

## CHAPTER 4

### VIBRATION CONTROL CONCEPTS

The damage experienced by the column-top condensers at Sasol indicated that the internal components of the heat exchanger, most notably the plate pack, experienced excessive dynamic forces.

These excessive forces caused fatigue in the welds of the bottom header, leading to premature failure of the heat exchangers. To increase the lifetime of the heat exchangers and, therefore, the reliability experienced in the industry, these dynamic forces had to be decreased. Therefore, the efficiency of the vibration-control concept will be determined by the reduction of dynamic forces in the elements of the heat exchanger setup.

To determine the best way of reducing the dynamic forces, a number of vibration reduction concepts were studied.

#### 4.1. Reduction of the effects of flow-induced vibration

One of the most generally accepted ways of controlling vortex shedding vibration is the control of flow structures to eliminate the shedding of vortices, reduce the size of the vortices, move the vortex shedding frequency away from the natural frequency of the system or randomise the vortices.

All the options hinge on the fact that the flow structure can be altered, which is extremely difficult in the narrow flow regions of this compact heat exchanger.

The introduction of baffles or guides will increase the complexity of the system markedly, requiring changes in the primary design or the structure of the heat exchanger before installation could occur.

The introduction of the flow control structures will increase the pressure drop in the system. This is because the structures have to be in the flow region to be effective and the fact that many of the structures promote

laminar flow, which decreases the heat transferred and the efficiency of the heat exchanger.

#### **4.2. Controlling of natural frequencies**

Because flow periodicity only creates large amplitudes and, therefore, large dynamic forces when the vortex shedding or ejection frequency is close to the natural frequency of the system, the damage will be greatly reduced if the natural frequency were moved higher or lower than the vortex shedding and vortex ejection frequencies.

Due to the danger of fluid-elastic instability in cases where the structure is not stiff enough, the most obvious measure would be to increase the natural frequency of the plates in the heat exchanger by increasing the stiffness of the plates.

The plates in the heat exchanger could be stiffened in various ways:

By:

- Increasing the wall thickness of plates;
- increasing the thickness of panel assembly;
- increasing the number of dimples to increase the cross-coupling between sheets;
- decreasing the unsupported length of the panels; and
- introducing ribs to the plate structure.

These changes require a complete redesign of the plates in the heat exchanger, which could then, again, cause problems with the thermal characteristics of the heat exchanger.

The heat exchanger is primarily designed thermally and according to the flow conditions inside the panels. Therefore, the addition of structural requirements will complicate the design even further, risking the current high efficiency and other advantages, not to mention the added design time.

### 4.3. Introduction of damping

The introduction of the correct amount of damping makes it possible to avoid the excessive vibration amplitude caused by resonance. This reduction in the dynamic forces at resonance is, however, countered with higher dynamic forces caused by the damping at frequencies higher than the natural frequency, where the frequency ratio ( $\omega/\omega_n$ ) is larger than  $\sqrt{2}$ . Due to this there is an optimal amount of damping where the beneficial aspects are weighed against the negative aspects.

The dynamic forces we primarily want to control are the forces in the internal heat exchanger plates, which are caused by the displacement of the bottom of the heat exchanger relative to the heat exchanger casing.

To introduce damping directly between the casing and the plates, requires an elastomeric mount or a shock absorber to be placed between the plates and the casing. The most logical place to add damping would be at the anti-node point located at the bottom header, where the area of previous damage was located.

Additional damping can be added to the bottom header, but this requires the installation of the required struts connected to the mounting structure. These structures must be designed carefully so as not to impede the fluid-flow to the heat exchanger.

To include dampers in the structure, a number of structural changes must be made to the heat exchanger, although not as extensive as the stiffening of the structure discussed in section 4.2, it will still add cost and complexity to the modification of the heat exchanger.

### 4.4. Vibration isolation of the system

Vibration isolation of the system by replacing the very stiff steel connection of the current heat exchanger with a soft rubber-mounted system not only has the advantage of changing the natural frequency of the system to a value further away from the frequency of the flow-induced vibrations and, hence, reduces the dynamic forces in the elements of the heat exchanger under operating conditions.

In a study by Nel and Heyns (1996), the dynamic forces transmitted to the support structure of a vibrating machine could be significantly reduced by reducing the stiffness of the mounting system. Although this reduction would cause an increase in the displacement of the machine as a whole, the dynamic forces transferred to the support structure, and, possibly, the internal components, would decrease (Nel & Heyns, 1996).

It was, therefore, theorised that the replacement of the column-top condensers' current stiff steel connection to the support structure with a soft rubber mounting system would reduce the dynamic forces in the heat exchanger internals.

The isolation of the heat exchanger would require the introduction of soft rubber members between all the components currently connecting the heat exchanger to the column. This would result in the introduction of soft rubber mounts between the heat exchanger and the mounting structure, as well as the introduction of pipe bellows between the top header and the pipe connected to the structure.

Nel (2007) emphasised in his study that the characteristics of the pipe compensators used in industrial machine applications could not be ignored and that they significantly impacted on the effectiveness of the vibration isolation of the system.

By choosing the correct stiffness of the mounting system, the dynamic forces in the heat exchanger, most notably the plates, can be reduced. The damping introduced by elastomeric mounts and pipe compensators has the additional benefit of increasing the resistance to vibration due to turbulent buffeting experienced at the new natural frequencies.

As this approach does not require any modifications to the current design of the heat exchanger core, a reduction in the dynamic forces in the heat exchanger could be achieved without affecting the thermal properties of the heat exchanger negatively.

#### **4.5. Conclusion**

After comparing all the possible vibration control concepts, vibration isolation was selected as the most practical solution for implementation.

The isolation of the heat exchanger from its support structure would not affect the thermal performance of the heat exchanger at all, as no change would be made to the construction of the heat exchanger core or the flow structure within the core. This has the additional benefit that no additional pressure tests are required on the heat exchanger after the modification.

The design of the mounting system can be optimised for any size heat exchanger and operating conditions to provide effective reduction in dynamic forces for even the most critical and specialised heat exchangers.

The isolation could even be implemented in existing heat exchangers without serious modifications to the system, reducing the amount of hot work needed and the time needed for the repair.

For these reasons, it was decided to further examine the effect of the vibration isolation of dimple plate heat exchangers as a method of reducing the dynamic forces in the internals of the heat exchanger.