An offshore option

Florian Picard, Fives Cryo, France, presents a new heat exchanger solution suitable for offshore applications.

Brazed plate-fin heat exchangers are considered a key component in the cryogenic industry for applications such as LNG production, LNG transportation, natural gas processing, petrochemicals, and air separation. Their custom-made brazed structure provides a multi-stream, compact and efficient heat transfer solution.

Fives recently developed the brazed stainless steel plate-fin heat exchanger (BSSHX) as a solution to the challenges of high temperatures, high pressures and corrosive environments. BSSHXs are particularly suitable for offshore gas compression systems and are capable of being optimised according to both performance requirements and financial targets.

PFHE: A COMPACT AND EFFICIENT HEAT EXCHANGER TECHNOLOGY

The general structure of a brazed plate-fin heat exchanger is defined by a stacking arrangement of layers, which are separated from one another by a separating sheet. These layers, dedicated to the flow circulation, contain corrugated fins and are sealed along the edges with bars. The components of the core are brazed in a vacuum furnace in a single operation. Several thousand kilometres of brazed joints are thus produced between all of the components of the resultant solid core.

Headers and nozzles are then welded to the core to allow for connection to the inlet and outlet piping. The singular versatility of that multi-stream heat exchanger technology comes from both the possible range of complex flow configurations for layer geometries (co-current, cross-flow, counter-current, zigzag, etc.) and the large available range of fins types (straight, perforated, serrated and herringbone). The design of the stacking arrangement is also a crucial parameter that has to be adapted in order to achieve the expected overall performance.

Modular BSSHXs provide new opportunities and flexibility to fit in with customers’ needs. The technology proposes a new compromise solution in order to meet major financial targets of the plant design, with a greater degree of freedom.

Some features are customisable, including the following:

— Efficiency: counter-current heat exchanger systems are designed to minimise resistance to fluid flow through the exchanger and maximise the heat transfer surface area between streams. This can help to reduce OPEX costs by decreasing energy consumption and increasing process efficiency.

— Compactness: BSSHXs are capable of being reduced in both size and weight. This can make them useful in offshore applications, where lighter weight can result in reduced CAPEX.

— Availability: PFHEs are known to be robust and easy to repair and maintain if they are used in adequate operating conditions. Moreover, high temperature gradients and high pressure loads can be managed within this brazed PFHE structure. Suitable material can also be used to improve corrosion resistance.

— Competitive price: heat exchangers are completely brazed in one piece in a dedicated vacuum furnace. Brazing is not a restrictive assembling process, and is considered as smooth and flexible. As a consequence, complex configurations,
including many different components (bars, fins, parting sheets), which have a large range of thickness (from 0.1 mm to 20 mm), can be brazed all together in order to become a one-piece core. The right quantity of material is then used to produce an optimised heat exchanger at the best cost.

**GAS COMPRESSION SYSTEM: AN OMNIPRESENT PROCESS**

Gas compression systems are widely used in many industrial plants (natural gas processing plants, petrochemical and chemical plants, end-product gases, etc.), where higher pressures and lower volumes of gas are sought.

The design of a gas compression package is imposed by the project development philosophy of the field. It has to cover a large range of operating conditions and accommodate a combination of different process conditions (variable suction pressure, varying mass flow, highest discharge pressure, etc.). These often require the system to have several stages of compression, which can usually be provided with intercooler exchangers.

**MULTI-STAGED UNIT WITH INTERCOOLER PRINCIPLE**

The gas enters the first compressor (P0) and then exits at the first pressure level (P1). Inevitably, the temperature will also increase. The gas is then cooled down in the intercooler, in order to achieve a suitable temperature level for the next compression stage. Condensed liquid is constantly removed from the gas stream prior to each compression stage, using a free water knock-out drum. The gas phase enters a new compression stage and the process starts again.

![Multi-stage gas compression system principle](image)

**THE INFLUENCE OF DESIGN PARAMETERS**

In general, both technical and financial considerations impact the intercooler choice, especially in an offshore application. Inevitably, an intercooler exchanger has to fit the process functioning specifications, which can include different operating conditions. The heat exchanger design is then optimised according to various parameters, e.g. safety, expected thermal performance, pressure drop requirements, weight, size, etc.

However, the main decision on any project is how to achieve the best balance between CAPEX and OPEX. This impacts the entire plant configuration, including the design of the heat exchangers. The most cost-effective option has to be picked among different competing alternatives, which could have different initial costs, operating costs, maintenance costs, and possibly different life cycles. For example, in offshore applications, the weight of the topside plant affects the overall economics of the project. Indeed, minimising the total weight of the topside structure heavily impacts the supporting structure, which could represent half of the total price of the system (FLNG, FPSO, etc.). Thus, maximising the efficiency of the system would lead to energy consumption minimisation during operation, which would maximise revenue. Therefore, engineers have to find the best process design solution to balance initial monetary investment with the long-term expense of owning and operating the plant, according to available and suitable technical solutions.

**USING STEEL PFHE AS AN INTERCOOLER**

Some large compressors require several MW of power to run. Consequently, a slight improvement in efficiency can result in large energy savings. Figure 4 represents the pressure-volume diagram for four different compression system configurations:

- The adiabatic curve represents the isentropic compression, with only one unique staged compression, but requires the maximum work.
- The isothermal curve, which represents the ideal single staged compression, at constant temperature, requires the minimum work. But this case is only theoretical and not possible in practice.
- The brown curve shows how a multi-stage compression system can increase overall efficiency of that system. The compression curve moves towards isothermal by means of standard intercoolers between each compressor stage. The cooler the gas is, the better the compression efficiency is.
- The red curve shows the improvement brought by the use of more efficient intercoolers. The compression curve moves closer to isothermal, which means that the overall gas compression efficiency rises significantly.

In brief, efficient heat exchangers used as an intercooler have several advantages on the overall gas compression system performance, including the following:

- Compression temperature profile approaches close to ideal isothermal functioning, so the work done by the compression system is reduced. Thus, less power is required to deliver the same quantity of gas at a given delivery pressure.
- It increases the volumetric efficiency for the same compression ratio.
- The machine can be smaller.
- Mechanical problems are minimised due to a lower operating temperature.
- Effects from moisture are better dealt with by favouring the drainage of condensate at each compression stage.
- The lubricating system is less impacted by high delivery temperature.
- The low pressure cylinder may be lighter.

**CONCLUSION**

BSSHx's respond to more stringent specifications, and seek to find the best compromise between both technical performance and best return on investment (ROI). They are particularly suitable for offshore gas compression systems. The heat exchangers' options are fully customisable to find the best compromise between thermal and pressure drop performances, cost and weight, while optimising availability, in order to improve the overall process solution.