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Constructal entransy dissipation minimization of round tube heat exchanger cross-section

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ABSTRACT

Cross-section of round tube heat exchanger with porous materials is optimized by taking entransy dissipation rate minimization as optimization objective. The non-dimensional mean temperature differences of the cross-section with and without high conducting fins inserted are derived, respectively. By taking the radius ratio R_{in}/R_{out} between inner radius and outer radius as a design variable, the entransy dissipation rates are minimized. The heat transfer ability of the heat exchanger without high conducting fins inserted is improved as R_{in}/R_{out} increases, and the non-dimensional mean temperature difference decreases from $2/(3\pi)$ to $1/(3\pi)$. The heat transfer ability of the heat exchanger with high conducting fins inserted is much better than that without high conducting fins inserted, and the entransy dissipation rate varies a little when R_{in}/R_{out} apart from 1.

1. Introduction

How to describe the performance of heat transfer process has been widely discussed in the scientific literatures. Maximum temperature difference is usually taken as the optimization objective in heat transfer optimization, but the minimization of maximum temperature difference reflects the optimization result of local part (the maximum temperature point), not the optimization result of the whole system. Some scholars used finite-time thermodynamics (FTT) or entropy generation minimization (EGM) [1–4] to optimize heat transfer processes. The entropy generation minimization is a heat transfer optimization aiming at exergy lost minimization, but the heat transfer mostly focuses on the heat transfer regularity and its transfer speed, not the exergy lost. The entropy generation minimization (EGM) is not entirety consistent with the heat transfer optimization objective.

To solve the shortage in current heat transfer theory, Guo et al. [5] defined heat transfer potential capacity and heat transfer potential capacity dissipation function to describe the heat transfer ability amount and its dissipation rate in the heat transfer process. In terms of the analogy between heat and electrical conductions, Guo et al. [6] validated that heat transfer potential capacity $E_{vh} = Q_{vh}T/2$ is a new physical quantity describing heat transfer ability which is corresponding to electrical potential energy. The new physical quantity was called as Entransy, and the heat transfer ability lost in heat transfer process was called as entransy dissipation. The concepts of entransy and entransy dissipation were used to develop the extremum principle of entransy dissipation for heat transfer optimization: For a fixed boundary heat flux, the conduction process is optimized when the entransy dissipation is minimized (minimum temperature difference); while for a fixed boundary temperature, the conduction is optimized when the entransy dissipation is maximized (maximum heat flux). The extremum principle of entransy dissipation was used in optimization of heat conduction [7,8], heat convection [9,10], radiative heat transfer [11] and heat exchangers [12–15]. The extremum principle of mass entransy dissipation and its application has also been discussed by Chen et al. [16].

Chen et al. [17] and Wei et al. [18] introduced Entransy concept and the extremum principle of entransy dissipation into heat transfer constructal theory [19–44], the “volume-point” heat conduction based on rectangular element was optimized objective on entransy dissipation minimization, and the results showed that the constructs based on entransy dissipation minimization could reduce the mean temperature difference more effectively than that based on maximum temperature difference minimization. Further, the extremum principle of entransy dissipation was used in constructal optimization electromagnet [45]. Xie et al. [46] optimized the heat transfer model of a rectangular solid wall with an open T-shaped cavity based on entransy dissipation minimization.

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