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"HEAT TRANSFER ENHANCEMENT IN HEAT EXCHANGER BY EXPERIMENTAL AND COMPUTATIONAL ANALYSIS IN A TUBE USING WAVY COUNTER TWISTED TAPE"

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ABSTRACT

Flow friction and heat transfer behavior in a Wavy twisted tape swirl generator inserted tube are investigated experimentally and Verificate in CFD The performance of heat exchanger with water as the working fluid becomes particularly important due to the thermal resistance offered by water in general. In order to compensate for heat transfer property of water, the surface area density of heat exchanger can be increased. The Growth of heat transfer in the use of wavy twist tape inserts with different twist tape ratio. The wavy twist tape generate vortex between the flow wavy Twist tape facilitate the exchange of more heat near the wall with the fluid in the core boundary layer is altered. It result heat transfer gradient at the surface which leads to the growth in heat transfer. Wavy Twist tape insert with twist ratio 8.33, 9.33 and 10.22.

The horizontal tube was subjected to constant mass flow rate & constant input cold & hot supply of water. The work include the Determination of friction factor heat transfer coefficient, overall heat transfer coefficient in the experimental setup for twist ratio 8.33 , 9.33 and 10.22 varies from 1.8 to 2.9 The result is also compare with the computational method. CFD technique is employed to perform optimization analysis of mesh insert.

The horizontal pipe along with mesh insert was modeled in ANSYS Fluent.CFD analysis was performed for twist ratio 8.33 , 9.33 and 10.22. For twist tape it was observed that the heat transfer coefficient vary from which varied from 2.34 to 3.10 times as compared to other. It was also observed that with increases in Reynolds number, the heat transfer coefficient increases where as the friction factor decreases. The result of computational investigation observed that the heat transfer coefficient vary from 1.9 to 3.9 times the smooth tube & the friction factor increased by 2.4 to 7.8 times the smooth tube. Computational investigation is the true for our experimental investigation & this validate the all result experimental result.

Key Words: *Heat Exchanger , Heat transfer coefficient , friction Factor , CFD Analysis , Experimental Analysis*

I. INTRODUCTION

"Heat transfer Enhancement " means Increase in heat exchanger's performance with the help of augmentation techniques, this can lead to more economical design of heat exchanger that can also help to make energy, material and cost savings related to a heat exchange process. for the augmentation of heat transfer in tube. The subject of heat transfer growth in heat exchanger is of serious interest in the design of effective and economical heat exchanger

Bergles et al., identified about 14 augmentation techniques used for the heat exchangers. These augmentation techniques can be classified into passive, active and compound techniques. Passive techniques do not require any type of external power for the heat transfer augmentation such as coating of Surface, rough surface, extended surface, displaced insert, swirl flow device, surface flow device, surface tension, additives for liquid, and additives for gases. Whereas, the active techniques need some power externally, such as electric or acoustic fields, surface vibration, mechanical aid, fluid vibration, injection, suction, jet impingement, etc., and compound technique are the combination of this two method.

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II. TRANSFER PROCESS

In a direct contact heat exchanger two fluid streams come into direct contact, exchange heat then separated. Common applications of a direct contact exchanger involve mass transfer in addition to heat transfer such as in evaporative cooling and rectification. In an indirect contact heat exchanger, the fluid streams remain separate and the heat transfers continuously through an impervious dividing wall or into and out of a wall in a transient. Thus, ideally there is no direct contact between thermally interacting fluid. [01] The effects of insertion of the helical tape turbulators with different helix angles on heat transfer and pressure drop in the tube [02] theoretical study on heat transfer characteristics and the performance of a cylindrical parabolic solar water heater with twisted tape inserted inside the absorber tube. [03] The twisted tape insert with a tight twist ratio provides an improved heat transfer rate at a cost of increase in pressure drop for low Prandtl number. [04] It gave an analytical model of the tape-generated swirl mechanism [05] Ratio of maximum velocity to mean velocity is smaller in swirl flow compared [06] and disturbs the local boundary layer of fluid flow.[07] The overall enhancement ratio increases with tighter twist ratio and decreases with increase in Reynolds number

Fig. 1 Wavy Twist Tap Insert

III. INSERT DESIGN PARAMETER

[08] If pressure drop is not consider. Then twisted tape is good option to use in turbulent flow [09] Heated flow friction factors for the swirl flow of liquids is substantially less [10] short length twist tape in circular tube and observed that Isothermal friction factor for swirl flow of liquids is substantially [11] Isothermal friction factor for swirl flow of liquids is substantially less than a plain tube.

The insert used for the experiment are wavy twisted aluminium strip twist tape, wavy twisted aluminium strip are a new kind of insert where no such experiments have been done thus giving us ample room for experimental studies. The aluminium strips width size 24.00 mm, thickness about 1mm and length 700 mm. Then the ends were tightened in the clamps and fixed on the lathe one end being fixed on the tool part side and the other on the chuck side. The chuck was then rotated slowly by hand, while the angle was being held in tension, to give it a desired wavy twist.

[12] Performed a direct numerical simulation for turbulent heat transfer in a concentric annulus and they observed that the thermal structure is more effective near the outer wall than near the inner wall. [13] Porous type of baffle is good for thermo hydraulic performance and there is an optimum height of the baffle. [14] neural Network to evaluate and predict boiling heat transfer enhancement using additives [15] simulate the crystallization fouling process in a heat exchanger by developing a C^{++} program and adopting UDF functions through fluent software and hence evaluate all the given models and

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Fig. 2 Experimental Setup

IV. HEAT TRANSFER AUGMENTATION IN HEAT EXCHANGER

For single phase flow, the heat transfer coefficient is generally expressed in terms of the Colburn correlation

$$h = JC_pG\,(Pr)^{-2/3}$$

The friction factor is defined on the basis of an equivalent shear force in the flow direction per friction area. This shear force can be either viscous shear (skin friction) or pressure force (from drag) or a combination of both. So without making an attempt to differentiate between them, it is possible to express them by fanning friction factor (f) given by

$$f = \frac{\tau}{\frac{1}{2}\rho v^2}$$

This is the basic equation of friction factor; the pressure drop (Δp) for internal flow through the tube can be calculated from equation

$$f_a = \frac{\Delta p \times di}{2 \times p \times L \times v^2}$$

The basic equation for the heat transfer rate in a heat exchanger is given by $q = UA_i\,\Delta T_m$

Where 'q' is the rate of heat exchanger, 'U' is the overall heat transfer coefficient based on 'Ai' and $\Delta T_{m,}$ is the logarithmic mean temperature difference, and is defined as:

$$\Delta T_m = \frac{\Delta T2 - \Delta T1}{\ln \frac{\Delta T2}{\Delta T1}}$$

Where

$\Delta T_1 = (\Delta T_{h1} - \Delta T_{c2})$,

$\Delta T_2 = (\Delta T_{h2} - \Delta T_{c1})$

In the case of heat flow through a flat wall, the temperature over the entire area of each face of the flat wall was identical and the temperature difference was simply the temperature difference between any points on the two faces.

$$Q = h_iA_i(t_p - t) = h_iA_i\Delta t_i\ ,$$

where t_p is the temperature

$$dQ = h_i\, dA_i\, \Delta t_i$$

$$\frac{d\Delta ti}{dQ} = \frac{\Delta T2 - \Delta T1}{Q}$$

$$\frac{hi\, dAi}{Q} = (\Delta T2 - \Delta T1)$$

then,
$$Q = \frac{hi\,Ai\,(\Delta T2 - \Delta T1)}{\ln \frac{\Delta T_2}{\Delta T_1}}$$

$$= hi\ Ai\ \Delta t_i\ LMTD$$

Experimental setup with known diameter and length and through which liquid could be circulated at various measurable flow rates

$$Q = mc\,(t_2 - t_1) = hi\ Ai\ \Delta t_i\ LMTD$$

Then the overall heat transfer coefficient is given by. $\frac{1}{U} = \frac{1}{hi} + \frac{1}{ha}$

- ➢ Neglecting the thickness of tube heat transfer through conduction

☐ Heat transferred to the cold water in the test section:

$$Q_c = m_c\,C_p\,(T_{c2} - T_{c1})$$

☐ Heat transferred from the hot water in the test section

$$Qh = m_h\,C_p\,(Th_1 - Th_2)$$

☐ The error in the present heat exchanger can be given as

$$\%\ error = \frac{Qh - Qc}{Qc} \times 100\%$$

☐ Dittus - Boelter equation

$$Nua = \frac{ha\,Dh}{k} = 0.023 Re^{0.8}\,Pr^{0.4}$$

Where, D_h = Hydraulic diameter = $d_i - d_o$
Thus, $Nui = \frac{hidi}{k}$

☐ The Darcy–Weisbach friction factor, f_D

$$\Delta p = fd \times \frac{L}{D} \times \frac{\rho v^2}{2}$$

$$= f \times \frac{L}{D} \times 2\rho v^2$$

Friction Factor variation in Heat Exchanger:-

(a) For Re < 2100 , $f = \frac{16}{Re}$
(b) For Re > 2100

Colbum's Equation:

$$f = 0.046\ Re^{-0.2}$$

Experimental results with the values that are obtained from computational verification plotted for which the experiment and computational method are used to determine the friction factor and shown the behaviour with Reynolds number

Factor vs Reynolds number for Wavy Twist tap: 8.3

The variation of experimental and computational friction factor with Reynolds number for Wavy Twist tap: 8.3
It is observed that as Reynolds number increases friction factor decreases.

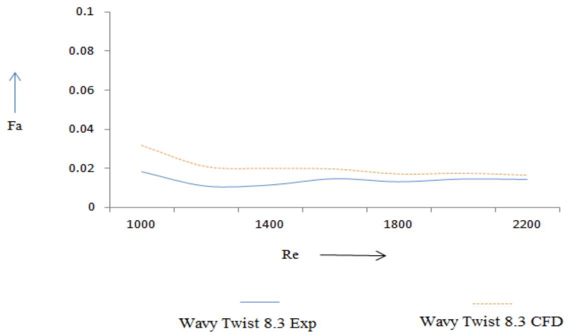

Fig. 3 Fa and Re for Wavy Twist tap: 8.3 Measure low pressure drop with high accuracy.

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Experimental Friction factor vs Reynolds number for wavy twist tap 8.3, 9.3 and 10.22

Higher degree of swirl is created inside the tube which leads to higher pressure drop: - Order of friction factor is: f_{exp}, wavy twist tap 10.22 > f_{exp}, wavy twist tap 9.3 > f_{exp}, wavy twist tap 8.33

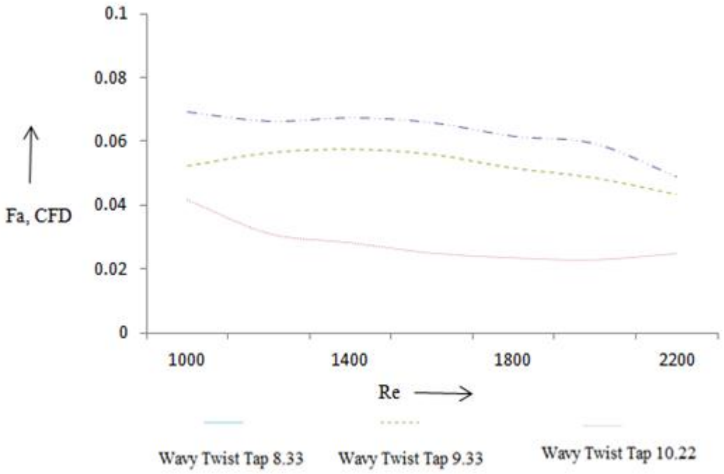

Fig.4 Experimental Friction factor vs Reynolds number Wavy twist tap 8.33, 9.33 and 10.22

Order, for their friction factor ratio is.

Wavy Twist 10.22, (fexp / f_{CFD}) > Wavy Twist 9.33, (fexp / f_{CFD}) > Wavy Twist 8.33 (fexp / f_{CFD}),

Heat Transfer coefficient of Experimental and Computational vs Reynolds Number

It is seen that, there is a very small difference between hi_{exp} & hi_{CFD} for wavy twist tap 8.3 at higher Reynolds number so we can easily say that the heat transfer equations hold true for our experimental setup.

Lower deviation between h_{exp} & h_{CFD} for low Reynolds number can be attributed to the phenomenon of natural convection taking place along with forced convection.

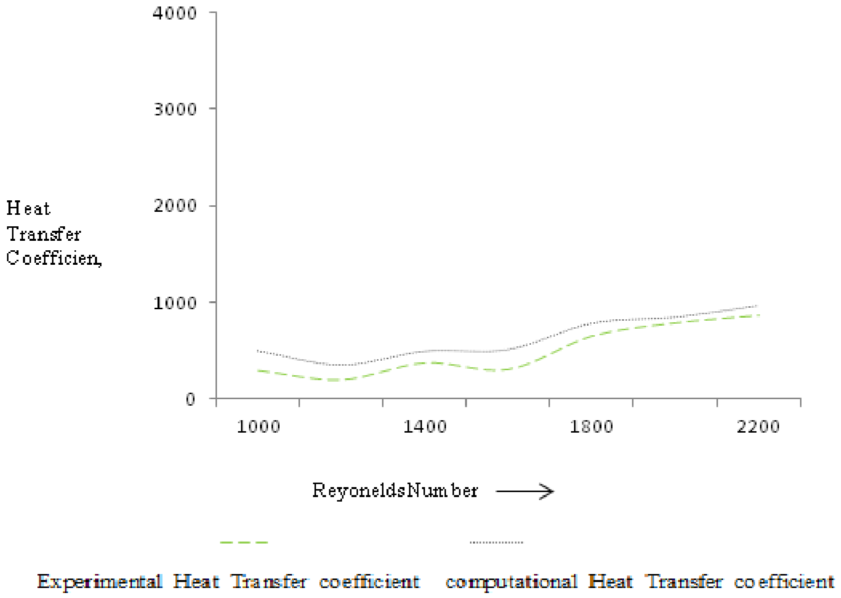

Fig.5 Experimental and computational Heat Transfer coefficient vs Reynolds Number

Heat Transfer coefficient (Exp) vs Reynolds Number for Wavy Twist tape ratio 8.33, 9.33 and 10.33

The experimental heat transfer coefficient for wavy twist tab 8.33, wavy twist tap ratio 9.33 and 10.22.varies with the Reynolds number.

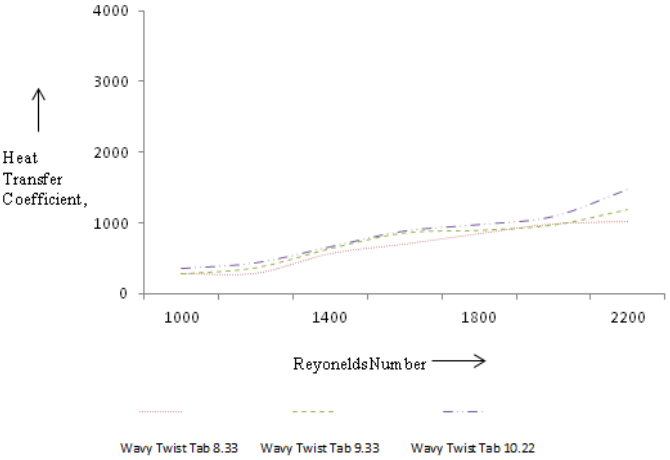

Fig.6 Experimental Heat Transfer coefficient vs Reynolds Number for Wavy Twist tab 8.33, Wavy twist Tab 9.33 and 10.33

It is observed that heat transfer coefficient for Twist tape ratio 10.22 is more than 9.33 and 8.33

CFD Heat Transfer vs Reynolds Number for smooth tube, tube with twist ratio 10.22, 9.3 and 8.3

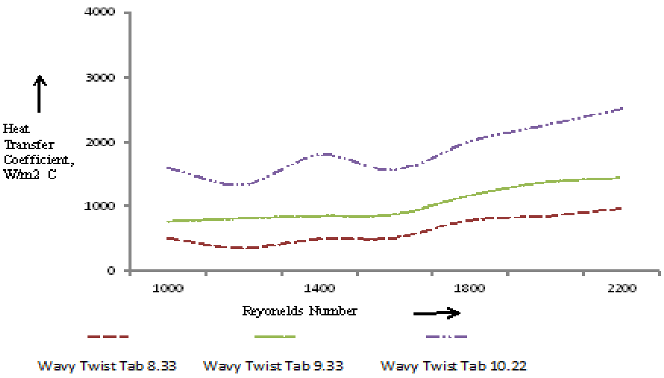

Fig. 7 CFD Heat Transfer coefficient vs Reynolds Number for Wavy Twist tab 10.22 , 9.33 and 8.33

It is observed that for all cause heat transfer coefficient increases with increasing Reynolds number.

Overall Heat Transfer coefficient vs Reynolds Number for wavy twist tab 10.22, 9.33 and 8.33.

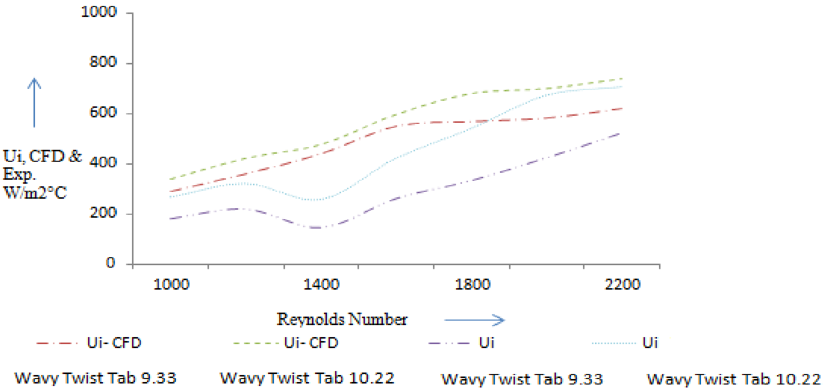

Fig. 8 Computational and experimental observation of overall heat transfer coefficient vs Reynolds number

Computational result performs better result as compare to the experimental result. Due to the limitation of the experimental setup.

This limitation as flows:
1. Variation in the mass flow rate of fluid
2. Heat losses by the outer tube wall
3. Lower Reynolds shows the small pressure difference, which is difficult to measure experimentally

V. CONCLUSION

CFD and Experimental work of wavy twist tape inserts to growth the heat transfer of a heat exchanger tube.

1. The Reynolds number and friction factor values for the heat tube with wavy twist tape insert are noticeably higher than that of wavy twist tap 8.33.
2. Wavy Twist tape gives the greater heat transfer result, because of higher degree of turbulence generated by the wavy twist tape which reduces resistance near the wall to promote better heat transfer as compared to other heat transfer growth used in heat exchanger for heat transfer growth.
3. In the case of wavy twist tape insert the friction factor varied from 2.34 to 3.10 times as compared to other.
4. Pressure drop result indicates that the friction factor depends primarily on Reynolds number as swirl flow increases the friction factor somewhat decreases at higher Reynolds number.
5. Friction factor increasing with a decreasing as the twist ratio Order, for their friction factor ratio is.

Wavy Twist 8.33, $(fexp / f_{CFD})$ > Wavy Twist 9.33 , $(fexp / f_{CFD})$ > Wavy Twist 10.22$(fexp / f_{CFD})$

6. The heat transfer process in experimental setup enhances by using wavy twist tape inserts.

The type of twisted tape indicate the increasing amount of enhancement efficiency Order, for their overall heat transfer coefficient ratio is:

Wavy Twist 10.22 ,$(Ui{,}exp/Ui_{,CFD})$ > *Wavy Twist 09.33*, $(Ui{,}exp / Ui_{,CFD})$ > *Wavy Twist 08.33* $(Ui{,}exp / Ui_{,CFD})$

7. Heat transfer coefficient increases as the wavy twist ratio increases it Vary 1.8 to 2.9 Times to Wavy Inserts 8.33
8. Maximum heat transfer gain by the twist tape with wavy twist ratio 10.22 as compare to wavy twist tape 9.33 and wavy twist tape 8.33.

Computational simulations in Fluent Software are reasonable agreement with our experimental result and existing correlations for heat transfer and friction factor.

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