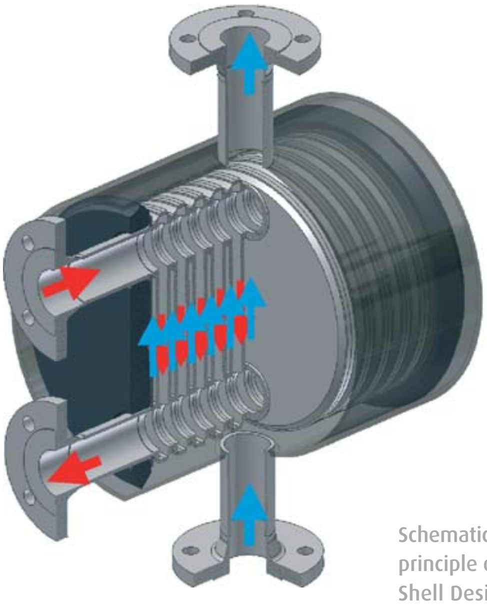
The plate-tube bundle heat exchanger taken literally

ENERGY SAVING IN A 300 BAR HYDROGENATION PROCESS

Fully welded plate heat exchangers of the plate and shell design combine the product advantages of tube bundle heat exchangers with those of gasketed plate heat exchangers. Cognis GmbH and GESMEX GmbH have taken this literally and in collaboration have tailored the energy saving for hydrogenation processes.



Schematic showing the principle of the Plate & Shell Design

Processes initiated catalytically are usually very energy consuming. In times of increasing energy costs possibilities for saving energy are constantly being sought in the chemical industry too. A possibility only utilised comparatively rarely at present is the complete transfer of as much of the excess energy as possible from a medium after exothermic reaction to the same medium before the reaction. Because of their compact construction and the enormous band width of their applications, fully welded plate heat exchangers of the Plate & Shell design are highly suitable for this. Above a working pressure of greater than the 100 bar however there was in the past no alternative to the existing tube bundle heat exchangers. This deficiency has been eliminated by a joint development between Cognis GmbH, Düsseldorf-Holthausen and GESMEX GmbH, Schwerin.

Cognis GmbH, a leading special chemicals company active throughout the world produces numerous products on its Düsseldorf site based on renewable raw materials such as palm kernel oil and coconut oil. In the Derivate plant field of business, methyl ester is converted into a saturated fatty alcohol with the aid of a catalyst (nickel, palladium, platinum) and hydrogen.

The thermodynamic task set for GESMEX GmbH, an innovative manufacturer of heat exchangers in the Plate & Shell design, was to design a heat exchanger for the recovery of the energy from an exothermic reaction process for pre-heating the media mixture being fed to the reaction up to the highest possible temperature level.

The assignment

Primary medium: hydrogen/methyl ester mixture
Secondary medium: hydrogen/fatty alcohol mixture
Process pressure: 200 – 300 bar
Process temperature: 50 – 300°C
Volumetric flow: 50 – 640 Dm^3/h

In a process for the manufacture of fatty alcohols, hydrogen is used as a circuit gas. Here the hydrogen fulfils a dual purpose, namely that of reaction partner and that of a means of transport. It transports the methyl ester used, with which it reacts through fixed bed catalysers in the tower reactor, and conveys the fatty alcohols obtained out of the reactor. Hence the hydrogen is used in a stoichiometric surplus. In addition to this it takes away the energy of the exothermic process.

To heat up the prepared hydrogen/methyl ester mixture, which is at a temperature of 50 ° C before the reaction, up to a reaction temperature of up to 300 ° C, two heating stages are used. In the first stage the hydrogen/methyl ester mixture is pre-heated against the hydrogen/ fatty alcohol mixture which is then hot due to the exothermic reaction. In a second-stage the temperature of this pre-heated circuit gas mixture is then raised to the final reaction temperature by high-pressure water steam. Thus the more thermal energy in the so-called pre-heater that can be transferred into the hydrogen/methyl ester mixture, the lower will be the requirement for costly high-pressure steam. In the planning for the new plants the required heat transfer surfaces of the pre-heater and also those for the subsequent peak heater can therefore be designed correspondingly smaller and thus less expensively.

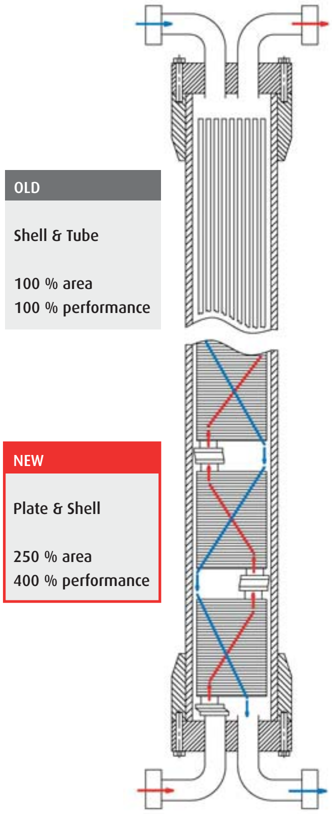
The design problem thus consisted in the replacement of the smooth bore tube bundle of an existing high pressure tube bundle heat exchanger while continuing to use the existing heat exchanger shell (615 mm diameter, 15,700 mm long).

Developed heat exchanger

GESMEX XPS 100 - 172 G 11
Fully welded plate packs in a plate and shell design
Heat transfers surface: approx 300 m^2
Plate material: 1.4404/AISI 316L
Plate thickness: 0.8 mm

Jointly with the Cognis Plant Engineers GESMEX has developed a completely new plate design especially for applications of this type and thus adapted the design of their reliable fully welded plate heat exchanger Type XPS to the requirements of the existing high pressure heat exchanger shell.

Along with the continuing high heat exchange performance of the plate design, the requirements with regard to the pressure drop not being too high and also the guarantee that solid contents (abrasion particles from the catalyser) will pass through, had to be incorporated into the new development. Plate samples were prepared, simulations of different flow states compared, concepts optimised and manufacturing processes for the pressing and welding of the plate packs and also their jointing elements were developed. The whole of the development work took place in close collaboration between the experienced plant personnel of Cognis Derivate plant, who are very experienced in the use of Plate & Shell heat exchangers, and the development engineers of GESMEX GmbH. To a large extent the material and welding advice rested with Cognis Welding and Materials Technology department. At the end of this product development stood the XPS gas plate which, as a result of its 45% deeper and 100% wider medium channels, is excellently suited for heat exchange between two gaseous media. It is also considerably better suited for the conveyance of solid particles with low sedimentation than the previously available standard plates of the plate and shell design.

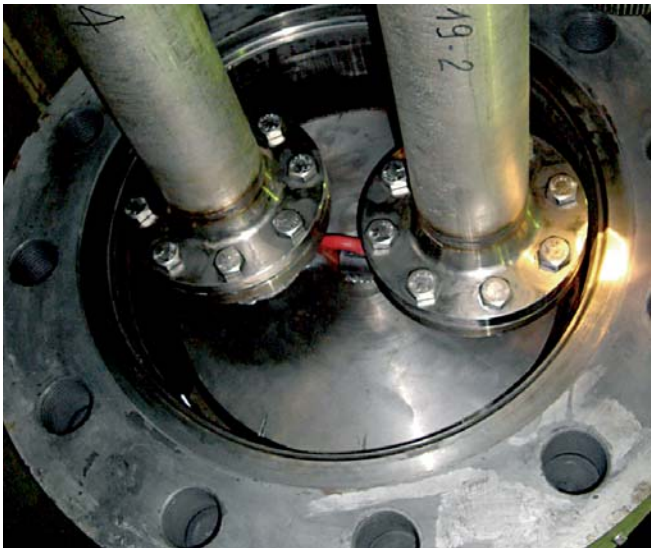


Schematic diagram before and after retrofit

Advantages

- Possible 2.5 fold increase in the heat transfer surface compared with the previously used tube bundles.
- Possible 4 fold increase in the heat transfer capacity compared with the previously used tube bundles.
- For new purchases the expensive high pressure shell can be designed smaller.
- Significant increase in the total process energy efficiency and with it savings in energy costs in the downstream heating processes.
- Thermodynamically safe design of transfer performance and pressure drop.

Without doubt the unique laser weld seams play a major part in the pressure and temperature resistance exhibited by the plate pack under the current operating conditions of 273 bar and 226 ° C. They


Installation of the plate packs interconnected in series into the existing shell

provide extremely reliable joint cross-sections of up to 3.5 times the plate thickness without having to suffer restrictions in the elasticity of the welded joint. As a result the old smooth bore tube bundles can now be replaced by several fully welded plate packs connected in series, without having to fear negative effects from disproportionate increases in pressure drop or a greater tendency to fouling.

Due to the use of this now patented new development the consumption of additional high-pressure steam in the downstream peak heater has already been able to be reduced by around 50-80 % in a comparative operation. With higher exothermic savings up to 100% are achievable. The design of the fully welded plate pack, which conforms to the rules and standards of PED 97/23/EC-AD 2000, is done in accordance with the current state of the technology and can also be done to other engineering standards such as e.g. ASME XIII Div. 1.

For special applications (e.g. for corrosive media) a higher grade material can be selected and used for the plate material. The retrofit of the Shell & Tube heat exchanger to the fully welded plate pack has been carried out by an experienced high pressure apparatus builder as part of a planned plant shut down.

For identical builds of heat exchanger of related types within hydrogenation operations, the necessary number and size of the required plate packs have already been determined. Since the assembling of the fully welded plate pack within the old heat exchanger shell in January 2009 the plant has been working reliably and free of malfunctions.

Conclusion

Due to the replacement of the tube bundles of an existing high-pressure Shell & Tube heat exchanger for a fully welded plate pack in the Plate & Shell design, at a reasonable expense, the economic viability of hydrogenation processes has been able to be considerably improved. The potential savings of this type of measure can be estimated to be much greater as the result can be transferred directly to the same sort of process.

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THIS ARTICLE WAS PUBLISHED IN A SLIGHTLY MODIFIED FORM IN MAGAZINE PROCESS worldwide 3/09.