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Optimization approaches for pillow plate heat exchangers

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Introduction

Pillow plate heat exchangers (PPHE) are made from hydroformed welded plates represent a promising alternative to conventional shell-and-tube and plate heat exchangers. However, the knowledge for the PPHE design is hardly available. Therefore, we performed a comprehensive CFD study on the fluid dynamics and heat transfer in pillow plates. In order to capture the real flow field, it is necessary to accurately reconstruct the complex PPHE geometry. This was achieved through deformation simulations. First numerical results show a large PPHE optimization potential with respect to various geometrical parameters.

Application and characteristics

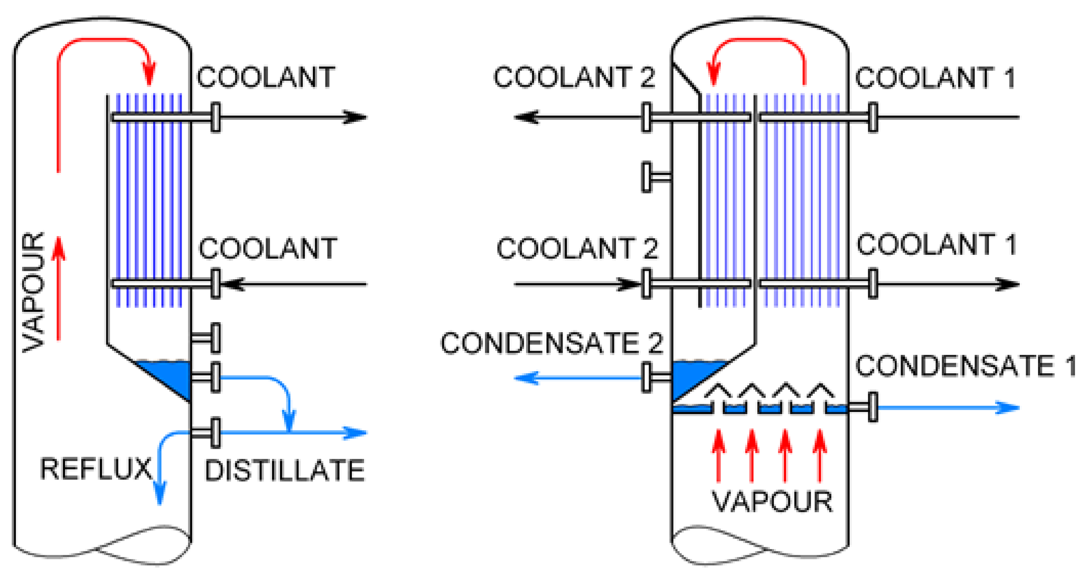

Fig. 1: Pillow plate heat exchangers as top condensers [1]

- Application areas: Top condensers and reboilers in distillation columns, heat integration
- Characteristics: a.o. excellent thermohydraulic performance, low production costs, high structural stability, hermetically sealed channels

Characteristic geometry parameters

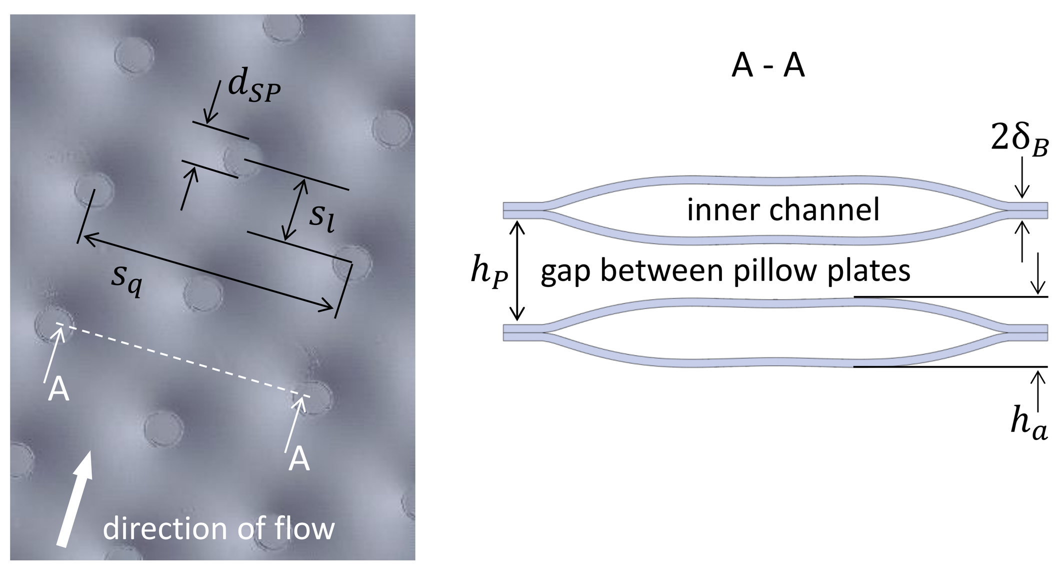

Fig. 2: Characteristic geometry parameters of PPHE

- Welding spots are made either by laser or resistance welding
- Pillow structure is generated by hydroforming

Channel geometry and flow configuration

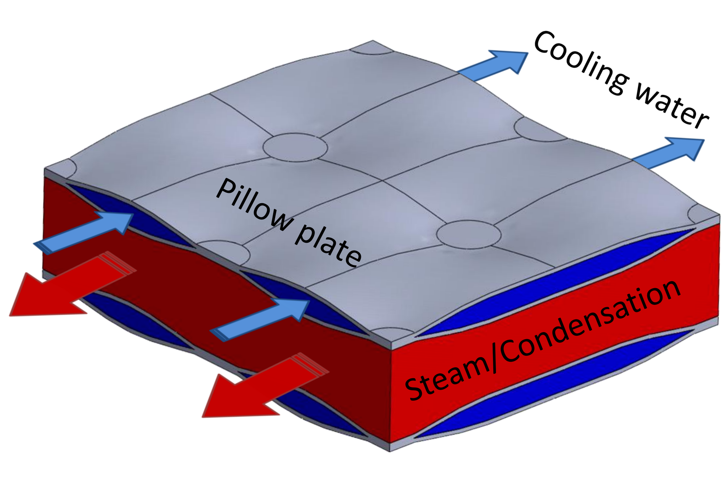

Fig. 3: Countercurrent flow in PPHE

- Inner channel: cooling fluid
- Outer channel: product stream

Optimization approaches

Optimization of inner channel:

Recirculation zones in the wake of welding spots are undesirable for heat transfer:

- Loss of heat transfer area
- Increased pressure loss
- Risk of fouling

Reduction of recirculation zones by using elliptical instead of circular welding spots

- Increased overall efficiency (≈25%)

Table 1:Thermohydraulic parameters

Welding spot	Δp $(mbar/m)$	h (W/m^2K)
circular	4.65	2212
elliptical	3.81	2123

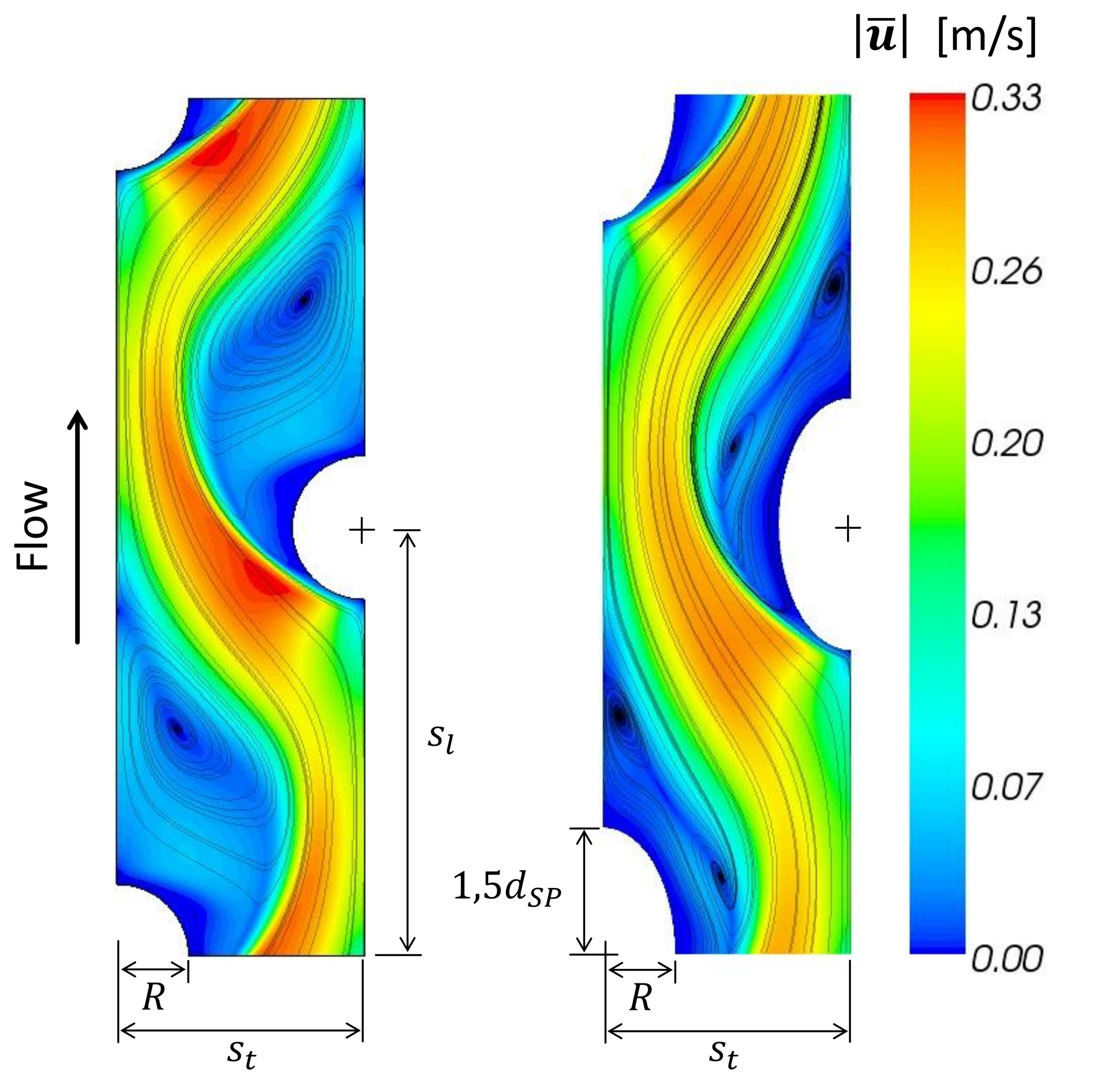

Fig. 4: Velocity field and streamlines in pillow plates with circular (left) and elliptical (right) welded spots

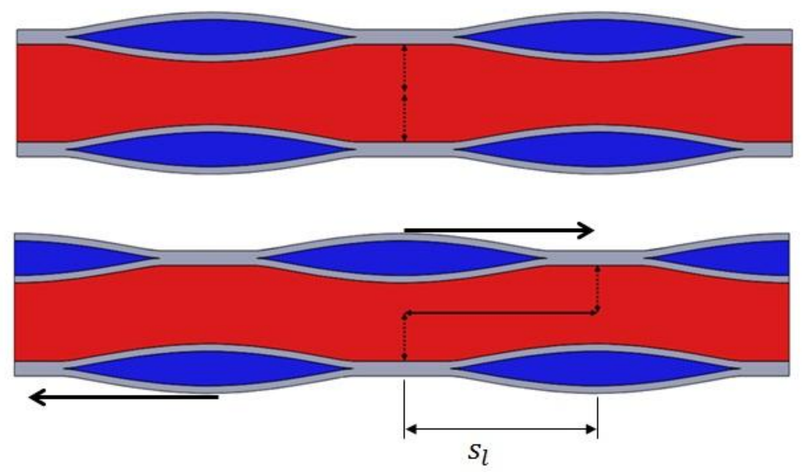

Fig. 5: Schematic representation of pillow plate shifting with $\varphi_l = 0$ (top) and $\varphi_l = s_l$ (bottom)

Optimization of outer channel:

Parallel shifting of adjacent pillow plates in flow direction

- Channel between the pillow plates becomes more even

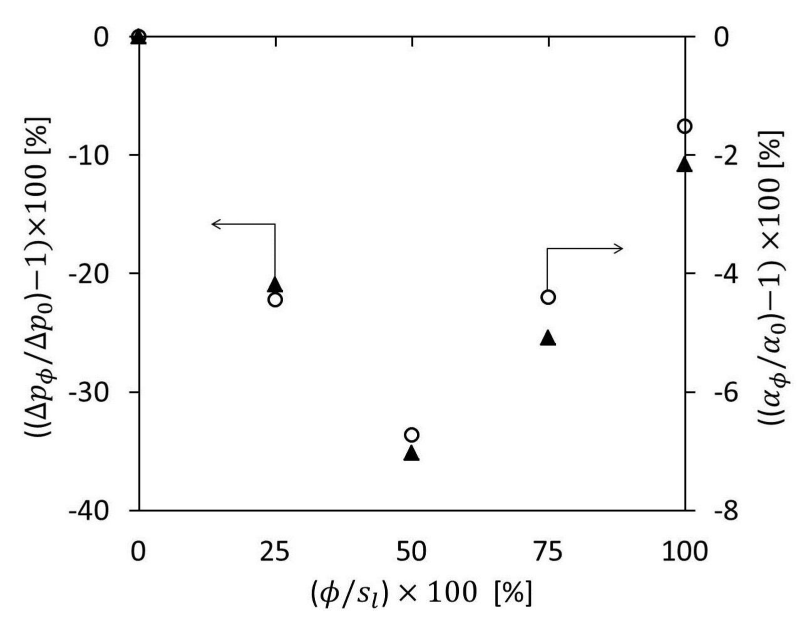

Fig. 6: Specific pressure drop and heat transfer coefficient for different shiftings related to the original case without shifting

Improvement of thermohydraulic performance

- Pressure drop decreases by about 35%
- Heat transfer coefficient decreases by about 7% only
- Best results for a shift of $\varphi_l = s_l/2$
- Increased overall efficiency (≈ 10%)

References

[1] Mühlthaler, W., “Thermo-Blech Wärmeaustauscher-Systeme“, Absolventen Aktuell, 13, 2-3, 2002

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