Effect of Baffle Geometry on Shell and Tube Heat Exchanger-A Review

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Abstract— Shell and tube type heat exchanger is used as universal equipment in many industrial departments, such as chemical industry, oil refining process, power plant, food industry, and so on. Heat exchanger is playing an important role in product quality, energy utilization and system economic and reliable performance. In recent years, there have been significant researches on the performance of shell and tube heat exchanger especially on the effect of baffle inclination angle, space, types upon heat transfer and pressure drop. The objective of this paper is to present the different effect of baffle on the pressure drop, overall heat transfer coefficient and other parameter.

Key words: shell and tube heat exchanger, baffle, heat transfer coefficient, pressure drop, mass flow rate

I. INTRODUCTION

Heat exchangers are widely used in refrigeration air conditioning, and chemical plants. They can be employed in various uses, for instance, to effectively transmit heat from one fluid to the other. Shell-and-tube heat exchangers (STHXs) are widely applied in various industrial fields such as petroleum refining, power generation and chemical process, etc. Tremendous efforts have been made to improve the performances on the tube side. For the shell side, the velocity and temperature fields are relatively complicated and the thermal hydraulic performance depends on the baffle elements to a great extent.

The shell and tube heat exchanger provide large ratio of heat transfer area to volume and weight. It provides this surface in a form which is relatively easy to construct in a wide of sizes which is mechanically rugged enough to withstand normal shop fabrication stresses, shipping and field erection stresses and normal operating conditions. The shell and tube exchanger can be reasonably easily cleaned, and those components most subjected to failure gasket and tubes can be easily been replaced. The shell and tube exchanger offers great flexibility of mechanical features to meet almost and service requirements.Thus, higher pumping power is often needed to offset the higher pressure drop under the same thermal load. Therefore, it is essential to develop a new type of STHXs with improved baffles and reduce pressure drop while maintaining and even increasing shell side heat transfer performance. To overcome the above-mentioned drawbacks of the conventional segmental baffle, Shell and Tube Heat exchangers with helical baffles were firstly proposed by Lutcha and Nemcansky. The helical baffles in STHXs are shaped approximately as helicoids in order to urge the shell-side fluid to flow in approximately continuous helical flow. They investigated the flow patterns produced by such baffle geometry with different helix angles and found that helical baffles could force the shell-side fluid to approach plug flow, which increased the average temperature driving force.

Helical baffle heat exchangers have shown very effective performance especially for the cases in which the heat transfer coefficient in shell side is controlled; or less pressure drop and less fouling are expected. It can also be very effective, where heat exchangers are predicted to be faced with vibration condition.

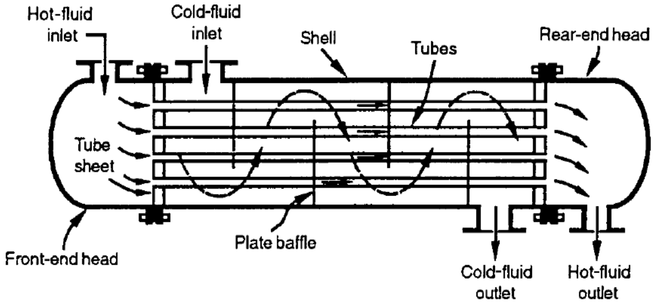

Fig. 1: Shell and Tube Heat Exchanger

A. *Yonghua You, Aiwu Fan, Suyi Huang, Wei Liu[1]:*

The numerical model is solved at shell-side Reynolds numbers ranging from 6813 to 22,326 for a STHX with flower baffles, and reasonable accuracy is demonstrated by the comparison with test data. The contours of the velocity and temperature fields, together with the distribution of convective heat transfer coefficient on the shell side, were obtained for the heat exchangers with and without flower baffles.

From the result it is clear that with the installation of flower baffles, the fluid velocity magnitude and convective heat transfer coefficient vary in a periodical way in the central part of the FB-STHX(flower baffle), and three regions with small, moderate or large convective heat transfer coefficients are generated after the flower baffles.

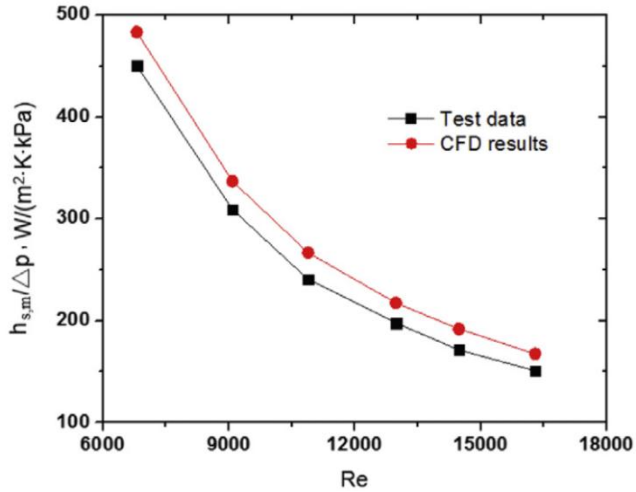

Fig. 2: Overall performance index $h_{s,m}/D_p$ on the shell side between CFD results and test data for the heat exchanger with flower baffles.

The overall heat transfer enhancement on the shell side depends on their compromise. As for the investigated FB-STHX (flower baffle), the heat transfer rate is effectively enhanced on the shell side. Moreover, a comparison of contours between FB-STHX and SG-

STHX(segmental baffle) was performed. It is found that they have different flow patterns, and the FB-STHX has a better overall thermal hydraulic performance than the SG-STHX. FB-STHX has a better overall thermal hydraulic performance than the SG-STHX.

Farhad Nemati Taher, Sirous Zeyninejad Movassag, Kazem Razmi, Reza Tasouji Azar [2]

They found that baffle spaces have significant impact on helical STHXs performances.

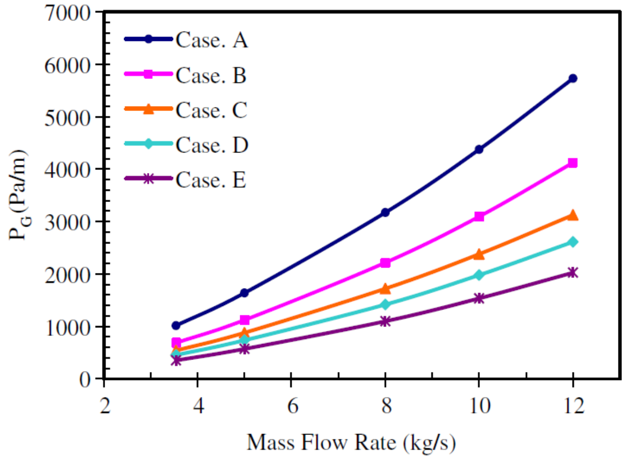

Fig. 3: Heat transfer coefficient per pressure gradient versus mass flow rate.

The major findings are summarized as follow:

(1) Pressure gradient increases with the decrease of baffle spaces.
(2) At the same mass flow rate and the same working condition, longer baffle spaces result in lower heat transfer coefficients.
(3) At the same pressure gradient, longer baffle spaces have higher heat transfer coefficients and among all simulated cases, case E (end-to-end type), resulted the highest heat transfer coefficient.

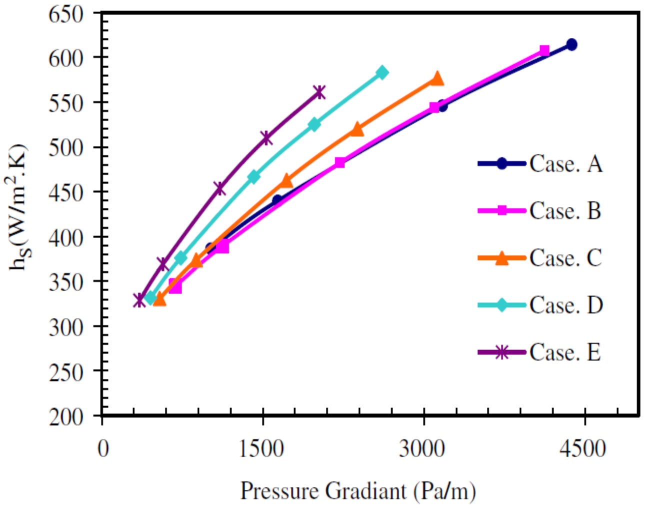

Fig. 4: Heat transfer coefficient versus pressure gradient

B. Mayank Vishwakarma, K. K. Jain[3]:

The researchers decrease the pressure drop and to increase the heat transfer and the ratio of heat transfer and pressure drop in shell and tube type heat exchanger by tilting the baffle angle up to which we get the minimum pressure drop.

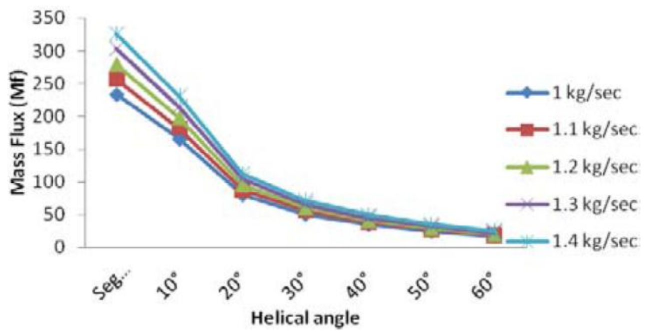

Fig. 5: Graph plot between shell-side mass flux and helical angle

The thermal analysis of helical baffle heat exchanger using Kern's method gave clear idea that the ratio of heat transfer coefficient per unit pressure drop is maximum in helical baffle heat exchanger as compared to segmental baffle heat exchanger.

C. Qiuwang Wang, Qiuyang Chen et al.[4]:

The numerical results show that, under the same mass flow rate M and overall heat transfer rate Qm, the average overall pressure drop D_{pm} of the CMSP-STHX(combined multiple shell-pass) is lower than that of conventional SG-STHX by 13% on average.

Under the same overall pressure drop D_{pm} in the shell side, the overall heat transfer rate Q_m of the CMSP-STHX is nearly 5.6% higher than that of SG-STHX and the mass flow rate in the CMSP-STHX is about 6.6% higher than that in the SG-STHX. The CMSP-STHX might be used to replace the SG-STHX in industrial applications to save energy, reduce cost and prolong the service life.

In this paper, a combined multiple shell-pass STHX with continuous helical baffles in the outer shell pass (CMSP-STHX) is investigated with CFD method and compared with a single shell pass STHX with segmental baffles (SG-STHX).

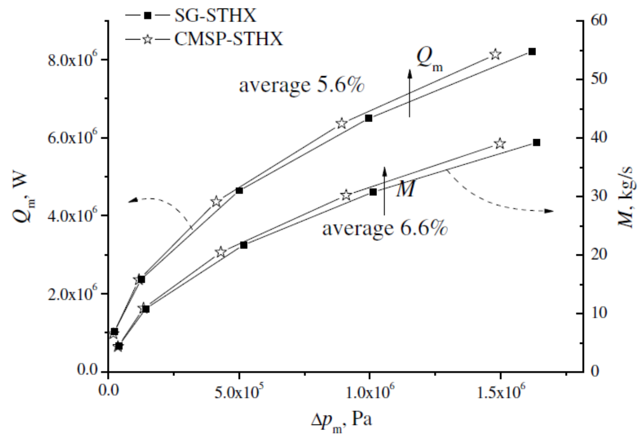

Fig. 6: Variation of Q_m vs. D_{pm}

The conclusions are summarized as follows:

(1) For the same mass flow rate M and overall heat transfer rate Q_m, the average overall pressure drop D_{pm} of the CMSP-STHX is lower than that of SG-STHX by 13%.
(2) For the same overall pressure drop D_{pm} in the shell side, the overall heat transfer rate Q_m of the CMSP-STHX is nearly 5.6% higher than that of conventional SG-STHX and the mass flow rate in the CMSP-STHX is about 6.6% higher than that in the SG-STHX.

D. M.R. Jafari Nasr, A. Shafeghat[5]:

They created shell-and-tube heat exchanger with helical baffle geometries in different arrangement and to investigated about the fluid flow patterns in shell side of helixchanger and then, to compare it with segmental baffle heat exchanger..

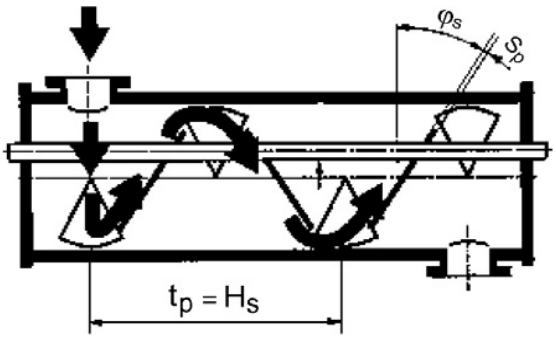

Fig. 7: A line diagram of heat exchangers with helical baffles with pitch angle (φ_s) and baffle space (H_s)

In order to achieve these, first geometry for the shell was created and then for both segmental and helical baffles system, with a given specific baffle spacing in different arrangement, and baffle's layout and nozzle's locations were considered. The exchanger's length was for 2000 mm with inner shell diameter of 225 mm. For different cases, gas oil with various mass flow rates was considered as the fluid inside the shell.

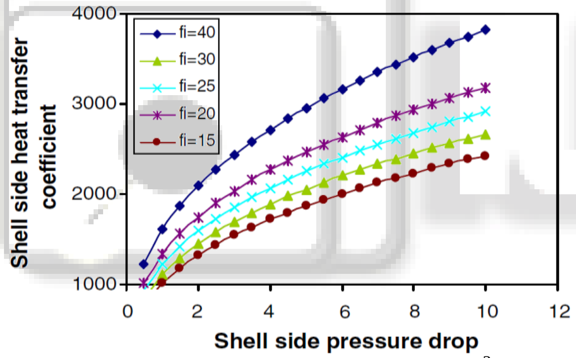

Fig. 8: Shell side heat transfer coefficient (W/m^2 °C) versus on shell side pressure drop changing in various pitch angles.

The results from computer programming and flow simulation demonstrated that in small angles, helical baffles heat exchangers achieved higher velocities due to reducing of cross areas, however, when a certain pressure drop is expected to fulfill the determined thermal duty a bigger area is required.

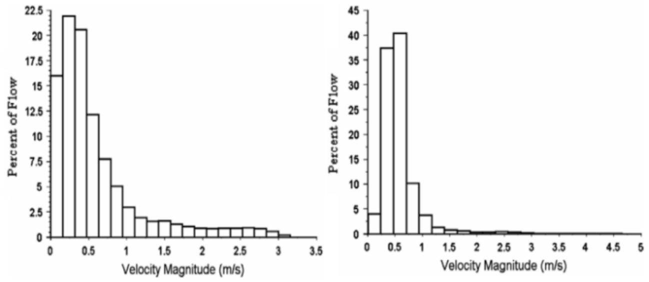

Fig. 9: Distribution of velocity vectors in segmental system (left) and helical system with the pitch angle of 15° (right).

The simulation of flow analysis in shell side showed that velocity distribution in helical baffle system is more uniform and homogenous than segmental baffle system. This leads to less fouling rate and also less erosion/corrosion occurrence inside the shell. Flow distribution in helical baffles systems with small angles is approached to segmental baffle conditions.

E. Wang Yongqing, Gu Xin, Wang Ke, Dong Qiwu.[6]:

The new type of shell-and-tube heat exchanger is with the H-shape baffle in shell-side. Following the design idea that fluid flows in a mixing pattern, the H-shape baffle is presented as tube support structure in shell-side. The H-shape baffle heat exchanger consists of a series of shell-side baffles, each constructed of an array of specific shape support slices. The specific shape slices are set at a selected angle with the axis of tube. Sketch of the H-shape baffle is shown in Fig 10. Tube bundle is supported by H-shape baffles which are laid out on a 90° square pitch with smaller clearances between the tubes and support slices.

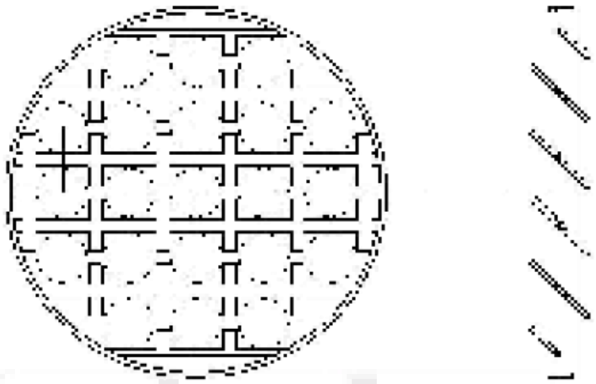

Fig. 10: Sketch of H-shape baffle

They concluded that at the same flow flux, both the heat transfer coefficient and flow pressure drop in shell-side of H-shape baffle heat exchanger lie between that of segmental heat exchanger and ROD baffle heat exchanger. The characteristics of shell-side of H-shape heat exchanger combine that of cross flow and longitudinal flow.

The H-shape heat exchanger merits both heat exchangers with cross flow in shell-side and with longitudinal flow in shell-side.

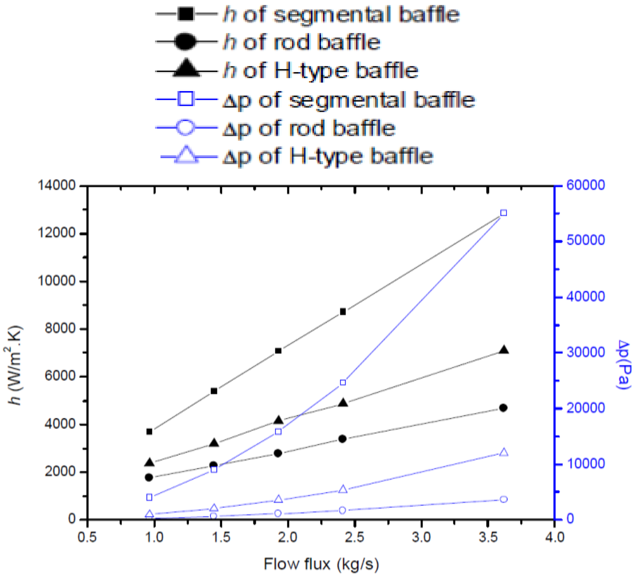

Fig. 11: Computational results for three heat exchangers

In the shell-side of H-shape baffle heat exchanger, fluid flows in a mixing flow pattern. The flow pattern avoids fluid velocity acute variety and kinetic energy loss, decreases the flow dead zone, and bigger transverse flow component reserves the bigger intense scour action of segmental baffle. The flow pattern strengthens fluid turbulence, thins heat transfer boundary layer around tubes, enhances heat transfer, and retains some advantages of ROD baffle heat exchanger at some degree.

In shell-side of heat exchanger, at some range of flow flux, H-shape baffle is an ideal tube support structure, which induces fluid flows in a mixing pattern and enhances greatly heat transfer. Application of the H-shape baffle heat exchanger in practices will be promising.

F. Simin Wang, Jian Wen et al[7] :

The numerical results showed that the shell-side helical pitch of streamlines decreases, and the velocity both in radial and axial directions increases obviously because of the blockage of triangle leakage zones.

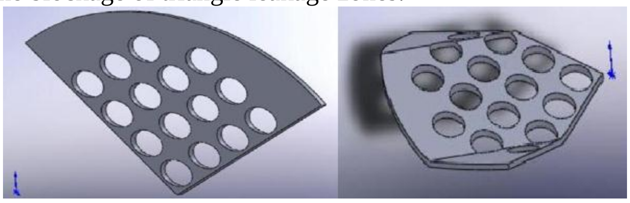

Fig. 12: Configuration of plain baffle and fold baffle

They found fault and original leakage flow through triangle leakage zones then participates in heat transfer, which may intensify the heat transfer performance of the heat exchanger. And experiments were also carried out to reveal the effects of fold baffles on the performance of heat transfer and pressure drop in STHXsHB. Under the operating conditions, the shell-side heat transfer coefficient α_0 and overall heat transfer coefficient K all increases with the shell-side flux and all the values of improved heat exchanger with fold baffles are larger compared with that of conventional heat exchanger with plain baffles. The overall heat transfer coefficient K increased. Though the shell-side pressure drop D_P increases, the associated pumping power penalty is very low compared with the increment of thermal flux.

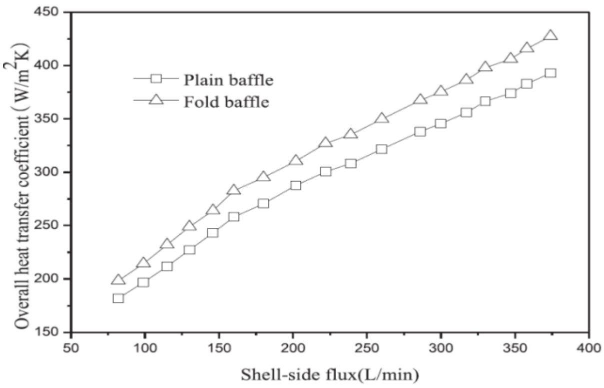

Fig. 13: Overall heat transfer coefficient K versus shell-side flux.

The fold baffle is a novel solution for the triangle leakage flow in STHXsHB.The configuration of a heat exchanger with helical baffles is improved by the application of fold baffles to block the triangle leakage zones between two adjacent plain baffles. The flow patterns of shell side in the heat exchanger was numerically studied and the results showed that the helical pitch of streamlines decreases and the velocity vectors both in radial and axial directions increase obviously for the configuration improvement. The heat transfer experiments were also performed to evaluate the performance of the improved heat exchanger with fold baffles.

Figs. 13 and 14 show the effect of fold baffles on shell-side heat transfer coefficient α_0 and overall heat transfer coefficient K, respectively. The variation trends with shell-side flux are the same for α_0 and K.

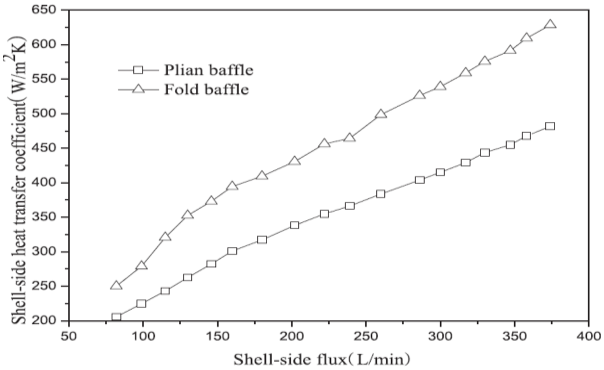

Fig. 14: Shell-side heat transfer coefficient $\boldsymbol{\alpha_0}$ versus shell-side flux

They all increase with the shell-side flux $\alpha_0$and K in the improved design are greater than those in the conventional one. Under the identical operation conditions, the shell-side heat transfer coefficient α_0 of the improved heat exchanger increases.

G. F. Nemati Taher, R. Tasouji Azar [8]:

F. Nemati Taher, R. Tasouji Azar [8] compared the performance comparison between in the shell-side by tube bundle replacement with segmental and helical baffles and obtains the result as the performance of shell and tube heat exchanger with helical baffle is better.

- Helical baffle arrangement provides smooth behaviour of the fluid flow on the shell side which leads to lower pressure drop. At the same pressure drop, helical baffles resulted in higher heat transfer.
- The aim of the project was to reduce fouling and pressure drop of the critical heat exchanger and; as a result, reduce operation and maintenance costs. Present paper consists of 3 phases.

From this figure.15 it is considered that the slopes for increasing heat transfer and pressure drop. With the increase of mass flow rate, shell-side pressure drop of segmental baffles increases dramatically while pressure drop of helical baffles does not increase as dramatic as segmental baffles. It is interesting that by considering proportionality of the achieved heat transfer to the lost pressure, helical heat exchangers result in higher performance because in the same pressure drop they benefit from higher heat transfer.

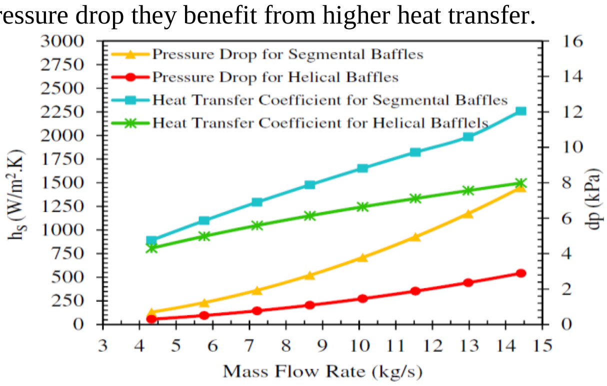

Fig. 15: Graph between Mass flow rates (kg/s) versus heat transfer coefficient (h_s)

H. Reza Tasouji Azar, Shahram Khalilarya, Samad [9]:

Reza Tasouji Azar, Shahram Khalilarya, Samad [9] measured the experimental data for the average heat transfer coefficient and pressure drop of shell-side in segmental and helix bundles and calculated for the same mass flow rate and then these data are compared with the data from code and EXPRESS. And obtain the results shows that in addition to improved heat transfer performance of the helix bundle over segmental bundle, helix bundle achieved two to three times longer operational run times.

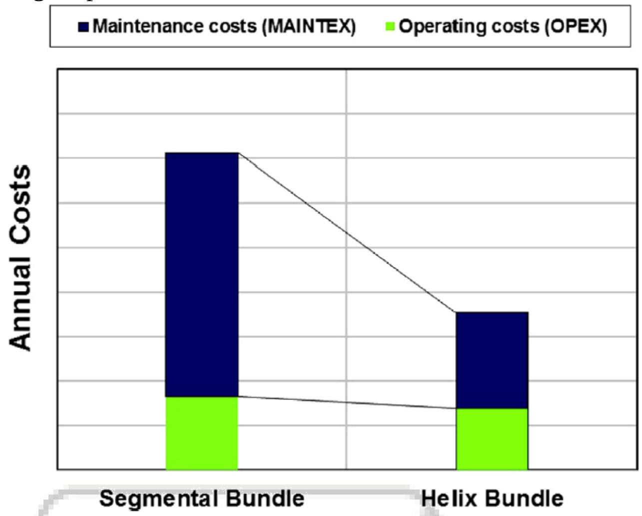

Fig. 16: Operating and maintenance costs; Bundle replacement

From economic point of view, the initial and installation costs of helix bundle to segmental bundle could be increased, but maintenance and operating costs can be decreased.

II. CONCLUSION

- Various types of baffles are utilized for the different purposes according to the application and requirements. From the study of research paper we can conclude as below:
- Heat transfer coefficient in shell-side of H-shape baffle heat exchanger is lies between that of segmental heat exchanger and ROD baffle heat exchanger.
- At lower flow flux, compared with ROD baffle heat exchanger, H-shape baffle heat exchanger achieves bigger heat transfer coefficient with less pressure drop increase, which mends the disadvantage of ROD baffle heat exchanger that smaller pressure drop, but lower heat transfer coefficient as well.
- At bigger flow flux, compared with segmental heat exchanger, H-shape baffle heat exchanger achieves lower pressure drop with less heat transfer coefficient loss, which mends the disadvantage of segmental heat exchanger that big heat transfer coefficient but bigger pressure drop as well.
- In shell-side of H-shape heat exchanger, the characteristics of heat transfer and fluid flow combine that of cross flow and longitudinal flow.
- The H-shape heat exchanger merits both heat exchangers with cross flow in shell-side and with longitudinal flow in shell-side.
- Helical baffles resulted in better performance compared to segmental baffles in running time.
- Helical baffle arrangement provides smooth behaviour of the fluid flow on the shell side which leads to lower pressure drop.
- Flow separation phenomenon, mixing flow and back flow, abrupt changes of fluid flow direction at the baffles tips, higher velocity magnitude which all lead to higher pressure drop were observed for segmental baffles.
- For the same pressure drop, helical baffles resulted in higher heat transfer.
- Helix bundle achieved two to three times of operation run times than segmental baffle.
- Fouling is less with the helix baffle in comparison with segmental baffle.
- The total cost for helix baffle is less than segmental baffle.
- The effectiveness of helix baffle is obviously higher than that with segmental baffle.

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