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Estimation of enhanced heat transfer area targets in process industries

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Abstract

Efficient heat recovery is the fundamental requirement for energy usage in process industries, which can ensure reduction of the fuel consumption and greenhouse gas emissions. Optimizing heat transfer equipment used in industrial processes by heat transfer enhancement can significantly increase the heat recovery of the whole process. It is especially important when the heat transfer surface is manufactured from sophisticated corrosion resistant alloys. In this case it allows to reduce the cost of equipment, the environmental footprint of industrial process units, minimizes energy consumption and carbon dioxide emissions. The implementation of plate heat exchangers into industrial flowsheets needs proper design of this equipment. The heat transfer processes in this units takes place in the channels of complex geometry formed by plates pressed from thin metal. The form of plate corrugation determines the heat and hydraulic behaviour inside the channels formed by those plates. The design parameters of plates, from which the PHE is assembled, determine its behaviour. Geometry and size of plates significantly influence the PHE performance. So it is particularly important to come up with a proper design of PHE unit. It is essential to have a software tool, which enables to design the plate with the optimal geometrical parameters for the unit used for specified process conditions and to estimate the heat transfer area and cost targets for PHEs. Such software has been developed in a form of DLL module, which can be included in a general software package of HEN design.

The proposed software is relied on the developed mathematical model of PHE, which accounts for different plate types and corresponding corrugations geometry. It allowed providing the optimization algorithm based on MINLP method with inequality constraints. The objective function is the heat transfer area of PHE unit. The plate spacing, plate length, the corrugations inclination angle to plate's vertical axis and the ratio of corrugations' pitch to its height are the optimized variables. The developed algorithm is implemented as DLL module, which can be used for multiple calculations when optimizing heat exchanger networks (HEN).

For the Process Integration the ammonia refrigeration cycle was examined and the developed software for HEN optimization was used. The proposed solution envisages the application of 12 PHEs with the total heat transfer area equal to 58.25 m^2. Process

Minimum Approach Temperature is 5.85 °C. Utility Minimum Approach Temperature is 5.00 °C. Overall Minimum Approach Temperature is 5.00 °C. The analysis of the obtained solution shows that putting into new process 8 more heat exchangers with heat exchange area 94% enlargement will require extra 108% cost on heat exchange area. But the optimized HEN will improve the heat integration of the ammonia refrigeration cycle. It significantly reduces the utility capital costs, which are 35% less for the new process. The solution with standard pinch procedure gave Total Network Cost 487300 $/year. The total utility cost of the optimized HEN is 12% less than that figure and 40% less than for existing process. From the economic point of view the proposed process solution is more preferable.

The new software module for estimation of minimal heat transfer area of PHE, which can be achieved by optimizing plate and its corrugation geometry, was developed. This software can be used during heat exchanger network optimization on different stages of that process. The case study shows that the use of enhanced PHEs widens the space of possible HENs options and can lead to better global optimum. Other factors are possible heat transfer enhancement in tubular heat exchangers and mitigation of fouling on enhanced heat transfer surfaces, which are also included in the software developed.

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