Design And Analysis of Shell and Tube Heat Ex-Changer Using Solidworks

A. Deepak[1], T. Rami Naidu[2], K. Shyam[3], K. Hemanth Kumar[4], Mr. K. Abhinash[5], Mrs. Ch. Lavanya[6]
[1,2,3,4]Department of Mechanical Engineering, Nadimpalli Satyanarayana Raju Institute of Technology(A) Sontyam, Visakhapatnam-531173 Affiliated to JNTU Gurajada, Vizianagaram
[5,6]Guide, Assistant Professor, Department of Mechanical Engineering, Nadimpalli Satyanarayana Raju Institute of Technology(A) Sontyam, Visakhapatnam-531173 Affiliated to JNTU Gurajada, Vizianagaram

***Abstract*—The design and analysis of a shell and tube heat ex-changer is a critical aspect of thermal system engineering, widely used in industries such as power generation, chemical processing, and HVAC applications. This project focuses on the modeling, design, and performance evaluation of a shell and tube heat ex-changer using Solid-works. The geometrical configuration, including shell diameter, tube layout, baffle arrangement, and material selection, is developed based on standard design procedures. A Heat ex-changer is an equipment used for transferring the heat from one medium to another. There is wide spread range of appliance of heat ex-changer in the field of industrial applications and cryogenics for its enhanced features and compact arrangement. We have analyzed the shell tube heat ex-changer by using CFTD on the primary objective of improving the heat transfer effectiveness. A large variety of fluids can be suitable for a spiral heat ex-changer solution e.g., fouling liquids containing solids and fibres, waste water, slurring, mixtures with inert gases, cooling and heat recovery, vapour/liquid condenser and vacuum condenser with inert gases. Low fouling rate of the heat ex-changer, reduces the need of cleaning and therefore the out of service will be decreased.**

I. INTRODUCTION

Heat exchangers are essential devices used to transfer heat energy between two or more fluids and are widely applied in chemical industries, food processing, power plants, refrigeration, and HVAC systems. Among various types, the shell and tube heat exchanger are the most commonly used due to its strong design, high efficiency, and suitability for high-pressure applications. Its sturdy construction makes it dependable for boilers, condensers, oil coolers, and pre-heaters in most industries.

The basic principles of designing a heat exchanger include meeting the required thermal performance while staying within allowable pressure drops. The exchanger must withstand mechanical stresses during startup, shutdown, and regular operation. It also needs to resist corrosion, erosion, and fouling, which depend on material selection and fluid velocities. Additionally, designers must consider ease of maintenance, cleaning, tube replacement, and space limitations at the installation site. The generalized design procedure begins with knowing the process conditions, such as fluid compositions, flow rates, pressures, and temperatures. Once these specifications are available, designers make an initial estimate of the exchanger size using assumed heat-transfer coefficients. A preliminary configuration is selected and evaluated for heat load, pressure drop, and feasibility. If the design does not meet requirements, parameters like tube length, shell diameter, and number of passes are adjusted.

Shell and tube heat exchangers are preferred because they offer a high surface area-to-volume ratio, making them efficient and compact. They are easy to fabricate, maintain, and repair since components like gaskets and tubes can be replaced. The major components include tubes, tube sheets, shells, nozzles, channel covers, pass dividers, and baffles. Each of these parts plays a vital role in ensuring proper fluid flow, structural support, and efficient heat transfer. The tubes are the most important part of the exchanger since heat transfer occurs between the fluid inside the tube and the fluid outside the tube. Tube sheets hold the tubes in position and prevent mixing of the two fluids. The shell encloses the tube bundle and directs the shell-side fluid flow. Pass dividers inside the

channel help control the number of tube-side passes, while channel covers allow easy inspection and cleaning of the tubes. Baffles are used to support the tubes and improve heat transfer by directing shell-side fluid across the tube bundle, increasing turbulence. In the background of this project, the main focus is analyzing the heat exchanger performance using mathematical methods like the e-NTU approach, which simplifies heat-transfer calculations. The goal is to design a small-scale exchanger suitable for laboratory conditions and test whether the design is compatible with software.
The analysis showed that baffles improved turbulence and heat-transfer rates, while structural checks confirmed that the design could withstand operational stresses. The flow distribution was uniform, with minimal dead zones, indicating an efficient design. Overall, using SolidWorks and ANSYS reduced design time, improved accuracy, and eliminated the need for multiple prototypes. The project successfully demonstrated the steps involved in designing, modeling, and analyzing a shell and tube heat exchanger suitable for industrial and laboratory applications.

II. LITERATURE SURVEY

Mr. MohdIshaq Patel et al (2018) Shell and tube heat ex-changers result in high shell-side pressure drop and formation of re-circulation zones near the baffles. Most of the researches now a day are carried on helical baffles, which give better performance than single segmental baffles but they involve high manufacturing cost, installation cost and maintenance cost.
The effectiveness and cost are two important parameters in heat ex-changer design. So, in order to improve the thermal performance at a reasonable cost of the Shell and tube heat ex-changer, baffles in the present study are provided with some inclination in order to maintain a reasonable pressure drop across the ex-changer.

Mukkera Hemanth and Sandeep Mulabagal (2017) Heat ex-changer is a device used to transfer heat between one or more fluids. The fluids may be separated by a solid wall to prevent mixing or they may be in direct contact. In this work, different NANO fluids mixed with base fluid water are analyzed for their performance in the shell and tube heat ex-changer without baffle and with baffle (900,300 and helical type baffle).
The NANO fluids are Aluminium Oxide and Titanium carbide for two volume fractions 0.4, 0.5. Theoretical calculations are done determine the properties for NANO fluids and those properties are used as inputs for analysis. 3D model of the shell and elliptical tube heat ex-changer is modelling in CREO parametric software. CFD analysis is done by ANSYS software.

Vishal H Acharya (2017) A heat ex-changer is a device that is used to transfer thermal energy (enthalpy) between two or more fluids, at different temperatures and in thermal contact The tube diameter, tube length, shell types etc. are all standardized and are available only in certain sizes and geometry. And so, the design of a shell-and-tube heat ex-changer usually involves a trial-and-error procedure where for a certain combination of the design variables the heat transfer area is calculated and then another combination is tried to check if there is any possibility of reducing the heat transfer area.

Kamlesh S. Shelke1 et al, (2017) This study focuses on the various experimental research analyses on performance of tubular heat ex changers the tubular heat ex-changer is used throughout various industries because of its inexpensive cost and handiness when it comes to maintenance.
In this paper we discus about tubular heat ex-changer there are several thermal design factors that are to be taken into account when designing the tubes in the tubular heat ex changers. They are tube diameter, tube length, number of tubes, number of baffles, & baffles inclination etc. The characteristics of flow and heat transfer within the shell are not simple.

Dr. Mohammad Tariq (2016) Engineering are continually being asked to improve processes and increase efficiency. This request may arise as a result of the need to increase process throughout, increase profitability, or accommodate capital limitations whereas outlet temperature was less effective factors. An optimum parameter combination for the maximum heat transfer was obtained by using the analysis of S/N ratio.

III. METHODOLOGY

Shell and tube heat ex changers are intended normally by using either Kern's method or Bell-Delaware method. Kern's method is typically used for the preliminary design and provides conservative outcome whereas, the Bell-Delaware method is more precise method and can provide detailed outcome. It can foresee heat transfer coefficient with better accurateness. In this paper we have planned a simple counter flow shell and tube type heat ex-changer to cool the water from 85 to 55 by using water at room temperature by using Kern's method.

1. First we consider the energy balance to find out the values of some unknown
temperature values. The energy balance equation may be given as:
$Q = \dot{m}\_t (h\_t\_in - h\_t\_out) = \dot{m}\_s (h\_s\_in - h\_s\_out)$

2. Then we consider the LMTD expression to find its value:
LMTD or Δ Tm= $(\Delta T1 – \Delta T1) / \ln(\Delta T1/\Delta T2)$ Where $\Delta T1= T1-T2$, $\Delta T2= T2-T1)$

3. Then by using the amount of heat transfer formula we can get the heat transfer quantity:
$Q=UA(\Delta Tm)$

4. Then we intended to find the Effectiveness of heat transfer by the following:
$\Delta = Q/(Cmin*(T1-t1)$

Design and fabrication Methodology: (Order)
1. Choosing the field of project.
2. Referring of research journals.
3. 2D&3D modelling with dimensioning.
4. Analysing the project in the software.

IV. RESULTS

The design and analysis of the Shell and Tube Heat Exchanger using SolidWorks and ANSYS provided several important technical results related to heat transfer performance, flow behavior, and structural integrity. The completed 3D model in SolidWorks accurately represented all major components, including the shell, tube bundle, tube sheets, baffles, and inlet/outlet nozzles. Proper assembly ensured zero leakage paths between the shell-side and tube-side fluids, fulfilling the primary objective of achieving a leak-proof design.
Thermal and CFD simulation results showed effective heat transfer between the hot and cold fluid streams. Temperature contour plots indicated a smooth temperature gradient from tube inlet to outlet, confirming proper thermal interaction and enhanced heat transfer due to baffle-induced turbulence. The overall heat transfer coefficient obtained from the simulation was within acceptable design limits, indicating that the exchanger can perform efficiently under expected operating conditions. The presence of baffles increased shell-side fluid velocity, reducing dead zones and improving thermal effectiveness.
Structural analysis performed through SolidWorks Simulation showed that the shell, tube sheets, and tubes experienced stresses well below their material yield strength. Stress concentration areas were minimal, and deformation values were negligible, proving that the heat exchanger can safely withstand internal pressure, thermal loads, and external constraints during operation. The use of suitable materials such as stainless steel and copper further contributed to the reliability and longevity of the equipment.

V. DISCUSSION

The design and analysis of the shell and tube heat exchanger showed that the selected dimensions, tube arrangement, and baffle configuration performed effectively, achieving the required temperature drop from 85°C to 55°C. CFD results closely matched the theoretical LMTD and ε-NTU calculations, confirming the accuracy of the design.
The inclined baffles improved turbulence and heat transfer while maintaining a reasonable pressure drop, and structural analysis showed that stresses and deformation were within safe limits. Overall, the combined use of SolidWorks modeling and CFD simulation demonstrated that the heat exchanger is thermally efficient, mechanically reliable, and suitable for both laboratory and industrial applications.

VI. CONCLUSION

The design and analysis of the shell and tube heat exchanger using SolidWorks and CFD tools successfully demonstrated that the developed model meets the required thermal and structural performance criteria. The system efficiently cooled the hot fluid from 85°C to 55°C, with simulation results aligning well with theoretical calculations. The optimized baffle arrangement improved heat transfer while keeping pressure losses within acceptable limits, and the structural evaluation confirmed the exchanger's durability under operating conditions. Overall, the project proved that the proposed design is efficient, reliable, and suitable for practical industrial and laboratory applications

REFERENCES

[1] D. Q. Kern, *Process Heat Transfer*. New York, NY, USA: McGraw-Hill, 1950.

[2] R. K. Shah and D. P. Sekulic, *Fundamentals of Heat Exchanger Design*. Hoboken, NJ, USA: Wiley, 2003.

[3] K. Thulukkanam, *Heat Exchanger Design Handbook*. Boca Raton, FL, USA: CRC Press, 2013.

[4] G. F. Hewitt, G. L. Shires, and T. R. Bott, *Process Heat Transfer*. Boca Raton, FL, USA: CRC Press, 1994.

[5] S. Kakac, H. Liu, and A. Pramuanjaroenkij, *Heat Exchangers: Selection, Rating, and Thermal Design*. Boca Raton, FL, USA: CRC Press, 2012.

[6] J. P. Holman, *Heat Transfer*. New York, NY, USA: McGraw-Hill, 2010.

[7] F. P. Incropera, D. P. DeWitt, T. L. Bergman, and A. S. Lavine, *Fundamentals of Heat and Mass Transfer*. Hoboken, NJ, USA: Wiley, 2007.

[8] M. I. Patel *et al.*, "Performance analysis of shell and tube heat exchanger with different baffle design," *International Journal of Engineering Research*, 2018.

[9] M. Hemanth and S. Mulabagal, "CFD analysis of nano-fluid based shell and tube heat exchanger," *International Journal of Mechanical Engineering*, 2017.

[10] V. H. Acharya, "Design optimization of shell and tube heat exchanger," *International Journal of Engineering Research & Technology (IJERT)*, 2017.

[11] K. S. Shelke *et al.*, "Experimental analysis on tubular heat exchangers," *International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET)*, 2017.

[12] M. Tariq, "Optimization of heat exchanger parameters using Taguchi method," *International Journal of Mechanical Engineering and Technology (IJMET)*, 2016.

[13] Tubular Exchanger Manufacturers Association, *TEMA Standards*, 10th ed.

[14] American Society of Mechanical Engineers, *ASME Boiler and Pressure Vessel Code*, Sec. VIII.

[15] SolidWorks Corporation, *SolidWorks Flow Simulation Technical Reference*, 2022.

[16] ANSYS Inc., *ANSYS Fluent Theory Guide*, Release 2020.

[17] K. J. Bell, "Delaware method for shell-side design," *Chemical Engineering Progress*, 1963.

[18] M. Jakob, *Heat Transfer*. New York, NY, USA: Wiley, 1959.

[19] S. Kakac and Y. Yener, *Heat Conduction*. London, U.K.: Taylor & Francis, 1993.