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Review Of Heat Transfer Augmentation In Circular And Non-Circular Tube

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ABSTRACT

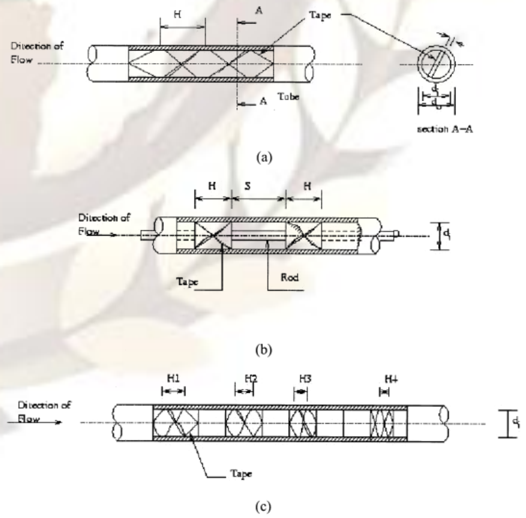
The present paper is a review of research work of last ten years on heat transfer growth in circular and non circular tubes. Active as well as passive methods are employed for increasing the heat transfer coefficient in heat exchanger; Passive methods do not require application of external power such as active method require. The effectiveness of both active and passive methods depends strongly on the mode of heat transfer, which might range from single phase free convection to dispersed flow film boiling. In the present paper stress is given on to work dealing with displaced insert into circular tubes (twist tap insert, screw tap insert, helical tap insert, wire mesh tape insert), non circular tubes (triangular, rectangular duct) and CFD based analysis in laminar and turbulent flow.

Keywords - CFD Analysis, Circular tube, Non-circular tube, Heat transfer growth, laminar and turbulent flow.

INTRODUCTION

Heat exchangers are used in different processes ranging from conversion, utilization and recovery of thermal energy in various industrial, commercial and domestic applications. Some common examples include steam generation and condensation in power and cogeneration plants, sensible heating and cooling in thermal processing of chemical, pharmaceutical and agricultural products, fluid heating in manufacturing and waste heat recovery, etc. "Heat transfer Growth" 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. in this review paper emphasis is given on displaced insert used in circular and non circular 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. [1983] identified about 14 augmentation techniques used for the heat exchangers. These augmentation techniques can be classified into Passive and active techniques. Passive techniques do not require any type of external power for the heat transfer augmentation such as coating of
The 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. Some new techniques like CFD analysis are used because this provides a qualitative and sometimes even quantitative prediction of fluid flows by means of, mathematical modeling (partial differential equations) numerical methods (discretization and solution techniques) , software tools (solvers, pre and post processing utilities) CFD enables to perform 'numerical experiments' (i.e. computer simulations) in a 'virtual flow laboratory'.

1. Circular Tubes Fitted With Displaced Insert in Laminar Flow:-



(a) full-length twisted tape, (b) regularly spaced twisted tape and (c) smoothly varying (gradually decreasing) pitch full-length twisted tape

Fig:-1 Laminar flow generator in circular tube

This review paper involving recent research work on heat transfer growth in circular tube. Many studies were conducted previously to analyze heat transfer growth in circular tube with displaced insert in laminar flow. [1] Sheeba et al., The thermal performance of thermosyphon solar water heater system fitted with helical twisted tape of various twist ratios has been perfo1rmed and presented. Conclusions made from the results that heat transfer enhancement in twisted tape collector is higher than the plain tube collector with minimum twist ratio and gradually decreases with increase in twist ratio. The overall thermal performance of twisted tape collector is found to increase with increase in solar intensity. [2] Eiasma Ard et al., investigated the behaviour of heat transfer and friction loss in circular tube. result shows that apart from the friction factor, Heat transfer rate can be substantially improved by using both the wavy surfaced wall and the helical tape. [3] P Selvaraj et al., used water and ethylene glycol mixture 90:10 (by weight) flow through the circular tube because ethylene glycol prevents corrosion and acts as antefreezing agent. They investigate that the maximum heat transfer enhancement is obtained up to 36% for circular Tube in laminar flow with grooved inserts as compare to simple tubes. [4] Veysel Ozceyhan et al., investigate the heat transfer enhancement in a tube with the circular cross sectional ring, uniform heat flux was applied to the external surface of the tube. The variation of Nusselt number, friction factor and overall enhancement ratios for the tube with rings were presented and the best overall enhancement of 18% was achieved. [5] P.K.Nagarajan and P.Sivashanmugam used 300 mm right-left helical twist with 100 mm spacer of different twist ratio on their investigation and found that Nusselt number for the tube fitted with 300 mm right-left helical twist is higher than that for plain tube for a given Reynolds number attributing to heat transfer enhancement due to swirl flow. [6] The synergy regulation among physical quantities of fluid particle is revealed by establishing formulas reflecting the relation between synergy angles and heat transfer enhancement. The physical nature of enhancing heat transfer and reducing flow resistance, which is directly associated with synergy angles α, β, γ, φ, θ and ψ . Besides, the principle of synergy among physical quantities is numerically verified by the calculation of heat transfer and flow in a thin cylinder-interpolated tube. [7] J P Meyer and J. A Olivier investigated the heat transfer and pressure drop data for enhanced tubes with helical coil insert. The investigation covered the laminar, transitional and turbulent flow regimes. This was brought about by the insert which break up the vicious sub layer. This was attributed to the insert obstructing secondary flows, which are induced by buoyancy forces, reducing the amount of mixing. Transition of flow independent of the inlet profile used. [8] Timothy et al. performed an experimental study of a double pipe helical heat exchanger used coil tape insert with laminar flow of fluid, and they found that increase in Nusselt number significantly in the entrance region and heat transfer rates were higher in counter flow configuration as compared to parallel flow. [9] M E Ali investigates that average heat transfer coefficient increases as number of coil turns decrease for a fixed diameter ratio. [10]Veeresh Uskele and R M Sarviya studied the heat transfer and friction factor characteristics of double pipe and plane tube heat exchanger, they found that heat transfer coefficient and friction factor increase with the decrease in twist ratio compared to plain tubes. [11] P. Sivashanmugam and S.Suresh studied the laminar heat transfer and friction factor characteristics in a circular tube fitted with full length helical screw tapes with different twist ratios under constant heat flux conditions, They reported significant improvement of the heat transfer rate for using the tape inserts and found that there is not much change in the magnitude of heat transfer coefficient to vary twist ratio sets. [12] Ujhidy et al., have studied and proposed Dean Number. Dean Number is a measure of the magnitude of the secondary flow, which is useful for the future investigation of heat transfer growth in circular tubes contained twist tapes. [13]Suresh Kumar et al. investigated the thermohydraulic performance of twisted tape inserts in a large hydraulic diameter annulus and found that thermohydraulic performance in laminar flow with a twisted tape is better than the wire coil for the same helix angle and Thickness ratio.

2. Circular Tubes Fitted With Displaced Insert in Turbulent Flow:-

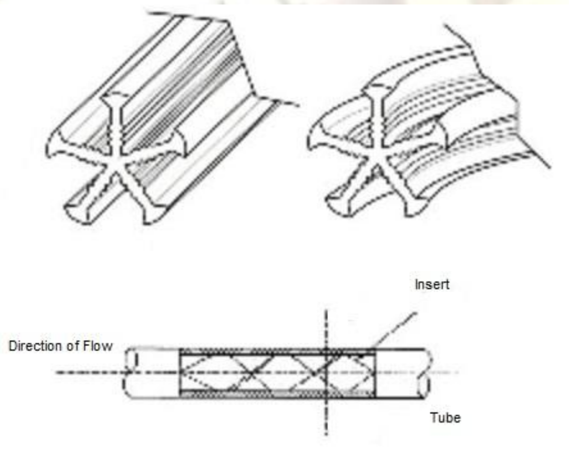
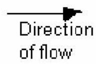


Fig:-2 Turbulent flow generator in circular tube

Investigation of displaced insert for turbulent flow in circular tubes is discussed in this section. Displaced insert in turbulent flow is effective up to certain Reynolds number. More Reynolds number block the flow passage and increases the pressure drop. [14] W. Noothong et al., studied influences of inserts on heat transfer and flow fraction property in a concentric double pipe heat exchanger. The turbulent flow was introduced by using twisted tape placed inside the inner test tube of the heat exchanger with different twist ratios; result shows thats twist ratio increases heat transfer rate as compare to plain tube.

[15]M.A.K. Chowdhuri et al., used special geometry is used inside the tube for turbulent flow. The test section is electrically heated, and air is allowed to flow as the working fluid through the tube by means of blowers. Same experiment is carried out to determine heat transfer through the same tube without any insert. Comparing the results obtained from these two different sets of experiments. it is found that heat transfer through tubes can be enhanced by using inserts inside the tube up to 9.8 times than tube without insert with turbulent flow. [16] P. Sivashanmugam and S. Suresh investigated that the heat transfer and friction factor characteristics of circular tubes fitted with full length helical screw element of different twist ratio with heat flux under turbulent flow conditions (Reynolds number 2700 to 13500), the maximum performance of the helical twist insert was achieved as compare to twisted tape insert in turbulent flow. [17] P. Murugesan et al. reported experimental investigations of heat transfer and friction factor for turbulent flow in a tube fitted with trapezoidal cut twisted tape. They found that Heat transfer coefficient and friction factor increases with the decreases in twist ratio. The trapezoidal cut twisted tape with twist ratios increases the heat transfer rate 41.8 % higher than plain tubes. [18]P.Coronel and K.P. Sandeep conducted experiments in helical heat exchangers with coils of two different curvature ratios, straight tubular heat exchangers at various flow rates and for different end point temperatures. The inside and outside convective heat transfer coefficients were determined based on overall heat transfer coefficient and a correlation to compute the inside convective heat transfer coefficient as a function of Reynolds number. [19] M. Mridha and K P D Nigam investigated turbulent forced convection in a new device of coiled flow inverter and found 4-13% enhancement in heat transfer as compared to straight helical coil while relative pressure drop was found to be 2-9%. Further, gain in heat transfer in coiled flow inverter for turbulent flow condition as compared to straight tube for same flow rate and boundary condition was 35-45% while increase in pressure drop found 29-30%. [20] Smith Eiamsa-ard et al. presented an experimental study on the mean Nusselt number friction factor efficiency in a round tube with short-length twisted tape insert under uniform wall heat flux boundary conditions. In the experiments, measured data are taken at Reynolds numbers in a turbulent region with air as the test fluid. The experimental result indicates that the short-length tapes perform lower heat transfer and friction factor values than the full-length tape around 14%, 9.5% and 6.7%; and 21%, 15.3% and 10.5% respectively. [21] Sharma et al., Conducted experiments to evaluate heat transfer coefficient and friction factor for flow in a tube and with twisted tape inserts in the transition range of flow with AI203 nanofluid are conducted. The results showed considerable enhancement of convective heat transfer with Al203 nanofluids compared to flow with water. [22] C Thianpong et al., investigated experimentally heat transfer and friction characteristics for water, ethylene glycol, and ISO VG46 turbine oil flowing inside four tubes with three-dimensional internal extended surfaces and segmented twisted-tape inserts. Experimental results show that tube with three-dimensional internal extended surfaces and twisted-tape inserts; enhance the convective heat transfer for the laminar tube side flow of highly viscous fluid.

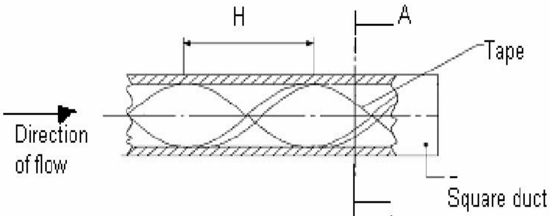


3. CFD Based Analysis in Laminar and Turbulent Flow:-

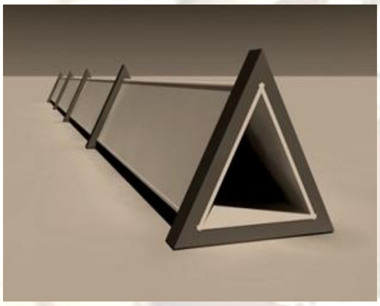
CFD is a method to numerically calculate heat transfer and fluid flow. This provides data that is complementary to theoretical and experimental.

Computational Flow Dynamics (CFD) investigation for laminar flow and turbulent flow with displaced insert in circular and non circular tubes represented in following section., [23] H.R Rahai and T.W Wong predicted that wire coil with a large pitch spacing increases the mixing, turbulent kinetic energy and half width but decreases the maximum mean velocity. [24] V Kumar and K D P Nigam introduced a device based on the flow inversions by changing direction of centrifugal force in helically coiled tubes. Complete flow fields and thermal fields in helical coil and bent coil configuration were studied using CFD Software (FLUENT 6.0). Three dimensional governing equations for momentum and energy under laminar flow Conditions were solved with a control volume finite difference method (CVFDM) with second order accuracy. Bent coil configuration showed a 20-30% growth in heat transfer due to chaotic mixing while relative pressure drop was found as 5-6%. [25] S Y Chung and H J Sung investigated a direct numerical simulation for turbulent heat transfer in a concentric annulus (Transverse curvature), and they observed that the thermal structure is more effective near the outer wall than near the inner wall. [26]V Kumar and K D PNigam studied convective heat transfer in chaotic configuration of circular cross section under laminar flow regime at different values of Dean Number and Prandtl number. Chaotic configuration showed a 25-36% enhancement in heat transfer due to chaotic mixing while relative pressure drop was 5-6%. Under heating condition (temperature-dependent viscosity), heat transfer was found higher in case of chaotic configuration as compared to the cooling condition (constant viscosity). [27]I Conte and X F Peng performed computer simulations for four rectangular coiled pipes with different angles of straight tube inclination (90, 15, 30 & 45°) at different inlet velocities. Better heat transfer performance was observed for the coil with smaller angle of straight tube inclination. [28] M Mridha and K P D Nigam investigated turbulent forced convection in a new device of coiled flow inverter and found 4-13% enhancement in heat transfer as compared to straight helical coil while relative pressure drop was found to be 2-9%. [29] B Zheng et al., studied combined convection and thermal radiation heat transfer in three-dimensional turbulent flow through a helical pipe with finite pitch simulated with CVFDM method. Thermal radiation had no significant influence for flow and temperature fields, especially in a fully developed region but it substantially enhanced total heat transfer in helical pipe. [30] T H Ko studied on laminar forced convection and entropy generation in a helical coil suggested optimal Reynolds number to be chosen as the flow operating condition so that thermal system could have the least irreversibility and best energy utilization.

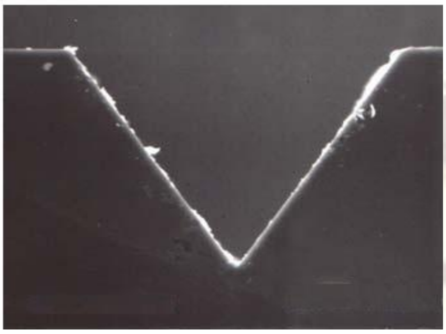
4. Heat Transfer in Non-Circular Tubes:-



(a) Flow in Rectungler Duct



(a) Flow in Tringuler Duct



(c) Flow in Half-triangular Duct

Fig 3 {(a), (b), (c)}. Heat Flow through Non-circular Tube

This study addresses heat transfer performance of various configurations of non-circular tubes. The majority of these studies were conducted to investigate fundamental transport phenomena occurring in the non-circular tubes. Sometimes, because of pressure drop limitations, the need for non-circular ducts arises in many heat transfer applications. Therefore interest to investigate heat transfer performance for various geometries of non-circular tubes like square, triangular, half triangular, Trapezoid section, etc. Square duct offers more surface to volume ratio than circular tube therefore more heat transfer enhancement was observed in square duct. Important investigations for square duct have been discussed in this section. [31] R. K. Khan et al., Conduct experiment to investigate the heat transfer augmentation in developing turbulent flow through a ribbed square duct. The results of ribbed duct are compared with the results of a smooth duct under the same experimental conditions. It is observed that the heat transfer augmentation in ribbed duct is better than that of the smooth duct. the mean temperature of air flowing through the ribbed duct increases by 2.45 percent over the smooth duct whereas in the ribbed duct Nusselt number increases by 15.14 percent than that of the smooth duct with a 6 percent increase in pressure drop. [32] Ho-Keun Kang et al. investigated the characteristics of a hydrodynamic and thermally developed turbulent flow through a square duct (30×30 mm) with twisted tape inserts and with twisted tape inserts plus axial interrupted ribs. Two heating conditions are investigated for test channels with twisted tape inserts and rib tabulators: (i) electric heat uniformly applied to four side walls of the square duct, and (ii) electric heat uniformly applied to two opposite ribbed walls of the square channel. The correlation for friction factor and Nusselt number are derived from the predicted date. The results show that uneven surface heating enhances the heat transfer coefficient over uniform heating conditions, and significant improvements can be achieved with twisted tape inserts plus axial interrupted ribs compare to the case of twisted tape inserts. [33] Seong Ho Han et al., performed the Numerical simulations and develop a new heat transfer coefficient correlation, the elliptic blending second moment turbulent closure precisely reflecting the effects of these thermo-physical property variations on the turbulent heat transfer is employed to model the Reynolds stresses and turbulent heat fluxes in the momentum and energy equations. Computational results related to the development of turbulent heat transfer during in-duct cooling of supercritical carbon dioxide were used to establish a new heat transfer coefficient correlation that would be widely applicable to a gas cooler design involving turbulent heat transfer of supercritical carbon dioxide in square cross-sectional duct flows.

[34]Mohammad Nasiri, reported the results of experimental investigation on the heat transfer performance of Al_2O_3/H_2O and TiO_2/H_2O nanofluids through square channel with constant wall temperature boundary condition. The flow regime through channel is turbulent. The nanofluids used in this research are Al_2O_3/H_2O and TiO_2/H_2O with different nanoparticle concentrations. Based on the results of the present investigation, for specific Peclet number, convective heat transfer coefficient and Nusselt number of

nanofluids are higher than those of distilled water. The enhancement increases with increasing nanoparticle concentration. [35] T. Astarita, G. Cardone., Give Detailed quantitative maps of the heat transfer distribution in a square channel with angled rib tabulators are measured by means of infrared (IR) thermography associated with the heated-thin-foil technique. Air flows in the channel where square ribs are mounted on two opposite walls at an angle of either 30° or 45° with respect to the duct axis. Two rib pitches, two different rib arrangements and two heating conditions are investigated. Results are presented in terms of local and averaged Nusselt numbers, which are normalised with the classical Dittus and Boelter correlation, for three different Reynolds numbers. [36] Suhas V. Patil, P. V. Vijay Babu has been carried out Experimental work to provide the heat transfer and isothermal friction factor data in a Square duct under constant wall temperature condition containing the twisted tape and helical screw tape with core rod inside. The helical screw tape insert not only has a significant effect on augmentation of heat transfer rate, but also considerable increase of friction factor. Triangular ducts are preferred because of their superior heat transfer performance, lower fabrication costs, easy construction and higher mechanical strength. The obstacles used destabilize the flow field, create swirl or vortices, and generate secondary flow field which are all responsible for augmentation of heat transfer rate.

[37] Saeed Zeinali Heri et al. investigated numerically laminar flow-forced convective heat transfer of Al2O3/water nanofluid in a triangular duct under constant wall temperature condition. Numerical results represent an enhancement of heat transfer of fluid associated with changing to the suspension of nanometre sized particles in the triangular duct. The results of the present model indicate that the nanofluid Nusselt number increases with increasing concentration of nano particles and decreasing diameter. [38] N. S. Berbish and M. Moawed., Experiments carried out on a semi-circular duct within a range of Reynolds number ($8{,}242 \leq Re \leq 57{,}794$) under uniform wall heat flux conditions. It is observed that, for a given value of Reynolds number, each of the local heat transfer coefficient and the friction factor has a relatively high value near the entrance of the semi-circular duct then it decreases with increasing the dimensionless axial distance until it approaches a nearly constant value at the fully developed region. [39] Dong Hyun Lee et al., investigated that heat transfer coefficients on the pressure side surface were increased significantly with rotation, while the suction side surface had lower heat transfer coefficients than the stationary channel. for the angled ribs, rib-induced secondary flow dominated the heat transfer characteristics and high heat transfer rates were observed on the regions near the inner wall for the 45° angled ribs and near the leading edge for the 135° angled ribs. [40]S. Eiamsa - ard et al .,observed that as compared to a channel, the heat transfer is enhanced by about 17% for a single triangular prism and by some 85% for a triangular prism pair mounted on the channel wall. Effects of the clearance between the prisms on the heat transfer augmentation. [41] G Sachdeva, R Vasudevan, and K. S Kasana investigated performance of heat exchangers with gas as the working fluid becomes important due to the high thermal resistance offered by triangular duct as compare to plain tube.

Conclusion:-

This review paper discuses the considerable experimental, Numerical and CFD work which has been done on heat transfer augmentation through internal inserts in circular and non circular tubes. Some kind of internal inserts are placed in the flow passage of a tube to augment the heat transfer rate like twist taps insert, screw tap insert, helical tap insert, wire mesh tape insert etc. so the inserts mixes the bulk flow well and therefore performs better in laminar flow. However in laminar flow the thermal resistance is not limited to a thin region. Hence It is concluded that inserts are effective in laminar flow.

Turbulent flow heat transfer augmentation in circular tube is an attractive and important phenomenon. Inserts used in turbulent flow is effective up to a certain Reynolds number because more Reynolds number block the flow and increase the pressure drop. Turbulent flow is more frequently encountered than laminar flow so a great change of local heat transfer rate in separated flow region is achieved and considerable heat transfer augmentation may result up to reattachment region.

Heat transfer of non-circular tube was found considerably higher than the circular tube because of non-circular tube which has a high surface to volume ratio.

However, the question of scalability remains unanswered because of practical difficulties in experimental work. There is a need of analyzing dynamics similarities amongst the geometrical similarities on large scale model covering industrial application , Further research is required to be conducted at a large scale on considerable range of curvature ratio, low range of curvature ratio, low range of Prandtl number and Reynolds numbers, temperature etc.

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