International Journal of Engineering Research and General Science Volume 3, Issue 1, January-February, 2015
ISSN 2091-2730

Review on Experimental Analysis and Performance Characteristic of Heat Transfer In Shell and Twisted Tube Heat Exchanger

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Abstract— All new heat exchanger applications in oil refining, chemical, petro-chemical, and power generation are accommodated through the use of conventional shell and tube type heat exchangers. The fundamental basis for this statistic is shell and tube technology is a cost effective, proven solution for a wide variety of heat transfer requirements. However, there are limitations associated with the technology which include inefficient usage of shell side pressure drop, dead or low flow zones around the baffles where fouling and corrosion can occur, and flow induced tube vibration, which can ultimately result in equipment failure. This paper presents a recent innovation and development of a new technology, known as Twisted Tube technology, which has been able to overcome the limitations of the conventional technology, and in addition, provide superior overall heat transfer coefficients through tube side enhancement. This paper compares the construction, performance, and economics of Twisted Tube exchangers against conventional designs for copper materials of construction including reactive metals.

Keywords— Heat exchanger, twisted tube technology, heat transfer, corrosion resistance, Vibration free, Increase efficiency, Baffles free.

I. INTRODUCTION

Heat Exchanger is a device used for efficient heat transfer from one fluid to other fluid a typical heat exchanger is shell and tube heat exchanger. They consist of series of finned tubes in which one of the fluid runs in the tube and the other fluid run over the tube to be heated or cooled During the heat exchanger operation high Pressure High temperature water or steam are flowing at high velocity inside the tube or plate system. A heat exchanger utilizes the fact that, where ever there is a temperature difference, flow of energy occurs. So, That heat will flow from higher temperature heat reservoir to the lower temperature heat reservoir. The flowing fluids provide the necessary temperature difference and thus force the energy to flow between them. The energy flowing in a heat exchanger may be either sensible energy or latent heat of flowing fluids. The fluid which gives its energy is known as hot fluid. The fluid which receives energy is known as cold fluid. It is but obvious that, Temperature of hot fluid will decrease while the temperature of cold fluid will increase in heat exchanger. The purpose of heat exchanger is either to heat or cool the desired fluid.

A heat exchanger is a device that is used to transfer thermal energy (enthalpy) between two or more fluids, between a solid surface and a fluid, or between solid particulates and a fluid, at different temperatures and in thermal contact. In heat exchangers, there are usually no external heat and work interactions. Typical applications involve heating or cooling crystallize, or control a process fluid. In a few heat exchangers, the fluids exchanging heat are in direct contact. In most heat exchangers, heat transfer between fluids takes place through a separating wall or into and out of a wall in a transient manner. In many heat exchangers, the fluids are separated by a heat transfer surface, and ideally they do not mix or leak. Such exchangers are referred to as direct transfer type, or simply recuperators. In contrast, exchangers in which there is intermittent heat exchange between the hot and cold fluids via thermal energy storage and release through the exchanger surface or matrix are referred to as indirect transfer type, or simply regenerators. Such exchangers usually have fluid leakage from one fluid stream to the other, due to pressure differences and matrix rotation/valve switching. Common examples of heat exchangers are shell and tube exchangers, automobile radiators, condensers, evaporators, air pre-heaters, and cooling towers. If no phase change occurs in any of the fluids in the exchanger, it is sometimes referred to as a sensible heat exchanger. There could be internal thermal energy sources in the exchangers, such as in electric heaters and nuclear fuel elements. Combustion and chemical reaction may take place within the exchanger, such as in boilers, fired heaters, and fluidized bed exchangers. Mechanical devices may be used in some exchangers such as in scraped surface exchangers, agitated vessels, and stirred tank reactors. Heat transfer in the separating wall of a recuperator generally takes place by conduction. However, in a heat pipe heat exchanger, the heat pipe not only acts as a separating wall, but also facilitates the transfer of heat by condensation, evaporation, and conduction of the working fluid inside the heat pipe. In general, if the fluids are immiscible, the separating wall may be eliminated, and the interface between the fluids replaces a heat transfer surface, as in a direct-contact heat exchanger.

II. HEAT TRANSFER ENHANCEMAENT TECHNIQUES

- Heat transfer enhancement is one of the fastest growing areas of heat transfer technology.
- The technologies are classified into active and passive techniques depending on how the heat transfer performance is improved.
- A twisted tube is a typical passive technique that uses a specific geometry to induce swirl on the tube side flow.
- The twisted tube heat exchanger consists of a bundle of uniquely formed tubes assembled in a bundle without the use of baffles.
- Twisted tube technology provide highest heat transfer coefficient possible in tubular heat exchanger.
- In uniform shell side flow the complex interrupted swirl flow on shell side maximizes turbulence while minimizing pressure drop.
- The tube ends are round to allow conventional tube to tube sheet joints.
- Swirl flow in tube creats turbulence to improve heat transfer.
- By keeping the flow turbulent one secures a high heat transfer performance.

III. REVIEW OF WORK CARRIED OUT

P.S..Gowthaman et al. have experimentally analyzed heat exchanger is a device used for efficient heat transfer from one fluid to other fluid a typical heat exchanger is shell and tube heat exchanger. They consist of series of finned tubes in which one of the fluid runs in the tube and the other fluid run over the tube to be heated or cooled during the heat exchanger operation high Pressure high temperature water or steam are flowing at high velocity inside the tube.

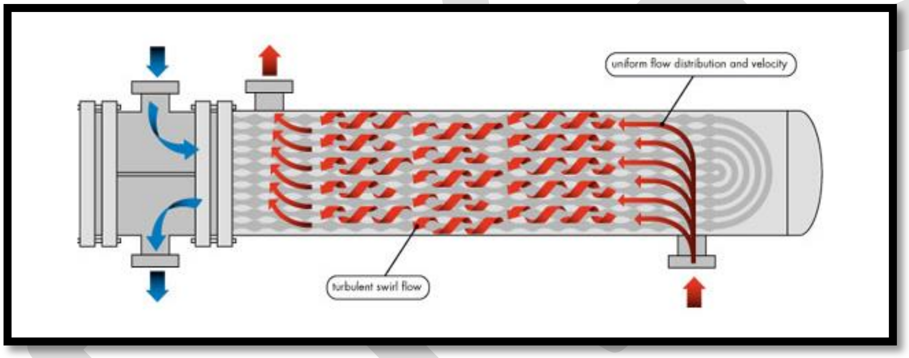

Fig.1.1 Shell and Twisted tube heat exchanger

Butterworth,D. et al have experimentally analyzed the Twisted Tube exchanger, it consists of a bundle of uniquely formed tubes assembled in a bundle without the use of baffles (Fig.1.1). 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 also cold water inlet and hot water outlet is indicated by blue colour from the top side and bottom side of shell respectively. The forming process ensures that tube wall thickness remains constant and the material yield point is not exceeded thereby retaining mechanical integrity. The tube ends are round to allow conventional tube to tube sheet joints .

The helical channel formed in the inter tubular space can be looked upon as series of consecutive short sections of which the build up of a steady velocity profile is interrupted by the constant direction change of the flow. Good transverse mixing is achieved by these interruptions, and the numerous disturbances keep the flow turbulent even at relatively low Reynolds numbers. The turbulent regime offers substantially higher convective heat transfer coefficients compared to laminar flow. By keeping the flow turbulent one secures a high heat transfer performance. These mechanisms contribute to higher heat transfer coefficients on the shell side flow (Fig.1.2). For the tube side flow there are several mechanisms that contribute to high thermal performance(Fig.1.3).

In a conventional shell and tube heat exchanger the radial temperature gradient on the tube side can be considerable because the transverse mixing is relatively low. More specifically the core of the tube flow will have a different temperature than the flow near the wall. The heat transfer between the two fluids is then reduced as a result of the lowered temperature difference across the wall. The twisted tube has an important feature that overcomes this problem. Because the swirl flow produces inertial mass forces there will by generated a secondary flow which enhance the tube side mixing.

A wide range of tube materials can be used including carbon and stainless steels, Cr-Mo alloys, duplex and super duplex alloys as well as titanium, zirconium and tantalum. Tube diameter may vary from 10mm to 15mm. The tube material used in this experiment is copper while the shell material used is mild steel. Tubes are assembled into a bundle on a triangular pitch one row at a time with each tube being turned to align the twists at every plane along the bundle length. This alignment results in tubes contacting adjacent tubes at many points along the length of the tube in the bundle (Fig.2). The completed bundle is then tightly strapped circumferentially to ensure no tube movement and a robust bundle is the end result, Bundles can be constructed with more than 5000 tubes depends on requirement but in this experiment 18 tubes are used and shell size up to 160mm in diameter with tube lengths up to 700mm, but in our actual setup we reduce number of tubes, diameter and lengths.

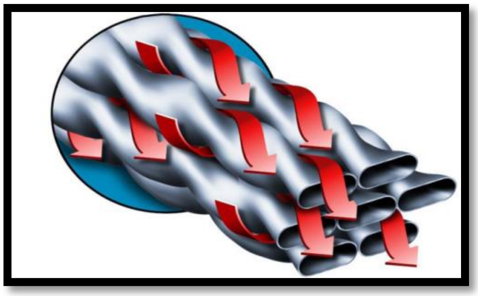

Fig.1.2 Shell side flow path (uniform shell side velocity)

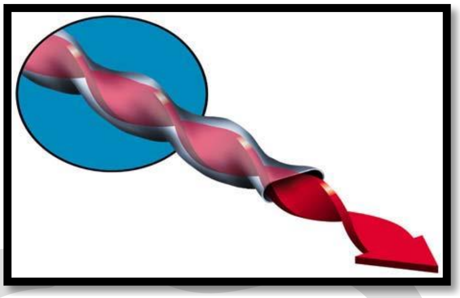

Fig.1.3 Inside tube hot water swirl flow path

The shell-side flow path is complex and predominantly axial in nature as shown above (Fig.1.2). Typically, the shell side flow area is approximately equal to the tube side flow area. The bundle is often shrouded to ensure shell side flow remains in the bundle and minimizes bypassing. Paths are available to allow the fluid to flow into and out of the bundle at each end. When high inlet and outlet velocities must be avoided, “vapor belts” may be used as with conventional designs. The Twisted Tube design imparts a swirl flow to the tube-side fluid enhancing the tube-side heat transfer coefficient.

The twisted tube is a baffle free design. One could think that this result in a fragile tube bundle construction making the heat exchanger exposed to fluid induced vibration. In reality the twisted tube design gives a more rigid tube bundle compared to the conventional shell and tube concept.

Fig.2 Completed twisted tube bundle

This is a consequence of the fact that each tube is in physical contact with the surrounding tubes along the whole length. These contact points are more frequent per unit length than baffle-to-tube joints in a conventional exchanger. The baffle free design is also claimed to give lower pressure drop (relative to heat transfer rate) because the shell side flow is not forced to do turns and pass sharp edges.

The shell side flow follows a complex pattern which is predominantly axial. To make sure that the shell side flow does not bypass the tubes, the bundle is shrouded. The shroud itself is a metal sheet that covers the bundle. The tube side flow is swirled enhancing heat transfer. The intensity of the swirl depends on the cross sectional shape and the twist pitch to diameter ratio.

This exchanger, shown in Fig.1.1, is generally built of a bundle of round tubes mounted in a cylindrical shell with the tube axis parallel to that of the shell. One fluid flows inside the tubes, the other flows across and along the tubes. The major components of this exchanger are tubes (or tube bundle), shell, front-end head, rear-end head, and tube sheets. A variety of different internal constructions are used in shell-and-tube exchangers, depending on the desired heat transfer and pressure drop performance and the methods employed to reduce thermal stresses, to prevent leakages, to provide for ease of cleaning, to contain operating pressures and temperatures, to control corrosion, to accommodate highly asymmetric flows, and so on. Shell-and-tube exchangers are classified and constructed in accordance with the widely used TEMA (Tubular Exchanger Manufacturers Association) standards (TEMA, 1999), DIN and other standards in Europe and elsewhere, and ASME (American Society of Mechanical Engineers) boiler and pressure vessel codes. TEMA has developed a notation system to designate major types of shell-and-tube exchangers. In this system, each exchanger is designated by a three-letter combination, the first letter indicating the front-end head type, the second the shell type, and the third the rear-end head type.

IV. Improving Efficiency

Increased heat transfer coefficient

- Swirl flow creates turbulence resulting in higher tube side coefficient.
- Uniform fluid distribution combined with interrupted swirl flow result in optimized shell side coefficient.
- 40% higher tube side heat transfer coefficient

Lower pressure drop

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

No vibration

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

Reduced fouling

- Baffles free design eliminates dead spots where the fouling can occure.
- Velocity is constant and uniform.
- Constant flow distribution controls tube wall temperature.

V. CONCLUSION

The construction, thermal characteristics, performance, and use of Twisted Tube type heat exchangers have been reviewed. 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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