Stefan Gavelin, Tranter International AB, Sweden, explains the advantages of using shell and plate heat exchangers over other designs.

Shell and plate, worth the wait

Plate heat exchangers have been used for many years in the hydrocarbon industry. The advantages of plate heat exchangers became more apparent with the introduction of the gasket free all welded plate heat exchangers in the early 1990s. However, the traditional all welded heat exchangers with square/rectangular plates (the four corner grid design) suffer from thermal and pressure fatigue due to the weak corner welds that often fail in dynamic processes, which results in unexpected shutdown and maintenance. Therefore, this design should be replaced by more reliable shell and plate heat exchangers in order to improve reliability and availability.

The benefits of using plate heat exchangers are well known. They are more efficient, occupy less space, are lighter and do not need to be cleaned as often as shell and tube heat exchangers. When the material is exotic (high cost), the cost is less than for traditional shell and tube heat exchangers due to lower heat transfer area requirements; therefore, costs are reduced where corrosive fluids are present. The traditional welded plate heat exchangers available are of the four corner grid design and are manufactured from either rectangular or square plates. These plates have sharp corner welds that, from a fatigue point of view, are catastrophic and insidious as the welds can fail without warning.

Shell and plate design

The shell and plate heat exchanger is a highly efficient, reliable compact plate heat exchanger. Despite the excellent performance in both stable and dynamic processes, many engineers are questioning the performance due to lack of product knowledge and operating experience. Many engineers are reluctant to try them without a great deal of support in terms of process references and actual recommendations from process licensors. Plate technology has been used successfully for more than a decade in main hydrocarbon processes.

The shell and plate heat exchanger has presented solutions to some of the traditional shell and tube/four corners grid limitations. It provides the thermal efficiency and the compactness of a plate heat exchanger while handling pressures and temperatures otherwise requiring shell and tube units. Its excellent resistance to thermal and pressure fatigue makes it superior to other welded technologies. The shell and plate design can also withstand challenging process conditions with liquids, gases, steam and two phase mixtures. The compact design enables very close temperature approaches and the small holdup volume provides fast startups and close following of process changes.

Fatigue resistance/testing

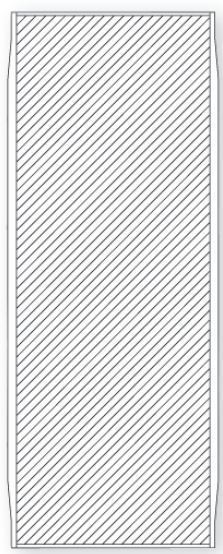
Fatigue failure occurs in components exposed to dynamic and fluctuating stresses. Under such circumstances, it is possible for failure to occur at a stress level considerably lower than the tensile or yield strength for a static load. Fatigue is important because it is the single largest cause of failure in metals, estimated to comprise approximately 90% of all failures. The maximum stress on a welded plate heat exchanger occurs at the circumferential welds around the port holes and the outer diameter of the plates. The cracks leading to failure originate at stress amplification places and it is therefore not hard to understand why circular plates have better fatigue resistance than rectangular plates.

If thermal fatigue resistance is an important design parameter, it is easy to understand that the traditional rectangular/square plates are only suitable for continuous processes with minor fluctuations in temperature and pressure. In the unlikely event that a process is 100% continuous over a longer period of time, this type of welded exchanger is well suited for the process. However, if 100% stability cannot be guaranteed by the process licensor nor the operator, this type of heat exchanger should not be used. When a weld fails, it must be repaired immediately and this will cause unexpected downtime, which can be very costly. Repairing the failed weld is not always a simple task and a weld repair is only viable for special cases.

The design of any component can have a significant influence on its fatigue characteristics. Any geometrical discontinuity can act as a stress raiser and fatigue crack initiation position. The sharper the discontinuity (i.e. the smaller the radius of curvature), the more dangerous the stress concentration. The probability of fatigue failure can be reduced by avoiding such structural irregularities and by making a design where sudden contour changes leading to sharp corners are eliminated. This is exactly what the shell and plate design provides and in addition to excellent thermal fatigue resistance, it also has the same thermal performance as all other welded heat exchangers on the market.

Recently, for welded plate heat exchangers, pressure fatigue (isothermal) has been shown not to be as critical an issue as thermal mechanical fatigue; initial tests of a welded plate pack consisting of circular plates ran into tens of thousands of cycles with relatively high frequency pressure fluctuations. The standard thermal fatigue test also exposes the heat exchanger to 5 - 10 bar pressure fluctuations and differentials (same side fluctuations, opposite side differentials). Specific information about the exact number of cycles a shell and plate can withstand is proprietary. However, most of them can withstand temperature fluctuations of over 150 ˚C for several thousand cycles.

The procedure for measuring the thermal fatigue resistance is not per any recognised standard. Common standards (e.g. ASTM) not only define the test method, but



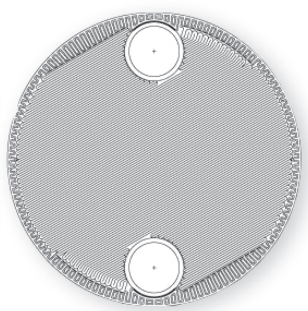


Figure 1. Schematic of a circular and a rectangular (four corner grid) plate. As shown, the circular plate completely avoids the critical corner welds.

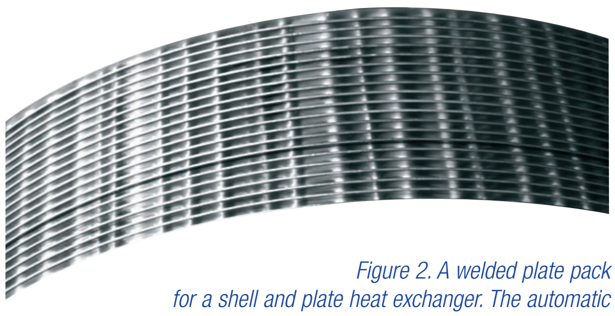


Figure 2. A welded plate pack for a shell and plate heat exchanger. The automatic welding process provides excellent high quality welds.

Table 1. Tranter shell and plate specifications	
Temperature	-50 ˚C to +350 ˚C. C-steel
	-200 ˚C to +900 ˚C, SS and special material
Plate material	1.4404, titanium, C276, alloy 825, AL6XN
Pressure	16/25/40 max. 100 bar
Maximum connection size plate side	ANSI 8 in. (DN200)
Maximum connection size shell side	ANSI 28 in. (DN700)

the test specimen to use for testing. This is not practical for a welded plate heat exchanger as the tests must show the actual resistance for the whole assembly and not the metal or a single weld joint for the metal. Normally, the fatigue test experimental test rig is designed to simulate actual operation (one of many samples). Essentially what is tested is the ability to withstand thermal mechanical fluctuations as experienced in the field, and to locate the weak point in the heat exchanger assembly and identify the mode of failure.

Cleaning the shell and plate

A common question is how the shell and plate heat exchanger is maintained. The shell and plate design offers full maintainability with an option for removable plate pack core via a bolted cover on one end of the shell, which enables the unit to be fully cleanable. As for other types of welded heat exchangers, the most common cleaning methods are chemical and mechanical cleaning. Chemical cleaning is often sufficient for plate heat exchangers and is beneficial as the unit does not have to be dismantled if a mobile cleaning in place (CIP) device is used; therefore chemical cleaning is often enough to restore the original performance of the heat exchanger.

In the event that chemical cleaning is not sufficient, it is possible to use mechanical cleaning in order to restore the performance. Mechanical cleaning means that any deposits are removed by a high pressure water jet. However, a plate heat exchanger consists of very narrow channels, which makes mechanical cleaning less efficient than for other types of heat exchangers. No welded plate heat exchanger is practical to clean even if the plate packs are accessible. Thus if heavy fouling is expected, a different type of heat exchanger should be used. One reason for choosing gasketed plate heat exchangers is that some applications require full access to the plates in order to clean them properly. It is possible to dislodge these materials with chemicals, but this involves risks of also attacking the plates.

Applications for shell and plates

The shell and plates can be used as overhead condensers for condensation of light hydrocarbons from the fluid catalytic cracking (FCC) unit in a refinery. Because of the possible close temperature approach, the shell and plate is well suited for heat recovery into the boiler feed water saving energy consumption in the refinery. For maximum heat recovery, the temperature approach should be as small as possible and because of the small hold up volume in combination with the high heat transfer coefficient, the shell and plate is particularly suited for the application. It should also be mentioned that the shell and plates allow for large connections on the vapour side (shell side) and smaller on the plate side, which makes it easy to optimise a unit not only thermally but also economically.

Another application for shell and plates is as thermosyphon reboilers in stripper columns in gas sweetening processes. The static head created from the liquid level in the column creates a pressure differential that pushes the fluid through the heat exchanger. The fluid enters at the bottom and is evaporated with progression downstream of the plates. The fluid leaves the heat exchanger at the top and flows back to the column through the rising pipe. For evaporation and condensation applications, the shell and plate combines a short vapour flow path with a relatively small hydraulic diameter, which allows efficient heat transfer while maintaining a low pressure drop. This is especially important in thermosyphon reboilers as the static head can be wasted if a heat exchanger with a long flow path is used.

Another application where shell and plates can help solving fatigue problems is in a gas compression process. The gas is typically compressed in several stages working with equal pressure ratios and mechanical work input. The hydrocarbon gas is cooled in the inter stage cooler between each compressor pair and condensed liquids are separated from the gas stream in a knockout drum. As the pressure and temperature is fluctuating, this is a perfect application for shell and plates, especially offshore where space and weight is limited. As for the shell and plate reboiler, the short flow path is of benefit as it will contribute to higher overall compression efficiency (based on energy input versus enthalpy increase) since the expected pressure drop can be kept relatively low.

Figure 3. An assembled shell and plate heat exchanger ready to replace a rectangular all welded heat exchanger in a hydrocarbon process.

Advantages of shell and plate design compared to other types of heat exchanger

- Less than half the size of a shell and tube unit for comparable duties as a result of higher heat transfer coefficient created by the corrugated patterns of their plates.
- Turbulent flow even at low velocities, keeping the plates free from scaling and fouling longer than the laminar flow in shell and tube units.
- Small temperature approaches, which contributes to higher overall heat recovery, therefore higher cost savings.
- Easy to maintain due to the option for removable plate pack core via a bolted cover on one end of the shell in combination with a traditional CIP unit.
- Superior to any other type of welded heat exchanger due to the lack of corner welds, which are critical in other 'four corner grid' designs.

Conclusion

It is very common to see incorrect selections and decisions with plate heat exchangers. A plate heat exchanger design is useless if it has been carried out in isolation, which is a common occurrence. The shell and plate can contribute to higher reliability and availability in the industry and can easily replace the old welded plate heat exchangers with rectangular/square plates. Engineers are beginning to enjoy the advantages of all welded shell and plate heat exchangers, but there is still a lot of work to be done for the manufacturers as many process licensors have a very conservative attitude.