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Design of Tube Bundle Insert for Shell and Tube Heat Exchangers

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Abstract

Shell and tube heat exchanger manufacturing industries are inserting and removing tube bundle manually which involves challenges in center alignment of shell and tube bundle. The manual method damages the tubes and baffles as well as rubber seals which involve more labors hours. In the research work, automatic trolly is made for tube bundle insertion in the shell. It is observed that the proposed process of tube insertion is safer and reliable with 90%-time reduction over manual method as studied in the actual trials.

1. Introduction

The shell and tube heat exchanger (STHE) are work horses of the industries. These are used in many industries including process, thermal, refrigeration, air conditioning, dairy, electrical, electronics etc. for different applications. The STHE consists of shell for inserting tube bundles. The shell and tube fluids are different and may flow in parallel or counter directions. The residence time of the fluid in the shell is increased by providing baffles and pass arrangements. The heat exchanger is used for transferring energy from one fluid to another either by mixing or indirect contact through walls. The fluid passing though the shell side and tube side is depending on the properties of fluids and applications. The tube bundle is inserted in the shell for enhancing the surface contact between two fluids by providing baffles. The passes are provided in the shell side as well as tube side for increasing the contact time between two fluids for more effectiveness. The boiler shells are 10 to 20 m longer depending on the applications which weighs more than 50% of shell in terms of tonnes. The tube bundle assembly into the shell is very risky matter with the help of crane considering sagging and baffle arrangement. Therefore, in this research, different designs are proposed for inserting tube bundle into the

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shell to minimize the defects to keep the quality of heat exchangers as per Tubular Exchanger Manufacturers Association (TEMA) standards.

2. Shell and Tube Heat Exchanger

The main objective of research is to design and develop the mechanism for insertion of tube bundle into the shell without damage. Presently, the tube bundles are lifted with the help of cranes and inserted into the shell with great efforts. The tubes may be damaged due to the heavy weight of the tube bundles. Thus, the automatic mechanism is developed and used in the company for insertion of tube bundle into the shell. A problem with the current method is that the tube bundle assembly is lifted by means of crane and the guided in the shell. This method is not appropriate as the tube bundle assembly contributes 70% of the heat exchanger weight for around 4 to 6 tonnes of heat exchangers. The lifting of tube bundles with the help of crane is having an adverse effect of sagging on the tubes which may leads to leaking of tubes. The manufacturing companies are facing large problems during assembly of heat exchanger because of eccentricity between shell and tube bundle axis due to misalignment of tube and shell axis. The efforts and time are saved by this method without damage with increase in reliability. Figure 1 shows the manual process of tube bundle insert in shell.

Figure 1. Manual tube bundle insert

3. Material and Methods of Tube Inserts

Following methods are used for insertion of tube bundles into the shell of heat exchangers at Atlas Copco company.

3.1 V block assembly

V-blocks are jigs which are used for holding the tube bundles for performing various operations such as drilling and milling. This is basic method without any accuracy which consists steel and cast-iron blocks as shown in Fig. 2. The V shape is formed with the help of advancement screws for holding the tube bundle. It has screw clamps to hold tube bundle.

Figure 2. V block

3.2 Section Beam

Figure 2 shows the section of I beam. This is one of the methods to hold and place the tube bundle in the shell. Flange and web are the part of the I section which are used in civil construction for restricting shear and bending moment.

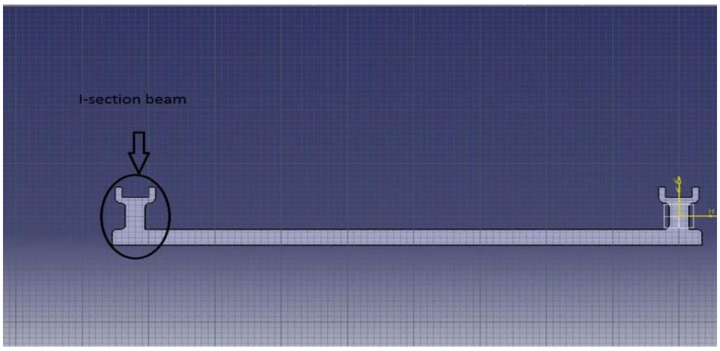

Figure 4. I-section bed

3.3 Motorized Screw Jack

The motorized screw jack consists of worm gear with electrical motor and self-locking mechanism. The electrical motor consists of servo motor, gear motor and stepper motor with DC motors. The jack capacity may vary from 0.25 to 100 tonnes.

Figure 5. Motorized screw jack

3.4 Edge Detector Sensor

The edge sensors are used for finding the position with respect to distance. The objectives of sensor are positioning of objects by the edge, level measurement, and position measurement.

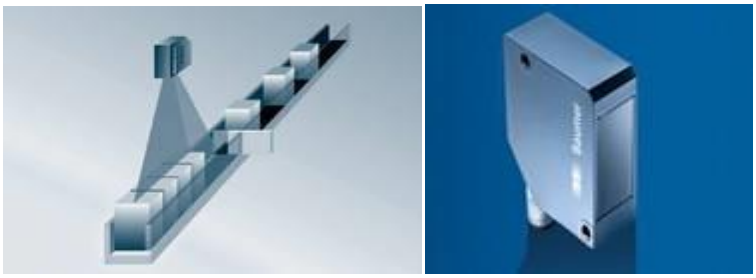

Figure 6. Edge Detector Sensor

3.5 *Proposed Design for Tube Bundle Assembly into the Shell*

The design involved the modified V-Block which was allowed to move laterally on the carriage along the rail. The tube shell was fixed on the V-block. The rail was loaded with the trolley having chuck clamp like the lathe clamp. The tube bundle should be fixed on the clamps and then pushed inside it.

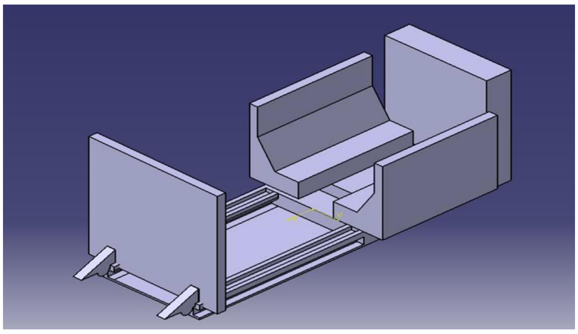

Figure 7. Proposed design 1

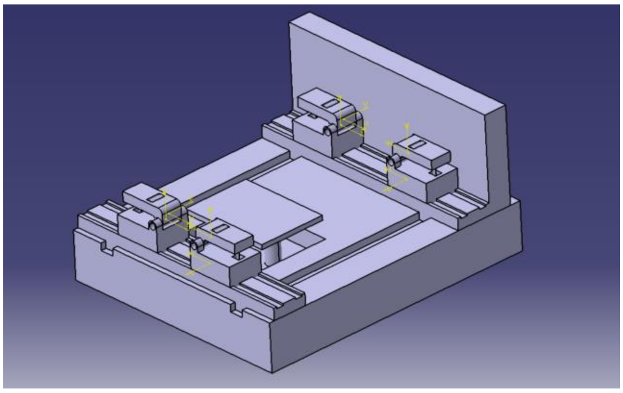

Figure 8. Proposed design 2

The second design was designed keeping in mind the rigidity and insertion of tube bundle into the shell inspired from lathe machine. It contains 2 carriages which would slide on the bed. There is protrusion on which rail plate is to support wheels of tube bundle once the smaller flange is inserted in shell. Only job left is to push the tube bundle which is done by using rope drive which is connected to wall. Increased weight and the complexity of the fixture was the prime disadvantage.

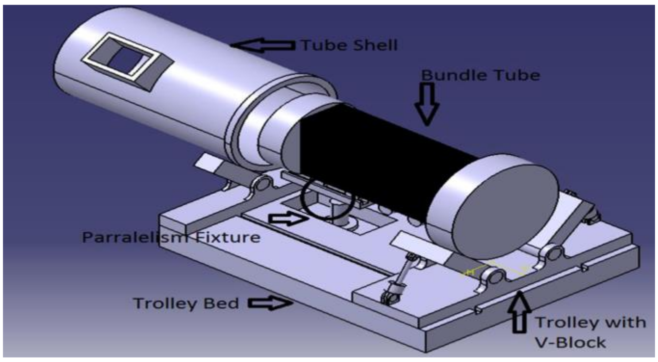

Figure 9. Proposed design 3

The design 3 used sensors and hydraulic components for alignment with the help of 2 V Blocks pivoted at two end ends which were mounted on the carriages. The V Block at the front would touch the diameter of shell and would generate an angle which would be directly given to the V block at the end. The V plates would be swivelled by hydraulic cylinder arrangement at the end. The carriages would slide in the slots along the bed. Another hydraulic piston cylinder arrangement (Parallelism fixture) was incorporated at a certain distance from the shell to guide the wheels of tube bundle and to support weight of some part of the tube bundle. The incorporation of hydraulic system needs the design of hydraulic power pack which makes the design bulky, complex, and costly.

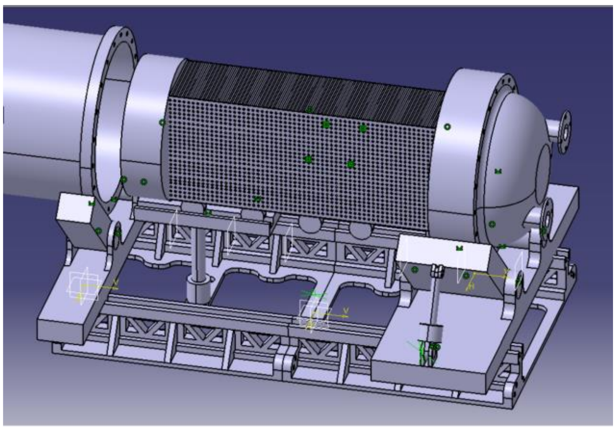

Figure 10. Proposed design 4

This design is same as the previous one, except reduction of weight in design of bed. The requirement was still not met as the weight exceeded as per the company standards. The design involves optimization of bed and solid V-blocks for standard diameters that consist of automated screw jack on sliding blocks for vertical movement of V-blocks which can be designed for different diameters. V- blocks can be replaced for specific set of diameters. The purpose of V-block for bundle tube flange is for center alignment with tube shell. The purpose of V-block at the shell end is for horizontal alignment of tube shell and the trolley. The bed of the trolley is highly optimized by introducing I-section beams at the bottom for obtaining greater rigidity to the structure. By performing various iterations, weight of the bed came out to be 100 kg for 1 meter length. Automated screw jack of high weight bearing capacity for parallelism fixture can also be used because hydraulic components are bulky and may leak if not used properly. For ensuring that the rail plate is exactly tangential to the inner diameter of the shell, edge detector sensor may be used. Using this new design around 80% time is saved for tube bundle with the reduced labor hours.

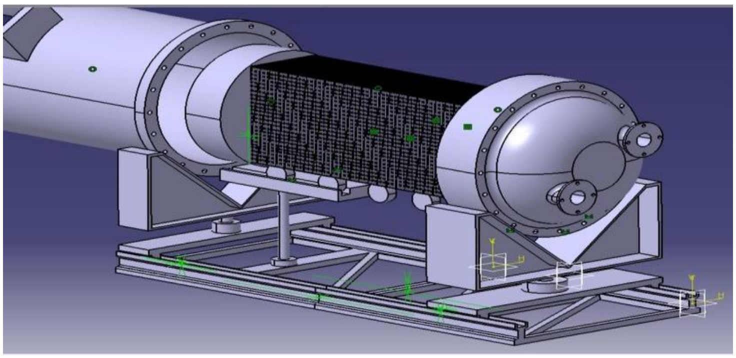

Figure 11. Final design of assembly for tube bundle

4. Calculations

The important calculations involved in the research includes designing the appropriate section for supporting the trolley and the design of primary V-block. The I-sections are available in standard sizes and have standard materials.

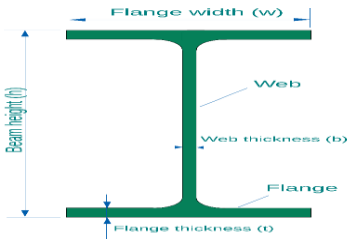

Figure 8. I section

The equation used for design is given as follows.

$$\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R} \tag{1}$$

Where, M is bending moment acting on the beam (N-mm), M is polar moment of inertia (mm^4), σ is shear stress acting on the beam (MPa), y is perpendicular distance of CG from neutral axis (mm), E is modulus of elasticity (MPa) and R is radius of bending (mm). For calculating bending moment, half of the weight of complete assembly falling on the center of beam is considered. The maximum weight of tube bundle trolley comes out to be 7.5 tonnes. But, keeping in mind the safety issues and importance, I-section was designed for 10 tonnes almost 33% higher than available load. The maximum stresses available in the beam were calculated as $\sigma t = 221MPa$. According to the standard, I-section are manufactured from ASTM A36 alloy steel. The ultimate tensile strength (S_{ut}) = 550MPa. It is found that $S_{ut} > \sigma_t$, the design is safe with the factor of safety of 2.5.

References

1. Kantilal P. Patil, Sachin S. Barve, Design, and optimization of equipment for insertion of tube bundle of heat exchanger, Int. Journal of Modern Engineering Research (IJMER), Vol. 3 (4), 2013, 2019-2022
2. D. Kishor, D. Sriniwasa, J. Nityanadam, Experimental studies and controller design of shell and tube heat exchanger using with or without insert, Int. Journal of Modern Engineering Research, Vol. 3 (4), 2013, 1126- 1132
3. R.V. Patil, S. S. Bhutada, N. R. Katruwar, R. R. Rai, K. N. Dhumke, Vibrational analysis of a shell and tube type of heat exchanger in accordance with tubular exchanger manufacturer's association (TEMA) norms, Int. Jou. of Engg. And Science, Vol 3 (4), 2014, 59-64.
4. Ivan Sunit Rou, Dipti Ranjan Patra, Sidhartha Sankar Padhi, Design and fabrication of motorized automated object lifting jack, Journal of Engineering, Vol. 4 (5), 2014), 6-12.
5. Kumar Pandey, Shailesh Kumar Maurya, Ajit Tiwari, Jawed Rafiq, S.K. Dwivedi, Highly efficient motorized screw jack, International Journal of Computational Engineering Research, Vol 3 (5), 2013, 35-41.
6. V. B. Bhandari, Design of Machine Elements, Tata McGraw Hill, Third Edition, 184-194.
7. John. Edwards, Design and Rating of Shell and Tube Heat Exchanger, 2008
8. J. H. Lienhard, A Heat Transfer Textbook, 5th Edition, Phlogiston Press, 2019
9. Yunus A. Cengel and Afshin J. Ghajar, Heat and Mass Transfer, Fundamentals and Applications, 2017, 5th Edition, McGraw Hill Education
10. Heba Abdelhamid, Ayman Bakry, Hagar Alm ElDin Mohamad, A review on comparative performance of shell-and-tube heat exchangers with various design configurations, Journal of Engineering Research, 6(3), 2022, 159-168
11. A. khan, I. Shah, W. Gul, T. A. Khan, Y. Ali, S. A. Masood Numerical and experimental analysis of shell and tube heat exchanger with round and hexagonal tubes, Energies, 16(2), 2023, 880-889
12. E. J. Fernandes, S. Hassan, Design and analysis of shell and tube heat exchanger, International Journal for Simulation and Multidisciplinary Design Optimization, 13, 15 (2022)
13. Bhatkar, V.W. and Sur A, An experimental analysis of liquid air jet pump, Frontiers in Heat and Mass Transfer, 17(12), 2021, 1-5
14. Bhatkar, V.W., Kriplani, V.M., and Awari, G.K., Alternative refrigerants in vapor compression refrigeration cycle for sustainable environment: a review of recent research, Int. Journal of Environmental Science and Technology, 10, 2013, 871-880
15. Bhatkar, V.W., Experimental study of multistage indirect evaporative coolers, JP Journal of Heat and Mass Transfer, 24(1), 2021, 69–77
16. Bhatkar, V.W., Kriplani, V. M. and Awari, G. K., Experimental performance of R134a and R152a using microchannel condenser, Journal of Thermal Engineering, Vol. 1(7), 2015, 575-582.