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Numerical Analysis of Flow and Heat Transfer Enhancement in a Pipe with Twisted Tape

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Abstract- This work aims to present a numerical model for heat transfer intensification in a heat exchanger tube equipped with novel V-cut twisted tape. The effects of different cut ratios (0.6<b/c<1.25) on the turbulent flow characteristics and thermal performance of the system will be investigated over the Reynolds number range from 4000 to 12000. All the simulation will be performed for fully developed turbulent flux in the Reynolds number range with uniform heat flux of 5000 W/m2. The numerical results of heat transfer (Nusselt number, Nu), pressure drop (friction factor, f) and enhancement Performance Factor in a tube with twisted tapes (V-Cut) were reported in the study.

Keywords- Twisted tape, design, thermal analysis, heat exchanger.

I. INTRODUCTION

Heat transfer enhancement techniques have grown in popularity as high-performance thermal systems have been developed. Heat transfer augmentation procedures refer to many different of methods for increasing heat transfer rates while minimizing the system's overall performance. In industrial, heat exchangers are commonly utilized both for cooling and heating. The use of twisted tape within flow route to create turbulence was among the most popular passive heat transfer augmentation strategies owing to its advantages of ease of fabrication, operation, and low maintenance.

The enhancement of something like the thermo hydraulic performance of heat exchangers is referred to as heat transfer enhancement or augmentation approaches. A broad range of inserts are often used in numerous strategies (both passive and active) researched for augmentation of heat transfer rates within circular tubes, particularly if turbulent flow was included. To improve the thermal performance of heat transfer devices, a variety of techniques are used, including treated surfaces, rough surfaces, swirling flow devices, coiled tubes, and surface tension devices.

Moreover, due to fouling or scaling, the barrier to heat transmission rises as a heat exchanger gets older.Heat exchangers used during maritime applications and also the chemical industry are especially prone to these issues. There seems to be a requirement to improve the heat transfer rate in particular applications, including such heat exchangers dealing with poor thermal conductivity fluids (gases and oils) and desalination facilities. The heat transfer rate can indeed be enhanced by disrupting the fluid flow (breaking the viscosity and thermal boundary layers), but really the pumping power used in the process will likely rise dramatically, resulting in a high pumping cost. As a result, numerous strategies have been presented in recent years to accomplish a desired heat transfer rate inside of an existing heat exchanger while using little pumping power.

Inserts are gotten a lot of press, but not for their impact on the properties of the employing fluid [8, 14]. Fins, twisted tapes, porous discs, turbulators, perforated plates, and dimples are among some of the inserts used within tubes to improve heat transmission towards the working fluid [15–19]. Twisted tapes have already been commonly used inside tubes to improve heat transfer performance and to have demonstrated to have a lower impact on pressure drop than other improvement techniques such fins [20–23].

Swirl flow is formed with increased axial fluid velocity and along tube in some kind of a tube integrated using twisted tape inserts, resulting in enhanced heat transfer [24–27]. Twisted tapes also produce a mixing flow similar to that of a turbulator that improves heat transmission [27–30]. As a result, the thermal performance of a twin pipe heat exchanger with or without twisting tape inserts was examined in this work with varied cut-out ratios.

II. RESEARCH METHODOLOGY

In heat exchangers, twisted tape inserts were commonly utilised to improve heat transmission. They improve heat transmission via creating swirl flow there in flow channel, which allows for better mixing within the fluid and increases the flow channel's effective flow length. They also increase pressure drop, yet in many circumstances, their overall performance is determined to be beneficial. The necessity to increase the thermal performance of heat exchangers has resulted in a slew of changes to them in order to save energy, reduce material costs, and mitigate environmental deterioration. Heat transfer enhancement or

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heat transfer augmentation techniques are the terms used to describe such approaches. Enhancement approaches lower the thermal resistance of a traditional heat exchanger through encouraging a greater convective heat transfer coefficient with or without increasing the surface area.

As a consequence, a heat exchanger's size can indeed be lowered, or an existing heat exchanger's heat duty can indeed be raised. The numerous heat transfer improvement approaches may be divided into two categories: passive and active. The use of passive approaches does not necessitate the use of external power. Surface or geometrical alterations are commonly used, as well as the incorporation of an insert material or extra device. In active approaches, any type of external power is used to produce the necessary flow modification and rate of heat transfer enhancement.

In circular channels, twisted tape (TT) inserts are amongst the most common passive heat transfer augmentation strategies. It's a gadget that creates a swirling flow. Swirl flow is given it to fluid when they have been put in circular channels. The agitation of the fluid, the decrease overall effective flow length, and the mixing generated by cross stream secondary flows all contribute toward the improved heat transfer. A metric called "Twist ratio" is used to identify twisted cassettes. The performance of a modified twin pipe heat exchanger is investigated in this paper by altering the cut-out ratio.

1. Research Model:

Fig. 1 shows a heat exchanger tube integrated with a novel double V-cut TT with uniformwall temperature. The geometrical parameters include the tube length (L), tube diameter (D),tape width (w), twist pitch (y), tape thickness (δ), and V-cut dimensions (b, c) are listed inTable 3.1.

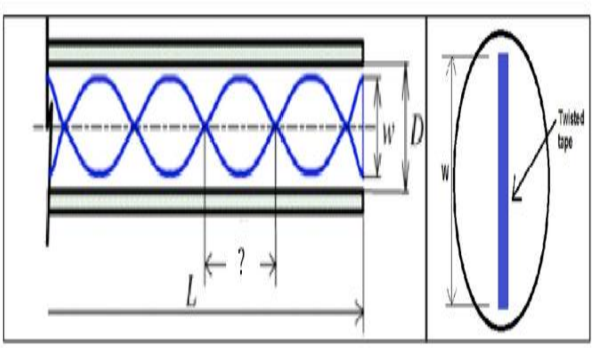

Fig 1. Research model.

Five cases corresponding to the heat exchanger tube equipped with TT without cut, V-cuts with b/c = 0.6, 0.8, 1 and 1.25 are selected in the present numerical simulations.

All five cases maintained the same twist ratio y/w=3 and tape thickness of 1mm. Conventional PTT is used as the baseline case. Water is selected as the working fluid.

The turbulent flow with Reynolds number (Re) ranging from 4000 to 12,000 is considered. The water flow at thetube inlet is considered uniform velocity and uniform temperature profiles.

2. Governing Equation:

The flow is steady, turbulent, three-dimensional and incompressible. The RNG k- ε turbulence model with enhanced wall functions is selected for numerical analysis of heat exchanger tubes integrated with TT.

The governing equations (continuity, momentum, energy, turbulent kinetic energy (k), and dissipation of energy (ε) are:

$$\frac{\partial}{\partial x_j}(u_j \rho u_i) = -\frac{\partial p}{\partial x} + \frac{\partial}{\partial x_j}\left\{\mu\left[\frac{\partial u_i}{\partial x_j} - \rho \bar{u_i'} u_j'\right]\right\}$$

$$\frac{\partial}{\partial x_j}(\rho u_i T) = \frac{\partial}{\partial x_i}\left\{\left[\frac{\mu}{Pr} + \frac{\mu_t}{Pr_t}\right]\frac{\partial T}{\partial x_i}\right\}$$

$$\frac{\partial}{\partial x_i}(\rho u_i k) = \frac{\partial}{\partial x_j}\left\{\left[\frac{\mu_t}{\sigma_k} + \mu\right]\frac{\partial k}{\partial x_j}\right\} + G_k - \rho\varepsilon$$

$$\frac{\partial}{\partial x_i}(\rho u_i \varepsilon) = \frac{\partial}{\partial x_j}\left\{\left[\frac{\mu_t}{\sigma_\varepsilon} + \mu\right]\frac{\partial \varepsilon}{\partial x_j}\right\} + \frac{\varepsilon}{k}[C_{1\varepsilon} G_k - \rho C_{2\varepsilon}\varepsilon]$$

Since a turbulence model's accuracy in predicting unfavourable pressure gradient boundary layer flows is critical, the Realizable – (RKE) model was used in this study. The transport equations in thetensor version for the Realizable k-turbulence model are presented above. FLUENT may combine the two-layer model with enhanced wall functions to achieve the aim of had an almost modelling technique that has the accuracy of the traditional two-layer approach for fine-near-wall meshes while without dramatically reducing precision on wall-function meshes.

As a result, in the near-wall zone, the wall function treatment is being used to break this viscous sublayer. “At all rigid barriers, the logarithmic law of something like the wall is utilised to estimate kinetic energy and momentum, while the local equilibrium is used to determine the turbulent dissipation rate.” The model being supposed to be a three-dimensional geometric structural model. Inside the Reynolds number range of 4000–12000, all tests are carried out for fully developed turbulent flow.

III. RESULTS AND DISCUSSION

In Fig. 2, the variation of Nusselt number with Reynolds number in the tube fitted with TT, the tube fitted using PTT, and the plain tube is shown. The Nusselt number increases with rising Reynolds number across all instances. VTT heat transfer rates were greater than those of a simple tube with no twisted tape or other v-cut ratio, as predicted.

Because of the rise in turbulence intensity & flow length over the Reynolds number range, the lower twist ratio (PTT) heat transfer rate [4, 7] is larger than that of the higher ones (*1.25*).

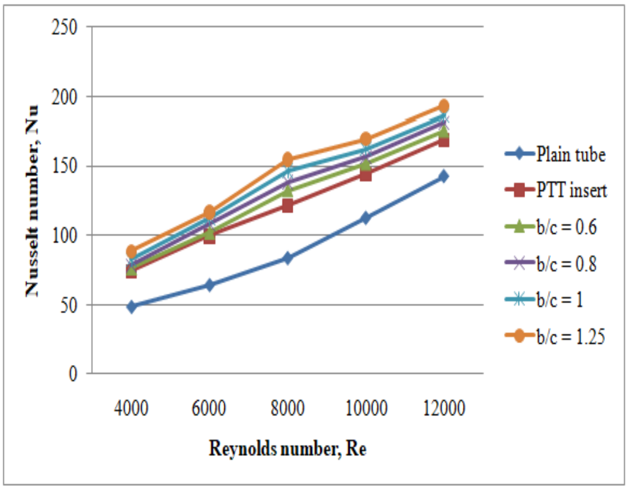

Fig 2. Variations of Nusselt number against Reynolds numbers for different double V-cut ratios.

IV. CONCLUSION

The properties of heat transmission and friction factor for various twisted tapes (V-cut) and (P-TT) put inside a horizontal pipe having varied v-cut ratios have already been quantitatively examined.

As a result, the following conclusions are reached:

- The usage of twisted tape improves heat transfer efficiency. With all twisted ratio values, the (V-cut) twisted tape provides a superior heat transfer enhancement than the (P-TT).
- Given the strong vortex flow created by twisted tapes, the rates of heat transfer always are higher for such pipe provided with twisted tapes than for the plain pipe. The rate of heat transmission with both the v-cut ratio (1.25) is higher than the twisted ratio, according to the results (0.6).
- For Reynolds numbers around 12000, the highest augmentation in heat transfer during model flow circumstances is observed whenever Nusselt number ratio is equal to1.962 that occurs within (V-cut) twisted tape with v-cut ratio (1.25).
- For, the highest thermal performance factor is 1.974 (V-cut) twisted tapes with the twisted ratio (1.25) at Reynolds number (12000).

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