Twisted Type Shell and Tube Heat Exchangers

[1]Pradip Pathade, [2]Anmol Singh
Department Of Chemical Engineering
Mahatma Gandhi Mission's College Of Engineering and Technology, Kamothe, Navi Mumbai, Maharashtra 410209.

***Abstract* - Many industrial facilities face problem of effective heat transfer due to the performance issues of heat exchangers. Optimizing changes in flow regime and redesigning heat exchangers for best possible heat exchange for maximizing profits. Twisted tube type shell and tube heat exchanger (TTSTHE) combats nearly all performance drawbacks in conventional heat exchangers. 'Twisted Tube Technology' is the new technology in the era of heat transfer equipment.The concept of swirl flow moment of fluid creates turbulence enhancing thermal-hydraulic performance of TTSTHE. The TTSTHE increases the overall efficiency of heat transfer.Fig [4]. The advantage of twisted type shell and tube heat exchanger over conventional heat exchanger are Studied in this paper on the basis of economics, performance and material of construction including reactive metals for improved performance, no vibration, and no dead spots etcetera. The retrofit situation is increased capacity, lower installed cost, lower shell side pressure drop and low fouling over shell and tube heat exchanger. The literature also supports the application of twisted type shell and tube heat exchanger in large scale and small scale industries. The challenges faced are mostlyin operating and maintaining this type heat exchangers. However, engineering and design standards are crucial for design and construction consideration of heat exchanger needs to be looked into.**

***Keywords*: optimizing, profits, twisted tube technology, TTSTHE, swirl flow, retrofit, fouling.**

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1. INTRODUCTION

Economics of chemical process industry is strongly related to size, operating and maintenance cost of heat exchange equipment. Twisted tube shell and tube heat exchangers (TTSTHE) are compact having values greater than 700 m^2/m^3**[3]**.In process design and development these exchangers have wide range of applications than the niches currently being used in industry. In 1994 Koch Heat Transfer Incorporated (former Brown Fin tube Company) has been manufacturing and marketing TTSTHE to world market. Their opinion was that main barrier to heat flow in conventional heat exchangers is the convective resistance to heat flow on inner and outer tube surface. Considering losses and resistances thermal effectiveness is only 60-80% with the back and forth flows of shell side fluid giving higher pressure drop than expected value. Also, flow around baffles is not uniform creating fouling, dead spots, and low heat transfer. Instead they suggested the use of TTSTHE as a solution in which the tubes are subjected to a unique forming process in one step ensuring constant tube thickness and yield point is not exceeded which results in oval tubes twisted along the longitudinal axis. The twist pitch's' is the tube length between each 360 degree twist. In twisted tubes the swirl flow produces secondary flow which enhances turbulence in low Reynolds number range on both tube side and shell side **[4]**. Materials used for tubes are carbon steels, stainless steels, titanium, copper and nickel alloys. TTSTHE is a baffle free design because every tube is kept in contact point by six surrounding tubes per each 360 degree twist by proper alignment of tubes **Fig [2]**.Pressure drop in the shell side is low because of baffle free design and shell side no sharp diversion of fluid. The twisting of tubes produces swirl flow which enhances tube side mixing. The shell side flow path is complex and axial in nature.
There is no solution that makes one technology absolutely superior, but there are technologies that for particular applications are more suited than others this concept are most required in **process designing and development**.
Example; as the sources of oil and gas are slowly exhausting new fields have to be explored which are often located on remote locations with difficult environment conditions because of large distances and deep seawater pipeline transformation to the consumer is too expensive. An alternative to pipeline transportation is Liquefied natural gas (LNG). By cooling the product it reduces volume by approximately 600 times, it means energy intensity in terms of volume is increased **[1]**. Hence it is economical and practical to ship the product to consumers. To cool the product and convert into LNG TTSTHE is the best choice.

2. Materials &Methods

Evaluate the performance and compare all parameters of conventional heat exchanger and twisted tube heat exchanger analytically.
Based on mathematical modeling equations of TTSTHE **[1],[4]**

$$Q = f_T * U * A * \Delta T_{lm} \text{.........} (1)$$

$$d_h = \frac{d_{max} * d_{min}}{\{3(d_{max}+d_{min})[(3d_{max}+d_{min})(d_{max}+3d_{min})]^{0.5}\}} \text{..........} (2)$$

$$Nu = \frac{h * d_h}{k}$$

$$Re = \frac{\rho * v * d_h}{\mu}$$

$$Pr = \frac{Cp * \mu}{k}$$

$$Fr = \frac{s^2}{d_{max} * d_h} \quad \ldots\ldots\ldots (3)$$

Tube side coefficient: $Nu = 0.21 * Re^{0.8} Pr^{0.4} * \left[1 + 3.74\left(\frac{s}{d_{max}}\right) - 1\right]\left(\frac{T_{wt}}{T_{bt}}\right)^n \ldots (4)$

Shell side coefficient: $Nu = 0.521 * Re^{0.8} * Pr^{0.4} * \left(\frac{T_{ws}}{T_{bs}}\right)^{-0.55} \ldots\ldots (5)$

Overall heat transfer coefficient: $U = \left(\frac{1}{hi} + \frac{L}{kc} + R_f + \frac{1}{ho}\right) \ldots\ldots (6)$

Total pressure drop $\Delta P_{total} = \Delta P_{entrance} + \Delta P_{core} + \Delta P_{exit}$ ……. (7)

Tube side friction coefficient: $f_D = 0.92 * \left(\frac{s}{d_h}\right)^{-0.55} * Re^{-0.18}$ …… (8)

Shell side friction coefficient: $f_D = 10.5 Fr^{-1.6181 + 2.263 log Fr}$ ……. (9)

Core pressure drop $\Delta P_{core} = \frac{f_D * L}{2 d_h \rho v^2}$ …… (10)

Nusselt number = f(Re, Pr, Fr)

Darcy friction factor = f(Re, Fr)

TTSTHE is a swirl flow device, which produces active centrifugal force flow field, promoting radial velocity change inside tubes which will have positive effects on heat & mass transfer. To allow optimization of TTSTHE swirl flow dimensionless no ‘Fr’ is defined

In TTSTHE the shell side HTC is increased because, there is an interruption of shell side fluid steady state velocity profile by change of flow directions in helical channels. **Fig [4]**

Also, due to the helical twist in tubes there is increase in velocity gradient at tube wall producing local secondary flow increasing tube side HTC. **Fig [3]**

3. RESULT AND DISCUSSIONS:

Example 12.1 pg. 761[5] & [1] Solving the problem & calculating for single pass countercurrent flow by analytical method we get following results.

Table 1: Comparison between conventional heat exchanger and TTSTHE.

Parameter	Unit	Shell and tube HE	TTSTHE
Heat duty (Q)	kW	4338.9	4338.9
Surface area of tube	m^2	0.30	0.46
No of tubes	-	918	594
Inside H.T.C (h_i)	W/m²°C	3810.9	6956.45
Outside H.T.C (h_o)	W/m²°C	2737	4450.34
Overall H.T.C (U)	W/m²°C	834.8	1065.58
ΔP_{tube}	kN/m²	7.26	11.26
ΔP_{shell}	kN/m²	4.31	3.136
Thermal Efficiency	%	60-70	90-95

Based on my examinations and **[1], [2], [3];**

- The thermal performance of twisted tube is excellent over conventional exchangers.
- Elimination of dead spots, less fouling on cross section due to evenly distributed flow on shell side. **Fig[5]**
- Due to rigid and packed tube alignment twisted tube bundle is self-supported eliminating chances of flow induced vibration. **Fig[2]**
- TTSTHE do not foul easily due increase in turbulence hence increase in maintenance and run time over conventional. **Fig[5]**
- Creating swirl flow has a cost in terms of pressure loss but also reducing the size of exchanger by a factor of 1.25 - 1.4.
- The increase in pressure drop is relatively small compared to gained heat transfer.

TTSTHE has large scale applications in petroleum, power, pulp &paper, etc.

4. CONCLUSION

The construction, thermal characteristics, performance, comparison of TTSTHE has been studied. It is examined that TTSTHE shows a number of advantages over conventional shell and tube exchangers. TTSTHE has more initial cost than conventional exchangers but, their payback time is shorter considering the process development it is a good investment to be made.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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NOMENCLATURE

d_{max} ,d_{min}-max &min diameter of twisted tube.
d_h- hydraulic diameter.
s –Twisted pitch.
Nu –nussel tnumber.

Re –Reynolds number.

Pr - prandtl number.
Fr - dimensionless swirl number.
T_{ws},T_{bs}- Temperature of wall and bulk flow on shell side.
T_{wt},T_{bt} - Temperature of wall and bulk flow on tube side.
f_D-Darcy friction factor.
ΔT_{lm}= logarithmic temperature difference.
f_T= correction factor for LMTD.

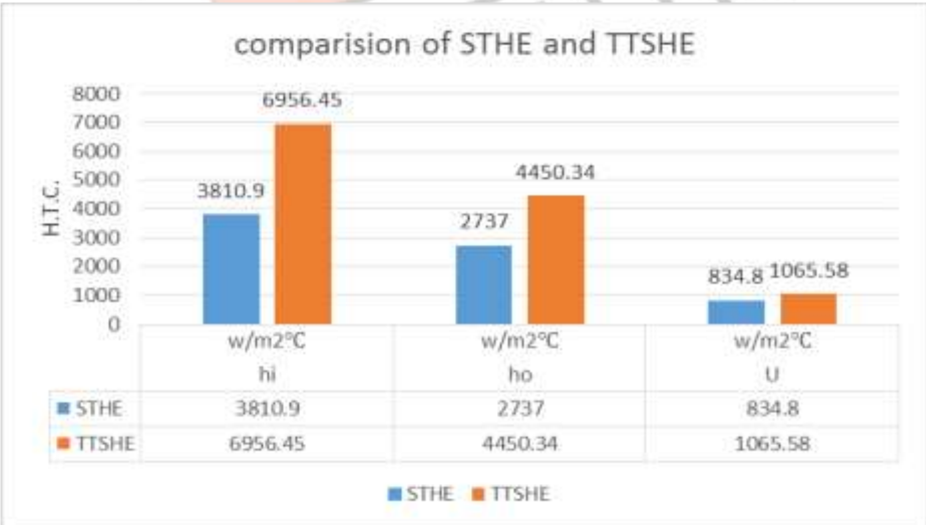

Fig 1: Thermal performance.

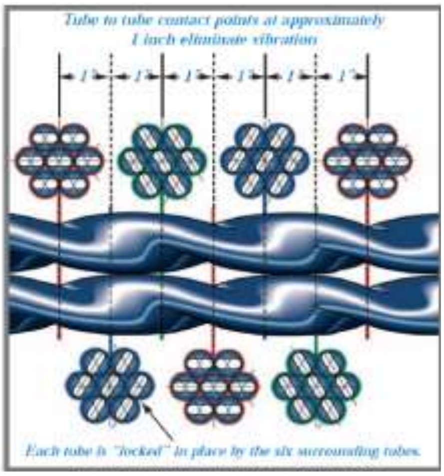

Fig 2: Tube alignment.

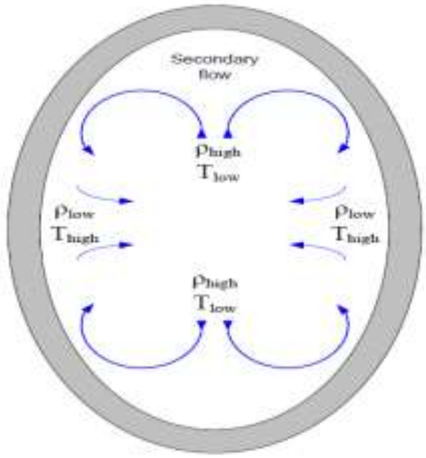

Fig 3: Cross section of twisted tube showing secondary flow

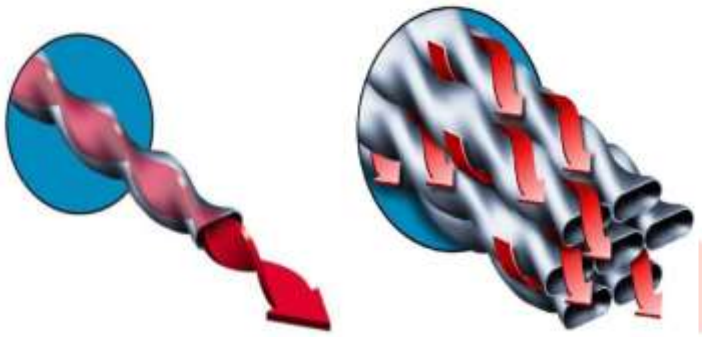

Fig 3: Twisted tube bundle

Fig 4: Flow pattern fluids in TTSTHE

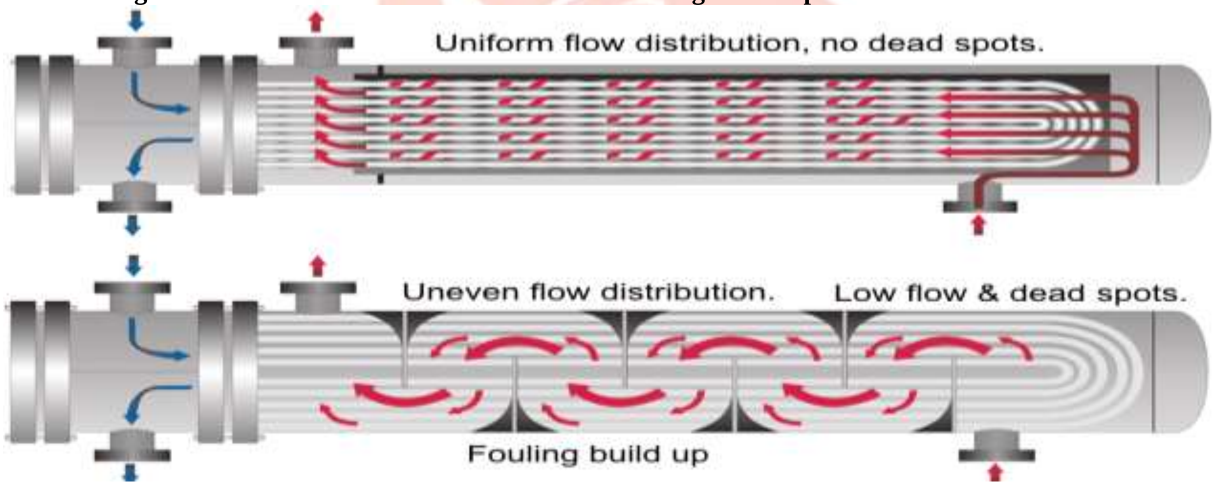

Fig 5: Flow pattern of shell side in twisted tube and conventional shell and tube.