CHAPTER 6

DESIGN OF AN EXPERIMENTAL TEST SETUP FOR VIBRATION ISOLATION

The experimental model is based on a 1:7 scale on the design drawings for the panel bank 301EX-2401 A/B (Appendix C) assembly drawing, compiled by DEG Engineering and provided by Zonke Engineering, who are the company's representatives in South Africa. The assembly drawing of the experimental setup is shown in Appendix D.

Due to the difficulty in modelling the shape and the flow passages of the dimpled plate to the correct scale, the dimpled plates were substituted by flat mild steel sheet metal.

6.1. Fluctuating force modelling

As there was no fluid flowing through the plates, the fluid-induced vibrations were modelled using an electric vibrating motor coupled to the bottom of the plate pack, as illustrated in Figure 38. These vibrations, caused by the motor, would simulate the fluctuating forces caused by the fluid flow on the plate pack as the motor was aligned with the fluctuating forces causing the relevant mode shape.

6.1.1. Amplitude

The amplitude of the force generated by the motor was adjusted by rotating the two halves of the unbalanced weight in the vibrating motor as illustrated in Figure 39. In this way the unbalanced force could be varied from 10% to 100% of the maximum unbalanced force, which was quoted by the manufacturer as 1.17 kN at normal rotational speed at a frequency of 50 Hz. Therefore, the fluctuating force amplitude could, theoretically, be adjusted from 117 N to 1.17 kN at 50 Hz.

The unbalanced force was adjusted by rotating two cast weights relative to each other, as can be seen in Figure 39. Due to the nature of the weights, the slot for 10% force allowed a significant amount of play, while the fixing bolts were loose. This fact caused uncertainty on the exact size of the unbalanced force once the bolts were tightened and used for the experiment.

Figure 38: The electric vibrating motor, used to induce the forced frequency

Figure 39: The adjustable unbalance plates on the vibrating motor

The exact unbalanced force interacting on the plate pack was determined experimentally by mounting the motor on metallic springs (to minimise damping) and measuring the resultant vibration over a number of forcing frequencies, as described in section 7.6.

6.1.2. Frequency

The frequency of the force was varied with a variable speed controller connected to the vibrating motor. As the motor was a standard 2-pole motor, the maximum rotational speed of the motor was 3000 RPM at an input frequency of 50 Hz.

By means of the variable speed controller, the speed of the motor could be set to any rotational speed by altering the input frequency between the values of 10 Hz and 50 Hz, with a small discrepancy due to the slippage factor of the drive.

Due to the fact that the unbalanced mass on a shaft caused an oscillating force at the same frequency as that of the rotation, the frequency of vibration could be altered between 10 Hz and 50 Hz by using the speed control unit illustrated in Figure 40.

Figure 40: The speed control used to control the forced frequency of the model

6.2. Model structure

To model the mechanical structure of the heat exchanger and, therefore, the mode shape, as closely as possible, the following elements of the real-world column-top condensers were incorporated into the vibration model.

6.2.1. Spacing

Spacing of the plates was provided by copper washers on two threaded rods at the top corners of the plate pack. In the manufacture of the real-life heat exchangers, these rods provided the spacing requirements during manufacture and stiffened the structure during operation.

6.2.2. Top and bottom headers

The top and bottom headers were replaced with a threaded rod using washers as spacers, as can be seen in Figure 41.

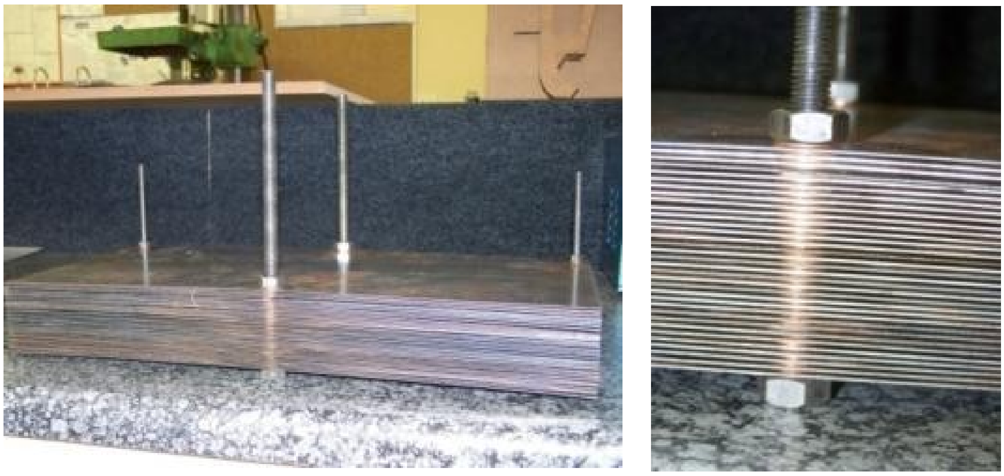

Figure 41: A photograph of the threaded rods simulating the spacing rods and headers

Although the real heat exchanger's plates were welded to the top and bottom headers, the plates were bolted together by using the threaded rod. The connection simulated the welded connection accurately without the need of welding in such confined spaces.

6.2.3. Guides

The U-shaped guides were a key part of the structural connectors of the heat exchangers. Due to the scale of the model, it became difficult to combine the needed strength, stiffness and manufacturability in one material. Masonite guides were, therefore, manufactured on a laser cutter, to provide the needed spacing and accuracy of the spacing requirements.

Figure 42: The assembled plate pack with Masonite guides

The plate pack was assembled and the bolts tightened to provide a plate pack that could be installed in the heat exchanger frame, illustrated in Figure 42.

6.2.4. Assembly

The plate pack was assembled into the model heat exchanger body by connecting the top threaded bar (header) and the top guides to the heat exchanger body. This closely resembled the structure of the real heat exchanger, as can be seen in Figure 43.

The bottom structure was connected to the bottom threaded bar (header) and the bottom guides. Again this structure closely resembled the real-world configuration used in the column-top condensers, as can be seen in Figure 44.

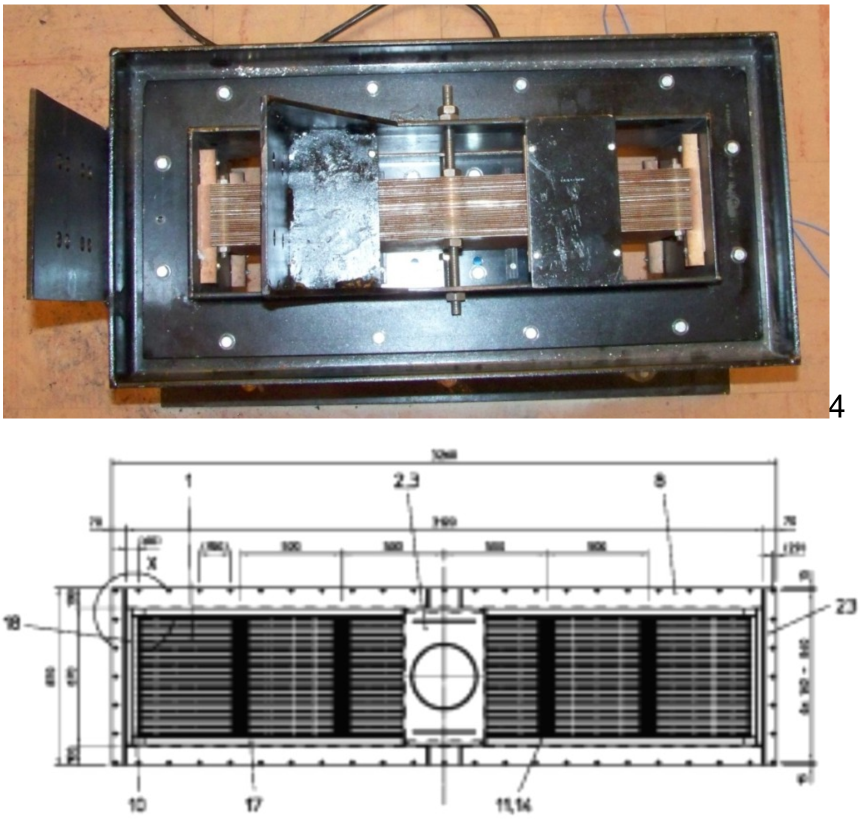

Figure 43: A comparison between the top views of the model heat exchanger with the real heat exchanger

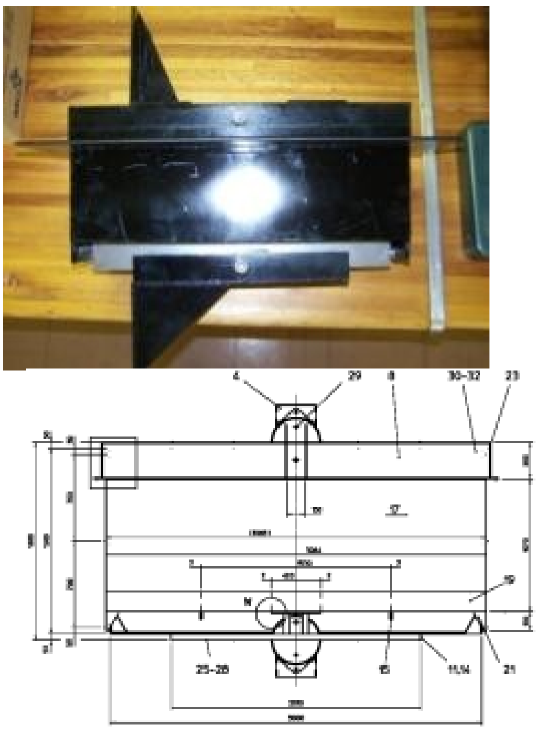

Figure 44: A comparison between the side views of the model heat exchanger with the real heat exchanger

After the heat exchanger model had been assembled, the model was ready to be mounted on the frame (reference structure) representing the column to which the real-world heat exchanger was mounted.

6.3. Mounting system

The mounting system connected the heat exchanger model to the frame representing the column to which the real-world column-top condenser was mounted.

Due to the requirements of the model to show the difference between the current stiff steel-mounted installation (very stiff) and the proposed soft rubber-mounted installation, certain changes were made to the model to make it possible to mount the same structure in both ways.

6.3.1. Model heat exchanger body

The heat exchanger body into which the heat exchanger model was mounted was designed so that the model could either be bolted directly to the frame, or a soft rubber mount system placed between the model and the frame. The support frame was bolted to the floor with Rawl bolts to provide as stable foundation as possible for the heat exchanger model as illustrated by Figure 45.

When the model had been stiffly mounted with steel bolts to the frame, the design simulated the very stiff connection that was used to mount the current condenser to the distillation column. As was the case in the current industrial mounting system, the bottom header was connected to the same frame with a pipe compensator.

As can be seen in Figure 46, the alternative mounting system was implemented by inserting Novibra Type 7B mounts between the model and the support structure, thereby isolating the model from the structure.

Figure 45: Support frame Rawl-bolted to the floor

Figure 46: Soft rubber mounts used to isolate the heat exchanger from the support structure

In order to simulate the isolation of the real heat exchanger in its real-world operational case where the top header also had to convey fluid through the heat exchanger, an additional pipe compensator was added to the top of the heat exchanger model.

6.3.2. Pipe compensators

In the current column-top condenser, the heat exchanger had one compensator at the bottom header to account for the thermal expansion of the differential expansion between the column and the heat exchanger.

To isolate the model in the case where the mounting system was implemented, another compensator was added to the top header pipe. This was done to make sure that the heat exchanger was totally isolated from the support frame to which it was mounted.

In the model, the smallest (DN 50) and most flexible (EPDM) commercial rubber pipe compensators (Type 39) were imported from Willebrandt Gummitechnik in Germany. The selected pipe compensator is shown in Figure 47.

Figure 47: An image of the selected pipe compensators used in the experiment

It was quite difficult to obtain compensators that were as flexible as was required by the scale of the experiment, because a decrease in size of the model increased the stiffness of the equally small compensators due to the smaller dimensions and the fact that the compensators were normally still designed for the same design pressure as the larger sizes (minimum 10 bar @ 100 °C).

To ensure that the heat exchanger model took the physical requirements of isolation into account, an additional compensator was connected to the top of the heat exchanger model. The two compensators can be seen in the experimental setup illustrated in Figure 48.

Both pipe compensators were connected to plates supported by gussets welded to the top and bottom structures. This location accurately simulated the connection of the real compensators to the top and bottom header pipes.

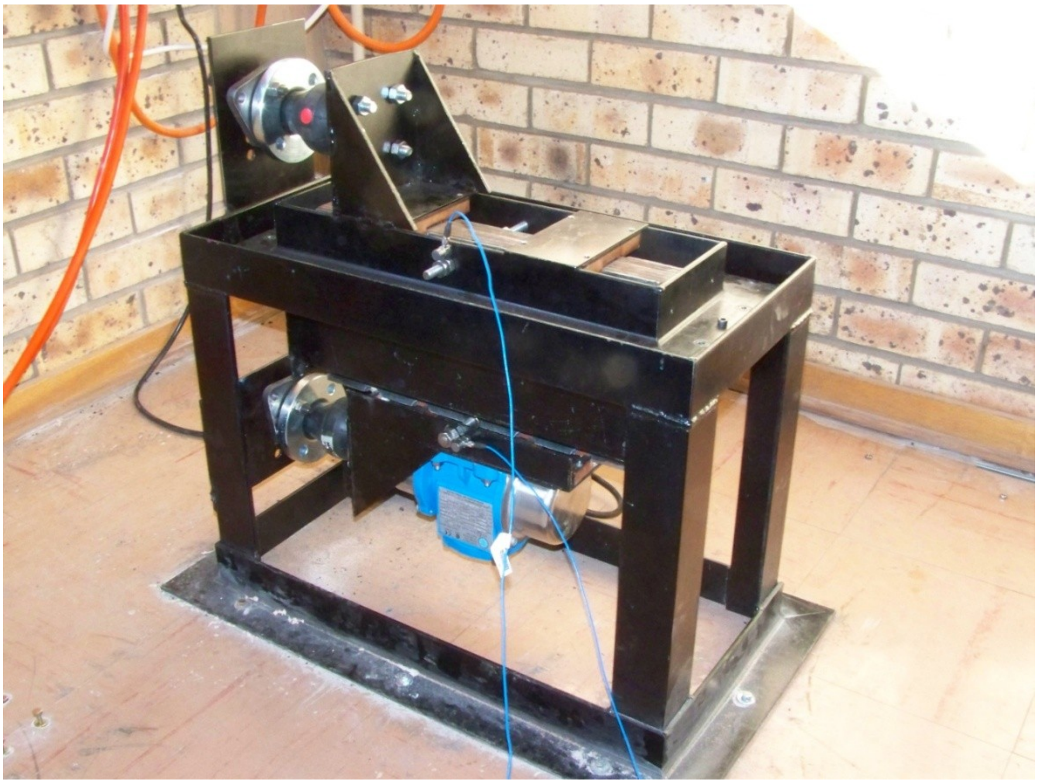

Figure 48: The vibration model in isolation configuration, showing the top and bottom compensators

6.4. Conclusion

The vibration model was designed and constructed in such a way that it incorporated all the important structural connections of the real column-top heat exchangers.

The fluid-induced vibrations were simulated by a vibrating motor, for which both the amplitude and oscillating frequency could be controlled, so that a number of forcing frequencies could be examined.

This model was intended to determine the effect of replacing the stiff steel mounted connection with a soft rubber mounting system that would isolate the model from the support frame, which was assumed to be very stiff.

This comparison would be indicative of the effect of the replacement of the tightly bolted connection of a column-top condenser with a soft rubber mounting system.