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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 the tube bundle manually, which involves challenges in the center alignment of the shell and tube bundle. The manual method damages the tubes and baffles as well as rubber seals, which involve more labor hours. In the research work, an automatic trolley 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 the manual method as studied in the actual trials.

1. Introduction

The shell and tube heat exchanger (STHE) are the workhorse 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 a 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 through the shell side and tube side depends on the properties of the fluids and applications. The tube bundle is inserted into the shell to enhance

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surface contact between the two fluids by providing baffles. The passes are provided in the shell side as well as the tube side to increase the contact time between the two fluids for more effectiveness. The boiler shells are 10 to 20 m longer, depending on the applications, which weigh more than 50% of the shell in terms of tonnes. The tube bundle assembly into the shell is a very risky matter with the help of a crane, considering sagging and baffle arrangement. Therefore, in this research, different designs are proposed for inserting a tube bundle into the shell to minimize the defects to keep the quality of heat exchangers as per Tubular Exchanger Manufacturers Association (TEMA) standards [1-2].

2. Shell and Tube Heat Exchanger

The main objective of the research is to design and develop a mechanism for the insertion of a 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 effort. 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 the insertion of the tube bundle into the shell. A problem with the current method is that the tube bundle assembly is lifted by means of a crane and guided into 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 a crane is having an adverse effect of sagging on the tubes, which may lead to the leaking of tubes. The manufacturing companies are facing large problems during the assembly of the heat exchanger because of eccentricity between the shell and tube bundle axis due to misalignment of the tube and shell axis. The efforts and time are saved by this method without damage, with an increase in reliability. Figure 1 shows the manual process of tube bundle insertion in the shell [3-4].

Figure 1: Manual tube bundle inserts

3. Material and Methods of Tube Inserts

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

3.1 V block assembly

V-blocks are jigs that are used for holding the tube bundles for performing various operations, such as drilling and milling. This is a basic method without any accuracy, which consists of steel and cast-iron blocks as shown in Figure 2. The V shape is formed with the help of advancement screws for holding the tube bundle. It has screw clamps to hold the tube bundle [5].

Figure 2: V block

3.2 Section Beam

Figure 3 shows a section of an I beam. This is one of the methods to hold and place the tube bundle in the shell. Flange and web are part of the I section, which are used in civil construction for restricting shear and bending moment.

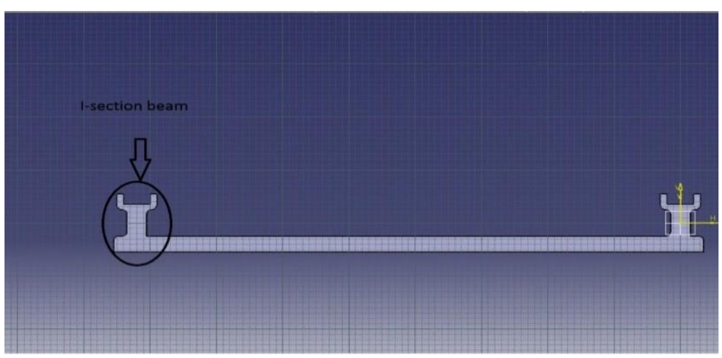

Figure 3: I-section bed

3.3 Motorized Screw Jack

The motorized screw jack consists of a worm gear with an electrical motor and a self-locking mechanism. The electrical motor consists of a servo motor, a gear motor, and a stepper motor with DC motors. The jack capacity may vary from 0.25 to 100 tonnes, as shown in Figure 4.

Figure 4: Motorized screw jack

3.4 Edge Detector Sensor

The edge sensors are used for finding the position with respect to distance. The objectives of the sensor are positioning of objects by the edge, level measurement, and position measurement, as shown in Figure 5 [6-8].

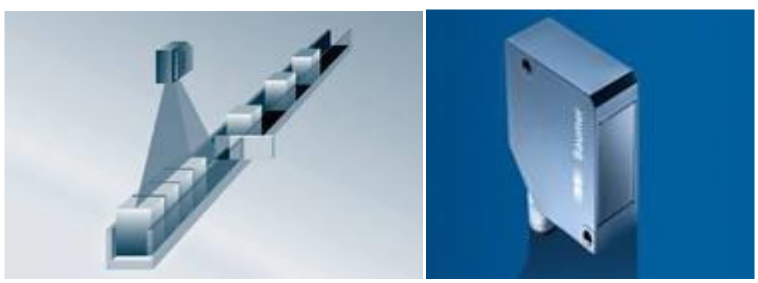

Figure 5: Edge Detector Sensor

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 a chuck clamp like the lathe clamp. The tube bundle should be fixed on the clamps and then pushed inside. Figures 6 to 10 show different proposed designs for tube inserts.

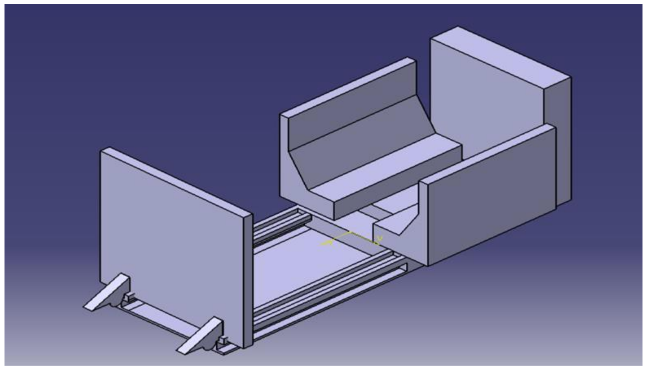

Figure 6: Proposed design 1

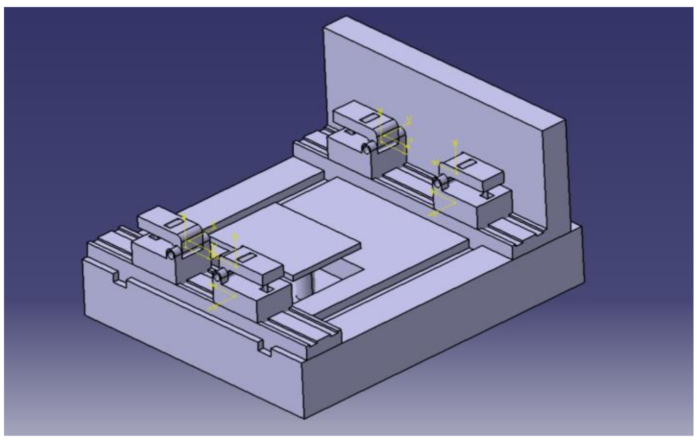

Figure 7: Proposed design 2

The second design was designed keeping in mind the rigidity and insertion of the tube bundle into the shell, inspired by a lathe machine. It contains 2 carriages that would slide on the bed. There is a protrusion on which the rail plate is to support the wheels of the tube bundle once the smaller flange is inserted into the shell. The only job left is to push the tube bundle, which is done by using a rope drive that is connected to the wall. Increased weight and the complexity of the fixture were the prime disadvantages [9-11].

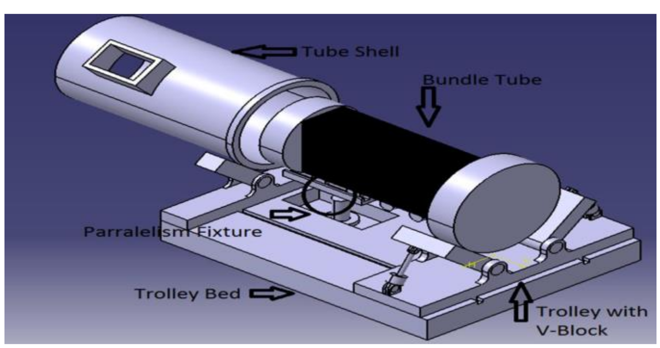

Figure 8: Proposed design 3

The design 3 used sensors and hydraulic components for alignment with the help of 2 V Blocks pivoted at end ends, which were mounted on the carriages. The V Block at the front would touch the diameter of the shell and would generate an angle that would be directly given to the V block at the end. The V plates would be swivelled by a 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 the tube bundle and to support the weight of some part of the tube bundle. The incorporation of a hydraulic system requires the design of a hydraulic power pack, which makes the design bulky, complex, and costly [12-13].

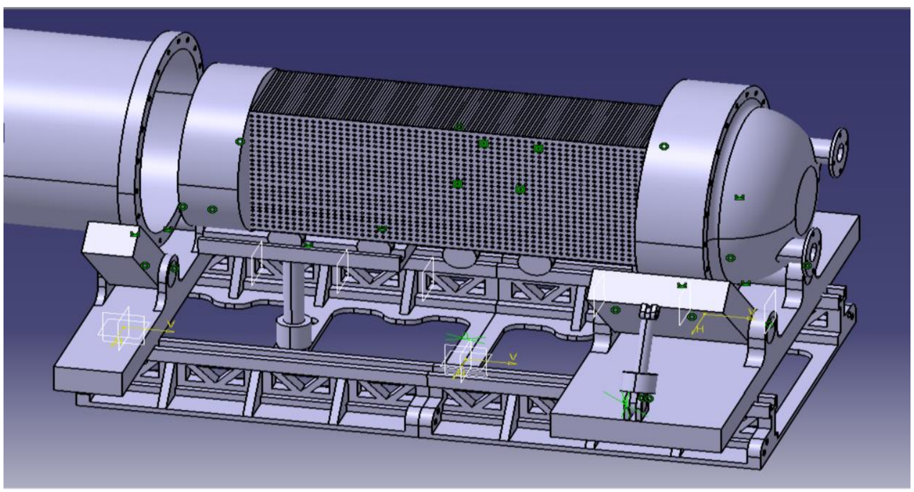

Figure 9: Proposed design 4

This design is same as the previous one, except reduction of weight in the weight of the bed. The requirement was still not met as the weight exceeded the company standards. The design involves optimization of bed and solid V-blocks for standard diameters that consist of an 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 a specific set of diameters. The purpose of the V-block for the bundle tube flange is for center alignment with the tube shell. The purpose of the V-block at the shell end is for horizontal alignment of the tube shell and the trolley. The bed of the trolley is highly optimized by introducing I-section beams at the bottom to obtain greater rigidity to the structure. By performing various iterations, the weight of the bed came out to be 100 kg for a 1-meter length. An automated screw jack of high weight-bearing capacity for a parallelism fixture can also be used because hydraulic components are bulky and may leak if not used properly. To ensure that the rail plate is exactly tangential to the inner diameter of the shell, an edge detector sensor may be used. Using this new design, around 80% time is saved for the tube bundle with the reduced labor hours [14-16].

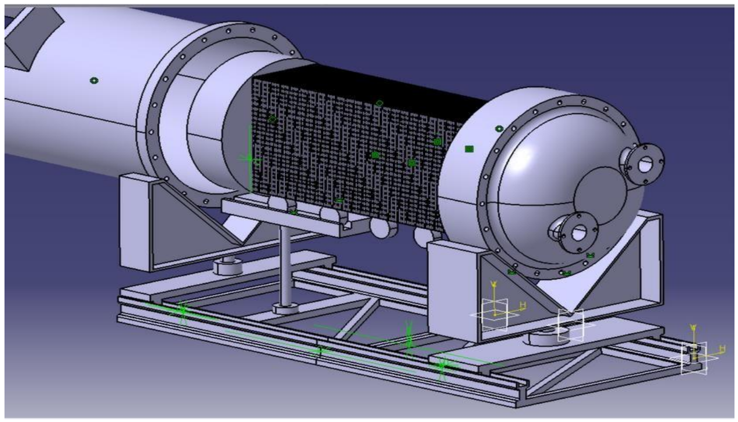

Figure 10: Final design of assembly for tube bundle

4. Calculations

The important calculations involved in the research include designing the appropriate section for supporting the trolley and the design of the primary V-block. The I-sections are available in standard sizes and have standard materials as shown in Figure 11.

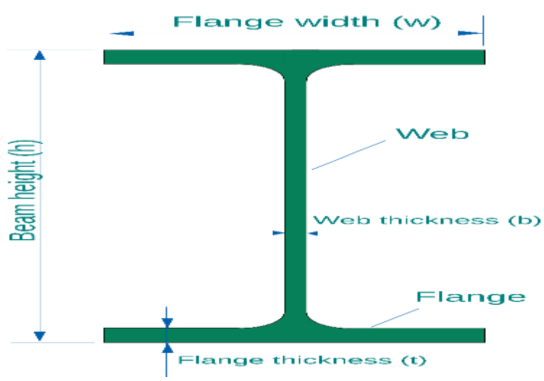

Figure 11: I section

The equation used for design is given as follows.

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

Where M is the bending moment acting on the beam (N-mm), M is the 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 the bending moment, half of the weight of the complete assembly falling on the center of the beam is considered. The maximum weight of the 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 the available load. The maximum stresses available in the beam were calculated as σt = 221MPa. According to the standard, I-sections 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 a factor of safety of 2.5.

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