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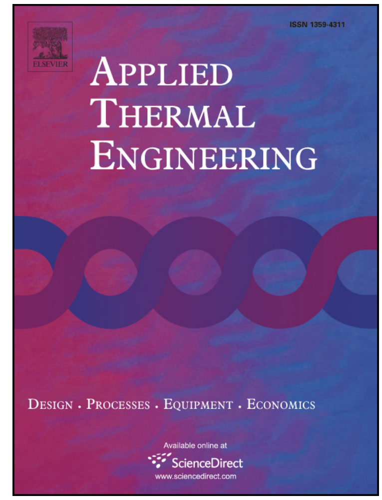

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Study of improvements on flow maldistribution of double tube-passes shell-and-tube heat exchanger with rectangular header

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Abstract

In this paper, a novel and simple method was proposed to improve the flow maldistribution in the rectangular header of the small and compact DTP-STHXs. The numerical simulation was carried out to investigate and evaluate the performance of flow distribution based on experiment. The results showed that the flow distribution of the second tube-pass with conventional header configuration was uniform enough to use in practice. Nevertheless, the flow distribution of the first tube-pass was seriously uneven with E_s = 0.157 and R_v= 2.21. The maximum absolute flow deviation E_i relative to the average flow rate was up to 42.1%. In addition to the first row tubes, the flow distribution of the rest of tubes has been improved dramatically after using the novel header configuration. Two approaches were further proposed to optimize it. Eventually, 90% of tubes within 10% flow deviation was obtained by the optimal header configuration (configuration B with θ = 50°) with E_s = 0.068 and R_v= 1.28. Compared to the conventional header configuration, the standard flow deviation E_s and the ratio R_v decreased by 56.7% and 42.1%, respectively.

1. Introduction

Heat exchangers are widely used in many industrial processes involving thermal energy transfer and conversion [1-4]. Among all, the type of shell-and-tube heat exchanger (STHX) is most favorable due to its larger heat transfer surface and compact design [5, 6]. In conventional heat exchanger design, one basic assumption is that the fluid flowing into exchanger core is even distribution. Nonetheless, in practice, the flow distribution in the header of the STHXs is never uniform [7]. For tubes connecting with the header of heat exchangers, flow maldistribution may be caused either by exchanger geometry design features or by actual operating conditions. The maldistribution of flow rate in tubes will significantly reduce the efficient and performance of heat exchangers [8,9]. Besides, the uneven flow distribution will also result in the non-uniformity in interior temperature field of the secondary side fluid. This will seriously affect the overall heat transfer characteristic and stable operation, especially for the small and compact STHXs [10]. The thermal stress and cracks for tube-sheet will also be further caused by uneven temperature field.

Although it is impossible to have an ideal flow distribution with zero flow deviation, many works have been carried out to make it better. The related research has been carried out generally through three aspects, namely theoretical, experimental and numerical analysis. For the theoretical model, Acrivos et al. [11] and Fang et al. [12] carried out a one-dimensional model and a discrete model respectively to determine the flow distribution in flow manifolds. Kubo and Ueda [13] put forward a theory to calculate the flow rate for each branch pipes and the results were in good agreement with the experiments. It is worth noting that the quality flow distribution was found to be independent of the Reynolds in the range of Re=30,000~100,000 in their work. For the single-pass shell and tube heat exchanger, K. Mohammadi et al. [14] presented a mathematical