. Design calculation result of double pipe heat exchanger

b) CFD analysis result of double pipe heat exchanger:

Mass Flow Rate	Hot Fluid T_{out} without twisted tape	Cold Fluid Tout without twisted tape	Hot Fluid Tout with twisted tape	Cold Fluid Tout With twisted tape
LPM	*K*	*K*	*K*	*K*
3	327.493	304.913	325.464	304.547
5	328.344	303.151	327.047	306.322
7	328.897	306.229	327.967	306.922
9	329.301	306.729	328.793	307.321

Table. 2. Analysis result of double pipe heat exchanger

CONCLUSIONS

In this work I have done design calculation for double pipe heat exchanger. From this I can find Reynolds number, prandl number, nusselt number, outlet temperature of hot fluid and cold fluid are calculated using heat exchanger design calculations. The calculations are done for various mass flow rate of a hot and cold fluid .Then the modeling and meshing of double pipe heat exchanger done using ANSYS-ICEM software. Analysis of double pipe heat exchanger for various mass flow rate was done using ANSYS – CFX. . The same analysis will be carried over same heat exchanger with twist tape insert with various twist ratios. Finally the results are compared for various mass flow rate conditions and vary the twisted tape twist ratio. All this CFD analysis will be carried out with Ansys CFX 14.0 and it will be carried out by using k - ε turbulence model and Governing equations are solved by adopting a control volume-based finite-Volume method with a high resolution scheme on an orthogonal non-uniform staggered grid and the pressure based terms of momentum equations are solved by the computational fluid dynamics.

Nomenclature

A	Area, m2
Cp	Specific heat, J/kg K
d	Tube diameter, m
h	Heat transfer coefficient, W/m2 K
k	Thermal conductivity, W/m K
L	Tube length, m
M	Mass flow rate, kg/s
Nu	Nusselt number
Pr	Prandtl number
Q	Heat transfer rate, W
Re	Reynolds number
T	Temperature, °C
U	Overall heat transfer coefficient, W/m2 K
u	Velocity, m/s
ρ	Density, kg/m3

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