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# Identification of Suitable Baffle Configuration for Better Performance Output of a Laboratory Shell and Tube Heat Exchanger Using Computer Aided Modeling and Simulation Analyses

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**Abstract:- There has been a remarkable upswing in the research centered on baffle configuration of a shell and tube heat exchanger. This research study, in the similar vein, aims to objectify the baffle configuration of a shell and tube heat exchanger to identify a suitable one which may help the equipment in achieving the prospects of a better thermo-hydraulic performance. The object of the research has been realized by incorporating comparative analysis to validate the model design of a laboratory shell and tube heat exchanger. Upon validation, the same design has been incorporated with various baffle configurations to identify and recommend a suitable baffle configuration for better and enhanced performance of a shell and tube heat exchanger.**

***Keywords:-*** *Shell and Tube Heat Exchanger, Thermo-Hydraulic Performance, Modeling, Validation, Simulation, Suitable Baffle Configuration.*

## I. INTRODUCTION

A shell and tube heat exchanger (here in after STHE) is a thermodynamic device which enables exchange of thermal energy between two fluids having different temperatures [1]. Therefore, the fluid with greater thermal content (higher temperature) transfers heat energy to the fluid with a lesser thermal content (lower temperature). In a STHE, this transfer of heat is enabled by tubes and shell. The shell of a STHE is the house to the network or bunch of tubes held together or stranded by circular discs or plates, known as baffles.

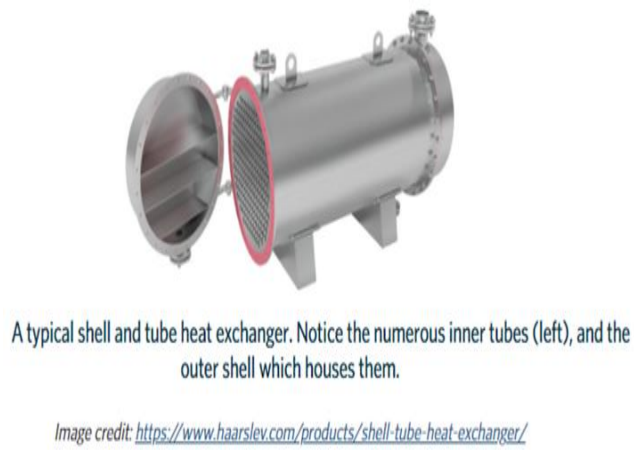


**Figure 1: A typical shell and tube heat exchanger**

The STHE has an engineered design, by which it is meant that its design can be engineered and re-engineered for its better performance. Perhaps, this is the primary reason why STHEs are majorly employed in industries, compared to the rest of the types of heat exchangers [2, 3]. There are a lot of researchers who have successfully devised and recommended various baffle configurations, upon undertaking deliberate and intensive contemplation [4-13].

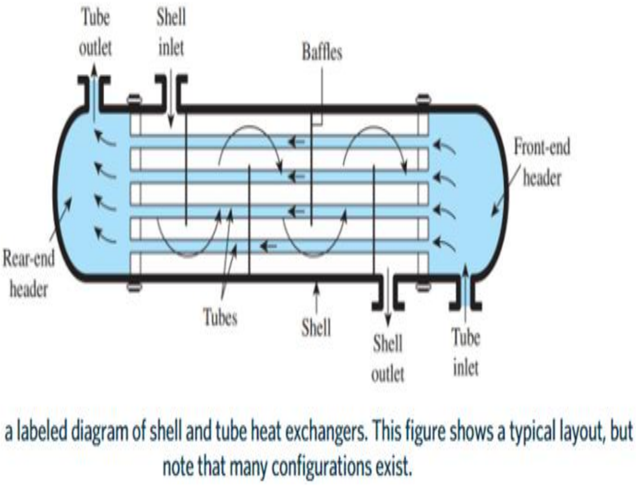


**Figure 2: Constituent parts of a laboratory STHE along with labeling**

On the basis of carrying out profuse amount of literature review, this research scholar is confident to undertake the task of conducting research to identify the most suited baffle configuration for improvement and enhancement of the performance of a laboratory shell and tube heat exchanger. This research endeavor has been emboldened based on the motivation of the supervisor and co-supervisor of the research scholar, as well as his personal keenness to update and upgrade his research profile by pushing a significant development into the arena of thermal engineering sciences.

## II. LITERATURE REVIEW

A comparative experimental investigation was carried out by Emad M.S. El-Saida and M.M. Abou Al-Soodb incorporating new segmental baffle configurations, namely, single segmental baffle, staggered single segmental baffle, flower segmental baffle and hybrid segmental baffle, to conclude that hybrid segmental baffle configuration has a more pronounced positive effect on the determinants of performance of a STHE [14]. Ali Akbar Abbasian Arania and Reza Moradia also conducted research on the topic of baffle configuration of a STHE by employing combined baffle and longitudinal ribbed tubes configuration, having both, triangular as well as circular shapes, each for disk baffle and combined segmental disk baffle configurations in a STHE. Their observations show that the average value of shell side heat transfer coefficient is enhanced in the case of disk baffle triangular tube and continuous segmental baffle configuration as compared to disk baffle circular tube and combined segmental disk baffle circular tube configurations [15]. Another attempt, worth mentioning, was that of Ahmet Aydin, Halit Yaşar, Tahsin Engin, and Ekrem Büyükkaya who tried to optimize a STHE by using new baffle geometries without any effect on the thermo-hydraulic performance. This research concluded that multi segmental baffles with new geometries cuts-in the pressure drop considerably which minimizes the operation cost of the STHE significantly, and additionally, also results in an improved rate of heat transfer [16]. Moving forward, Ambekar Aniket Shrikant, R. Sivakumar, N.Anantharaman, and M. Vivekenandan also undertook research analysis in a bid to account for the improvisation of heat transfer rate of a STHE using multiple segmental baffle configurations. The analysis drawn from this research suggests that single segmental baffles result in a comparatively better heat transfer coefficient, pressure drop, and heat transfer rate as against double and triple segmental baffles when employed in the same STHE [17]. In the similar vein, Ankit Kumar, and Ajay Kumar went a step further to bring into discourse another significant parameter termed as baffle cut which according to their research posts an unordinary improvement in the heat flux and transfer coefficient when the baffle cut is taken as twenty five per cent (25%) [18]. Likewise, Swapnil S.Kamthe and Shivprakash B.Barve carried out a review of different types of baffles employed in STHEs. Their research work was an investigative analysis of a number of baffle types used as integral parts in STHEs, namely, segmental, helical, trefoil hole, flower, plate and doughnut sort. The research and contemplation endeavor strengthened the view that of all the baffle types considered duly in terms of their impact on the performance of a STHE, helical ones have the potential of producing the best outputs for a STHE [19]. In a similar bid to review the developments surfacing with regard to optimization of baffle configuration of STHEs, Usman Salahuddin, Muhammad Bilal and Haider Ejaz carried out a comprehensive review of segmental and helical baffle configurations in a STHE. Based on their review, the analysis drawn indicated that the employment of helical baffle configuration in a STHE provides the opportunity to register an appreciable increment in the corresponding output parameters (performance determinants) of a STHE [20]. A comprehensive experimental study was carried out by Gao et al. to analyze the impact of baffle helix angle on the performance of a STHE. The group of researchers concluded that baffle helix angle is a key determinant with respect to the thermo-hydraulic performance output of a STHE [21]. Young-Seok Son and Jee-Young Shin prepared a computer aided model of an efficient STHE employing spiral baffle plates. Their research led to the conclusion that as compared to conventional heat exchangers, a STHE with spiral baffle plates eliminates the flaws and lacunae emanating from stagnation portions leading to a compromised heat exchanger performance. According to their research work, the overcoming of stagnation portions using spiral baffle plates adds considerably to the performance of the STHE [22]. Furthermore, Xinting Wang, Nianben Zheng, Zhichun Liu and Wei Liu presented numerically computed analysis for optimizing a STHE. Their optimization centered on incorporating staggered baffles in the heat exchanger. This led them to deduce that the STHE containing staggered baffles performs better than the STHE with continuous helical and segmental baffles. The analysis was drawn on the basis of staggered angle and baffle cut as two determinant factors behind the improved performance of a staggered baffle STHE [23]. J. Mahendran also contributed his research analysis on the optimization of baffle configuration for the better performance of a STHE. According to his research work, flower plate baffles ensure that the performance of a STHE is superior in comparison to

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conventional STHEs [24]. In a likewise manner, Wang et al. [25], Yang et al. [26], Zhang et al. [27, 28], Nemati Taher et al. [29], Wen at el. [30] and Ambekar et al [31]. inculcated various baffle configurations to account for the improvisation of STHE performance output. On the basis of the profuse amount of literature review carried out for the research topic, it is sufficing to conclude that baffles and their configuration in STHEs is like a window full of opportunities for researchers to investigate and invent a number of design modifications resulting in the performance amelioration of STHEs [32].

## III. RESEARCH METHODOLOGY

The idea of the research topic revolves around design and development of a computer aided model of an existing laboratory STHE and simulation of the same to obtain simulation results. The data already obtained from the physical performance of the same laboratory STHE has then been used to determine the validity of the designed model of the laboratory STHE through comparison with the obtained simulation results. Upon successful validation, a parametric study has been carried out with various baffle configurations to suggest and recommend the most suitable baffle configuration to produce better performance output for the laboratory STHE.

### 3.1 Development of Computer Aided Design Model of a laboratory STHE

The computer aided design model of a laboratory STHE for this research paper has been prepared using the solidworks software. Solidworks is CAD-CAM software. It is a latest design and development tool used for, both, two-dimensional (2D) as well as three-dimensional (3D) drafting. The laboratory STHE was designed in line with its physical appearance, as present at Department of Mechanical Engineering, Mehran University of Engineering and Technology (MUET), Shaheed Zulfiqar Ali Bhutto (SZAB) Campus, Khairpur Mirs-66020, Sindh, Pakistan.

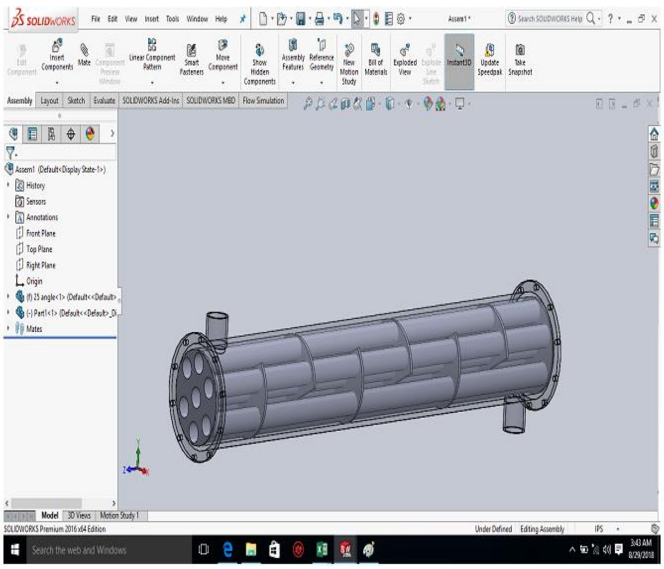

**Figure 3: Design of a Shell and Tube Heat Exchanger Model using Solidworks.**

The laboratory STHE present at Department of Mechanical Engineering, MUET, SZAB Campus, Khairpur Mirs-66020, Sindh, Pakistan, has the following design attributes, and the same were used for designing its solidworks model:

**Table 1: Design attributes of laboratory STHE available at MUET, SZAB Campus**

| S No. | Component of Laboratory STHE | Dimensional Attribute | Unit |
|---|---|---|---|
| 1 | Inner shell diameter | 90 | mm |
| 2 | Outer shell Diameter | 100 | mm |
| 3 | Tube Outer diameter | 20 | mm |
| 4 | Number of Tubes | 07 | mm |
| 5 | Shell/Tube length | 600 | mm |
| 6 | Baffles Space | 86 | mm |
| 8 | Thickness of baffle | 3 | mm |

### 3.2 Simulation of the solidworks model of the laboratory STHE

After preparing the solidworks model of the laboratory STHE, the model has been simulated. The simulation results were obtained and recorded for further necessary steps in pursuit of the research objective. In this case, the flow simulation module of solidworks was used which helped to obtain results from the designed model just like results from actual laboratory STHE are obtained after physical experimentation.

### 3.3 Validation of the design

In this stage of the research, the concurrency of simulation results and those of the experimental ones was determined via comparative analytical analysis approach. The validation was successful, and sufficient to motivate and encourage the principle researcher to undertake the task of incorporating various baffle configurations in the simulation of the laboratory STHE and carryout the execution of the model with these configurations to determine their suitability with regard to the laboratory STHE under examination. Validation, therefore, was taken as a qualification stage for the designed model of the STHE using solidworks software. Successful validation, for this researcher, means that the designed model of the laboratory STHE prepared is appropriate in its entirety, as the simulation result are concurrent, and in accord, with the experimental feedback of the same laboratory STHE.

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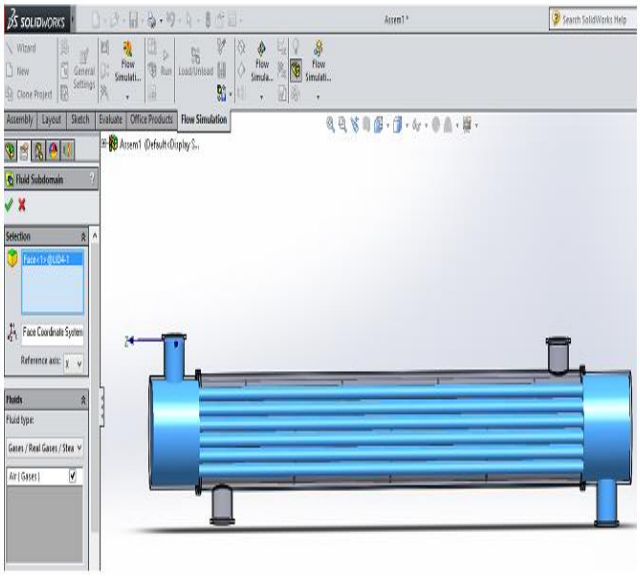

**Figure 4: Screenshot captured during the validation of the solidworks model of laboratory STHE**

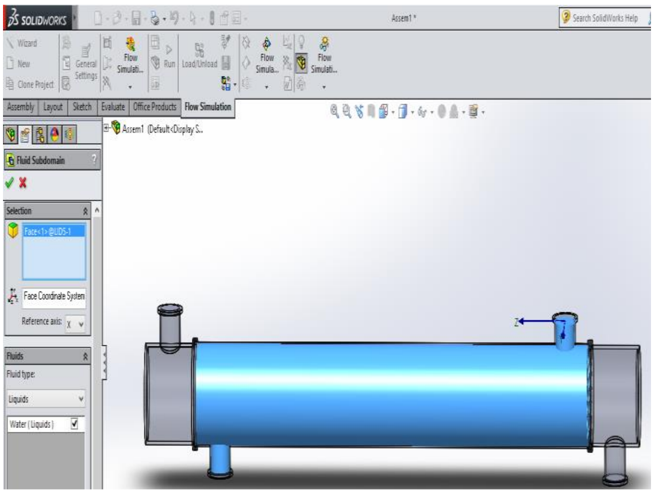

**Figure 5: Screenshot captured during the fluid selection for solidworks model of the laboratory STHE**

### 3.4 Incorporating baffle configurations in the simulation of laboratory STHE

The simulation of the laboratory STHE modeled using solidworks has been incorporated with three different types of baffle configurations, namely, segmental, continuous, and staggered baffle configurations. The simulation results obtained from these three baffle configurations have, then, been subjected to careful analysis and investigation to determine their suitability for the laboratory STHE in terms of heat transfer coefficient and heat transfer rate, and pressure drop. The careful probe into the effect of each type of baffle configuration on the performance of the STHE has led to the recommendations for the highly efficient baffle configuration for best performance output of the laboratory STHE.

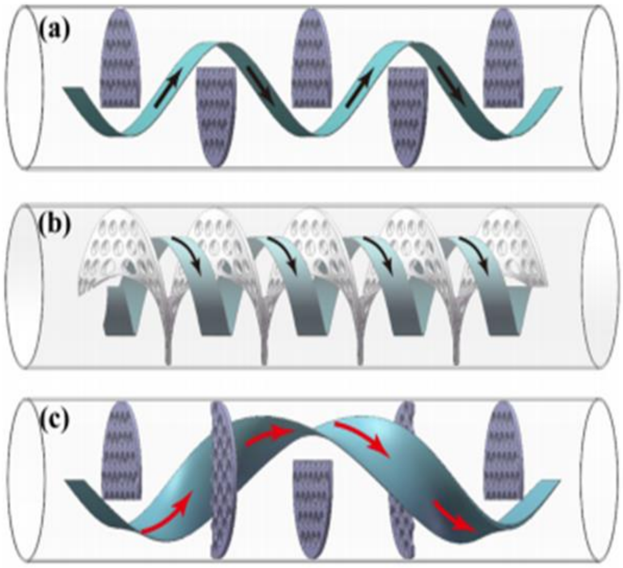


**Figure 6: From the top, (a) STHE with segmental baffle configuration, (b) STHE with continuous baffle configuration, and (c) STHE with staggered baffle configuration**

## IV. COMPARATIVE PERFORMANCE ANALYSIS OF DIFFERENT BAFFLE CONFIGURATIONS

The analyses drawn for putting forward the recommendations in this research paper are based on comparative performance analysis of each type of baffle configuration incorporated into the simulation of the laboratory STHE model. This comparative analysis is centered on three factors which contribute prominently in the overall performance of the STHE, namely, heat transfer coefficient and heat transfer rate, and pressure drop. The impact of each baffle configuration on the heat transfer coefficient and heat transfer rate, and pressure drop is shown below using combined analytical approach involving the effect of all the three baffle configurations on heat transfer coefficient and heat transfer rate, and similarly, the effect of all the three baffle configurations on the pressure drop. The combined analytical approach is a convenient means to compare the impact of each type of baffle configuration on heat transfer coefficient and heat transfer rate, and pressure drop, leading to a comfortable determination of the suitable baffle configuration to be employed by the laboratory STHE.

### 4.1 Impact of different baffle configurations on the heat transfer coefficient and heat transfer rate

The impact of each type of baffle configuration under examination, that is, segmental baffle configuration, continuous baffle configuration and staggered baffle configuration on the heat transfer coefficient and heat transfer rate is represented by the graphical image below:

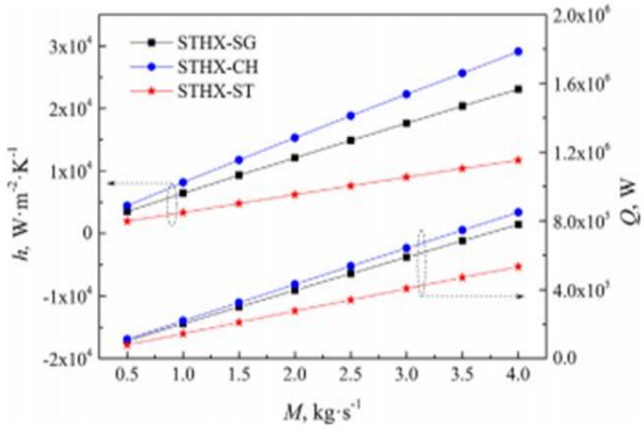


**Figure 7: Heat Transfer Coefficient and Heat Transfer Rate for segmental versus mass flow rate for segmental, continuous and staggered baffle configurations**

The values of heat transfer coefficient and heat transfer rate are plotted against mass flow rate with respect to the segmental, continuous and staggered baffle configurations in the above graphical picture. From the graph it is evidently clear that the continuous baffle configuration accounts for the highest values of heat transfer coefficient and heat transfer rate for a laboratory STHE.

### 4.1 Impact of different baffle configurations on the pressure drop

The different values obtained from the solidworks simulation of the model of laboratory STHE for pressure drop were plotted against the mass flow rate by employing segmental, continuous and staggered baffle configurations to give graphical representation to the results deduced from the workout out arrangement. After the graph was plotted, it was found that continuous baffle configuration in a laboratory STHE are better, in terms of pressure drop, as compared to if segmental baffle configuration or staggered baffle configurations were employed by the same laboratory STHE. Therefore, it is established that the continuous baffle configuration in a STHE are more suited to its performance as compared to segmental and staggered baffle configurations. This is also shown in the graph below:

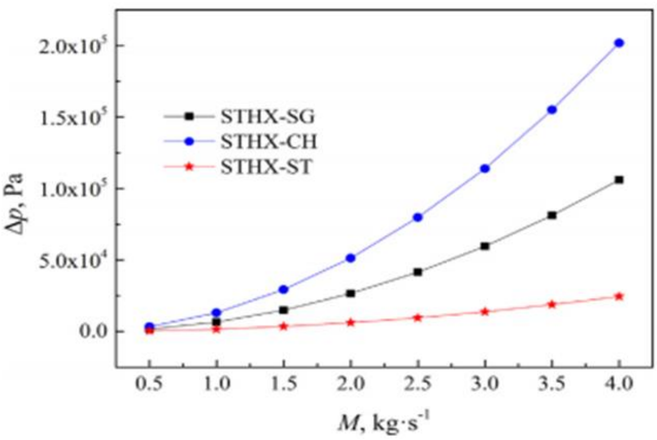


**Figure 8: Pressure drop versus mass flow rate for segmental, continuous and staggered baffle configurations**

## V. SUMMARY OF FINDINGS AND FUTURE RESEARCH DIRECTION

The crux of the research endeavor can be summed up by mentioning that if baffle configuration of a STHE are modified with having the luxury to incorporate one of the baffle configurations from segmental, continuous and staggered ones, then undoubtedly, continuous baffle configurations, as established by this research paper, posits the highest, improved and enhanced values of pressure drop, heat transfer coefficient and heat transfer rate. Therefore, in the light of the research based evidence extracted from the whole investigation process it is recommended that the laboratory STHE available at Department of Mechanical Engineering, MUET, SZAB Campus, may be incorporated with continuous baffles in order to achieve an increased output and enhanced performance from the device.

## VI. CONCLUSION

It is concluded that the baffle configuration is vital to the overall thermo-hydraulic performance of a STHE. It can be instrumental in elevating its output. On the basis of research work carried out in this research paper, it is worth mentioning that the continuous baffle configuration is more suitable for a laboratory STHE as compared to other types of baffle configurations, such as segmental baffle configuration and staggered baffle configuration, if the performance output of the STHE is measured in terms of its heat transfer coefficient, heat transfer rate and pressure drop, as deterministic parameters for the performance of a STHE.

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