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Review on Experimental Analysis of Heat Transfer in Shell and Twisted Tube Heat Exchanger

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Abstract— In recent years, the high cost of energy and material has resulted in an increased effort aimed at producing more efficient heat exchange equipment. The heat transfer rate can be improved by introducing a disturbance in the fluid flow (breaking the viscous and thermal boundary layers), but in the process, pumping power may increase significantly and ultimately the pumping cost becomes high. Therefore, to achieve a desired heat transfer rate in an existing heat exchanger at an economic pumping power, several techniques have been proposed in recent years

Swirl/vortex flow devices form an important group of passive augmentation techniques. Twisted-tube is one of the most important members of this group which employed extensively in heat exchangers, solar water heater, and chemical process industry. In this work, effect of the twisted tube on heat transfer in a shell and tube heat exchanger was investigating experimentally.

Keywords— Heat exchanger, Twisted tube, Swirl flow, Heat transfer.

I. INTRODUCTION

Most heat exchangers, including twisted tubes, have yet not been exploited commercially to their fullest potential. This may be a surrprising feature of the current industrial practice, particularly in context of viscous liquid applications, where substatial heat transfer enhancement can still be achieved. Inspite of the abundance of technical information, the critical need is Still the availability or lack of generalized thermal hydraulic design guidelines. The majority of correlations are for turbulent flows; laminar and particularly transition flows have recived little attention in spite of the fact that relatively higher heat transfer augmentation is possible in low reynolds number flows. This is because historically, early heat transfer enhancement devices were limited mostly to gas flow applications, such as fire-tube boilers.

The need for more efficient, smaller size exchanger in all varieties has resulted in the development of many heat transfer surfaces that claim to be more efficient than convenntional tubes. This makes a selection of surface configuration for a particular application by no means a simplle task. Just as most issues arre seldom black or white, so are most good solutions seldom unequivocal. Every single truth has a domain of its validity; outside the domain the truth does not hold. Dealing with the heat transfer and heat exchanger design follows this general principles. There is no solution that makes one technology absolutely superior, but there aretechnologies that for particular applications are better than others.

A. Heat Transfer Enhancement In Heat Exchanger

In order to augment heat transfer and to increase thermal performance of the heat exchangers heat transfer enhancement techniques are widely used. These techniques are classified in two groups, active and passive techniques. For active techniques heat transfer rate is improved by supplying extra energy to the system while in passive techniques the purpose is solved without use of any extra energy. The passive techniques include surface area extension (extended surfaces: fins), rough surfaces, inserts, turbulators also called swirl flow devices and coated surfaces.

Second generation enhancement technology is already common in the process industry. Brown fintube`s reccent research and development program is an effort to advance a third generati on of heat transfer enhancement technology, twisted tube exchnagers.

1) *Twisted Tube Exchangers:* A twisted tube is a passive heat transfer enhancement device, generally classified in a swirl flow device category. Swirl flow devices consist of a variety of geometrical flow arrangements that produce forced vortex fluid

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motion in confined flows. The enhancement in all cases occurs primarily due to fluid agitation and mixing induced swirl flow. An attarctive feature of twisted tube is that swirl is not, as in other techniques, produced by a device attached to the tube. As such, they do not require an extra attention during assembly, maintenance, inspection, or cleaning.

These devices consists of helically twisted, double radius oval tubes, welded by their round ends to tubesheets. The purely longitudinal shell-side flow in twisted tube bundles is rarely mentioned in the theory of heat exchanger design, despite its ability to provide considerable surface density, low-pressure drop, and high heat transfer coefficient. The bundle enhances heat transfer, tube-side and shell-side . In the tube-side flow shown in Fig 2, fluid becomes swirled and is affected by wall turbulence and by the different fluid layer velocities. In the course of the shell –side flow over tubes shown in Fig 1, circulation and mixing is generated. A secondary circulation generated by the centrifugal force of swirling also affects the in-bundle flow. Inside and outside hellically shaped tubes double to triple the overall heat transfer rate with about doubled hydraulic resistance. A simple use of such tubes instead of plane, rounded tubes, is equivalent to 30% reduction of the heat exchanger size while keeping a similar heat exchanger duty.

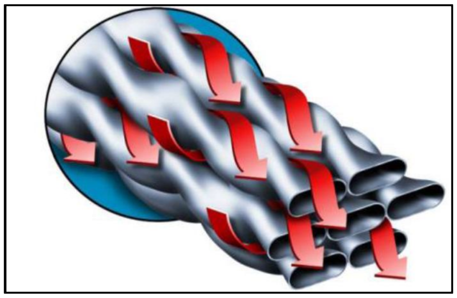

Fig. 1 Shell side flow path

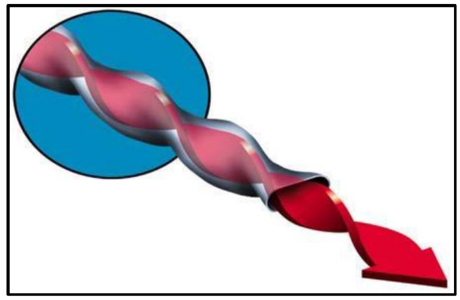

Fig. 2 Inside tube hot water swirl flow path

The twisted tube is a shell-and-tube heat exchanger. It consists of a bundle of tubes fitted inside a cylindrical outer shell. The design differs from a traditional shell-and-tube exchanger by having oval tubes twisted along the longitudinal axis. The number of twists per unit length can vary from design to design. The twist pitch s, is the tube length between each 360˚ twist. Each twisted tube is manufactured with round ends making it possible to fit them into the tube sheets by conventional methods.

The tubes are normally manufactured in a one-step operation ensuring a constant wall thickness and that the material yield point is not exceeded. The mechanical properties of the used material are therefore retained. Twisted tubes can be manufactured from a full range of materials including carbon steels, stainless steels, titanium, copper and nickel alloys. Arrangement of the tubes can either be done in a triangular or a rectangular pitch and the tube cross-section can be varied.

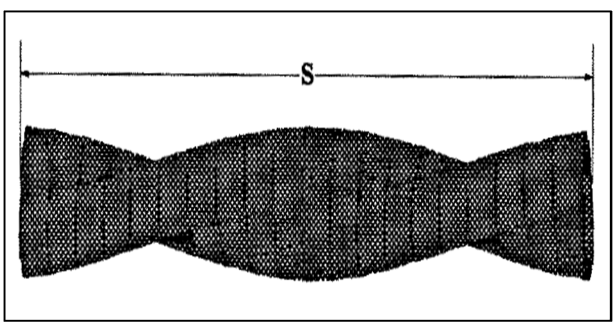

Fig. 3 Twisted Tube Geometry

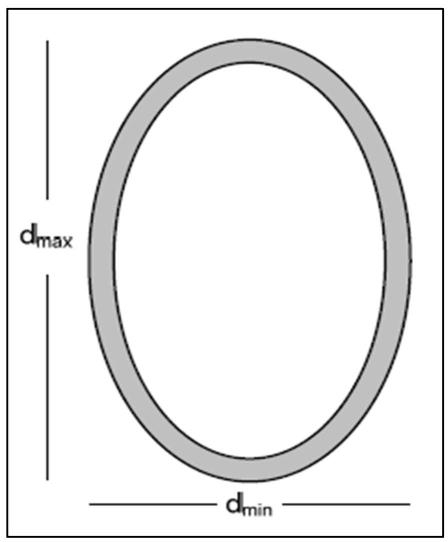

Fig. 4 Cross section of a twisted tube

The Fig 3 and Fig 4, shows the twisted tube geometry which has the twist pitch as well as the cross-sectional area of a twisted tube which is in elliptical cross section and the twist pitch is nothing but the distance travelled in 360˚ rotation.

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II. REVIEW OF WORK CARRIED OUT

Prof.R.Donald Morgan gives the comparison of the construction, performance, and economics of Twisted Tube exchangers against conventional designs for various materials of construction including reactive metals. Conventional TEMA (Tubular Exchanger Manufacturers Association) type shell and tube type heat exchangers consist of a number of round tubes attached to a tube sheet inside a cylindrical vessel, with tube sizes, tube lengths, and shell diameters varying depending on the requirements of the application. The thermal effectiveness (ε), of a shell and tube exchanger is normally calculated assuming perfect radial and no axial mixing of the shell side stream. In practice however, there is considerable axial mixing within a baffle compartment, and further, the stream is in cross-flow for part of the time rather than axial flow. The Twisted Tube exchanger consists of a bundle of uniquely formed tubes assembled in a bundle without the use of baffles (Fig. 5). The tubes have been subjected to a unique forming process which results in an oval cross section with a superimposed helix providing a helical tube-side flow path.

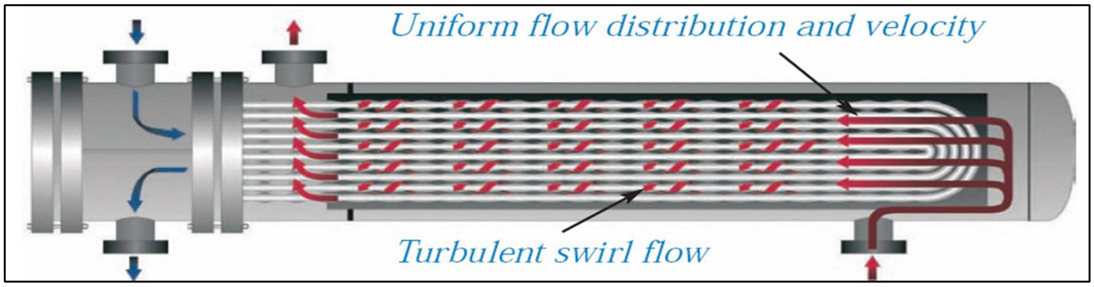

Fig. 5 Twisted Tube Heat Exchanger Bundle

The elimination of dead spots on the shell-side and the increased turbulence, both on the shell-side and the tube-side results in reduced fouling. Particulate fouling is reduced by the scouring action. Other types of fouling such as scaling and chemical reaction products are prevented by the removal of hot spots. Flow induced vibration can occur in conventional exchangers although special precautions such as "no tubes in window" are available to overcome the problem by providing more tube support. The most damaging vibration arises from fluid-elastic instability that can lead to damage within a few hours of operation. The possibility of such vibration in twisted tube exchangers is completely eliminated by axial flow and because the tubes are supported approximately every two inches along the tube length.

Prof. P.Eswar Raja Babu studied the recent innovation and development of a latest heat exchanger technology, known as Twisted Tube technology, which has been able to overcome the limitations of the conventional technology, this technology provides solution to almost all mentioned problems and provide good overall heat transfer coefficients through tube side enhancement. However the efficiency of the existing heat exchangers is poor and no longer high when used for longer time. In order to enhance the rate of heat transfer and efficiency twisted tube heat exchangers play a vital role. Recent advances in the range of design and operational reliability and flexibility have made twisted tube heat exchangers attractive in various industries, including offshore applications, pharma, dairy industries and in the field of petroleum processing industries. Taking into the size and surface area of contact, these heat exchangers can be cost effective in a wider range of applications than the traditional type of heat exchangers employed in process industries. This devices consists of helically twisted double radius oval tubes, welded their round ends to tube sheets. This device design is similar to structure of Human DNA which is double helical in patterns and extended all along the length and finally ends with DNA strands. The purely longitudinal shell side flow in twisted tube bundles thereby has an ability to provide high surface area (and density), low pressure drop, good heat transfer rates and coefficients. In comparing twisted tube to conventional baffled heat exchangers, it should be noted that the compactness of twisted tube bundles leads to high performance. Thus a twisted tube heat exchanger tube bundles tends to have higher heat transfer coefficients .This leads to higher overall performance despite the adverse effect smaller hydraulic radius has on the frictional pressure drop. He made the conclusion that It is ultimately apparent that the development of rationally optimized heat exchanger design with superior surface characteristics could be achieved only if the basic phenomenon are well known and understood. In spite of considerable activity , the field of enhanced heat transfer is not the old and casual. In fact it is anything but ordinary. Experimentation is difficult, modeling of the phenomenon is not that easy and it involves tedious work and calculations with sophisticated analytical and numerical techniques are required to get the results that exactly fit the model of the equipment and give satisfactory results. However this technology is more expensive than a conventional shell and tube, plate type heat exchangers, but their payback time is quite less. Taking the factors such as high heat transfer coefficients, high Reynolds ,Nusselts and Prandtle numbers, good flow characteristics and conditions favouring the rates of heat transfer it finds a unique position in the filed process engineering and all chemical engineering applications.

Prof. Parag S. Desale gives that such techniques keeping focus on passive augmentation techniques used in heat exchangers. The thermal performance behavior for tube in tube heat exchanger is studies for wire coil inserts, twisted tape inserts and their combination. The literature survey in this area shows that a lot of research work has been carried out on passive techniques, specially wire coil inserts and twisted tapes. They have done experimental investigation on wire coil inserts acting alone and by varying wire thickness, coil pitch, coil separation from tube wall, wire cross section and have developed correlations for Nusselt number with different variables listed. The same kind of experimentation is also been performed to study heat transfer and pressure drop for twisted tape inserts by varying tape thickness, twist ratio. S. He concluded that the results of smooth tube test are studied and the results from the combined devices are also compared with those from each device alone. Their result shows that twisted tapes are good with heat transfer improvement but are poor with friction factor analysis.

III. IMPROVING EFFICIENCY

A. Increased heat transfer coefficient

1) Swirl flow creates turbulence resulting in higher tube side coefficient.
2) Uniform fluid distribution combined with interrupted swirl flow result in optimized shell side coefficient.
3) Higher tube side heat transfer coefficient

B. Lower pressure drop

1) The longitudinal swirl flow of twisted tube technology reduces the high pressure drop associated with segmental baffles.
2) Twisted tube heat exchangers are usually shorter in length and have fewer number of passes for a lower pressure drop on the tube side.

C. No vibration

1) Baffles free design directs shell side fluid to true longitudinal flow.
2) Each tube using twisted tube technology is extensively supported at multiple contact points along its entire length.
3) Tube fretting and failure due to vibration is eliminated.

D. Reduced fouling

1) Baffles free design eliminates dead spots where the fouling can occurs.
2) Velocity is constant and uniform.
3) Constant flow distribution controls tube wall temperature.

IV. CONCLUSION

The construction, performance, and use of Twisted Tube type heat exchangers have been reviewed .These heat exchangers are compact and more effective than conventional shell and tube heat exchanger. The fabrication cost and the work during the fabrication is tedious work so it effects on the fabrication costing. It has been shown that this type of heat exchanger offers a number of advantages over the conventional shell and tube exchanger with segmental baffles. In suitable applications, Twisted Tube heat exchangers offers superior economic performance as defined by cost per unit heat load when compared to the alternative of conventional shell and tube type equipment

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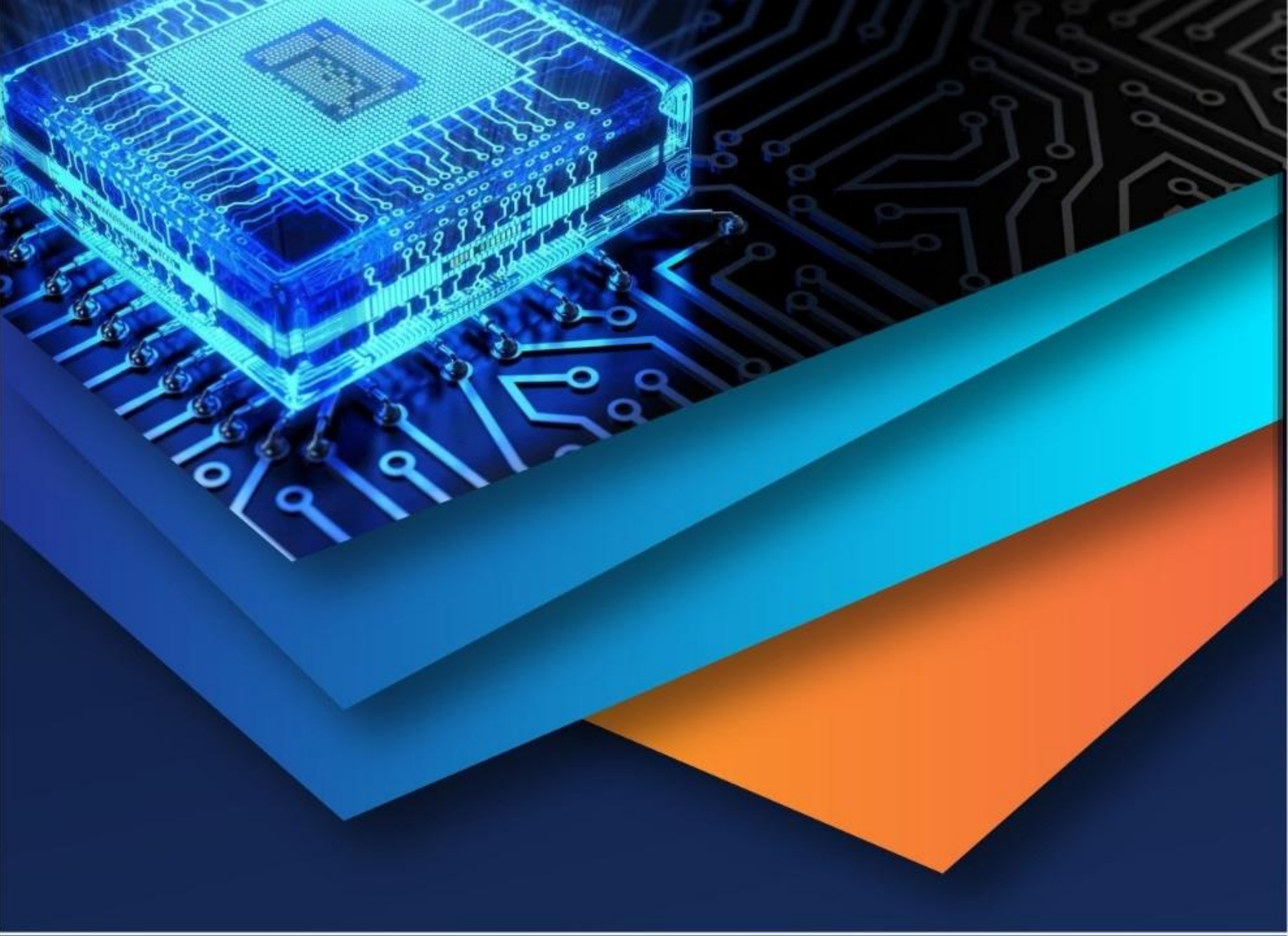

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