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The application of entransy dissipation theory in optimization design of heat exchanger☆

Jiangfeng Guo [a], Mingtian Xu [b,*]

[a] Institute of Engineering Thermophysics, Chinese Academy of Sciences, Beijing 100190, PR China
[b] Institute of Thermal Science and Technology, Shandong University, Jinan 250061, PR China

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ABSTRACT

The optimization of heat exchanger design is investigated by applying the entransy dissipation theory and genetic algorithm. It is found that the role played by the fluid friction is not fully taken into account when the working fluid of heat exchanger is liquid in single-objective optimization approach. In order to circumvent this problem, a multi-objective optimization approach to heat exchanger design is established.

1. Introduction

With the sharp decline of fossil fuels such as petroleum and coal, to use energy efficiently is one of effective ways to face the increasing energy demand. Heat exchanger as an important device in thermal system is widely applied in power engineering, petroleum refineries, chemical industries, and so on. Hence, it is of great importance to develop technologies which enable us to reduce the unnecessary energy dissipation and improve the performance of heat exchanger.

The evaluation criteria for heat exchanger performance are generally classified into two groups: the first is based on the first law of thermodynamics; the second is based on the combination of the first and second law of thermodynamics. The heat transfer in heat exchangers usually involves the heat conduction under finite temperature difference, the fluid friction under finite pressure drop and fluid mixing. These processes are characterized as irreversible non-equilibrium thermodynamic processes. Hence, in recent decades the study of the second group has attracted a lot of attention [1]. Inspired by the minimum entropy production principle advanced by Prigogine [2], Bejan [3,4] developed the entropy generation minimization (EGM) approach to heat exchanger optimization design. In this approach, Bejan [3] took into account two types of the irreversibilities in heat exchanger, namely, the heat conduction under the stream-to-stream temperature difference and the frictional pressure drop that accompanies the circulation of fluid through the apparatus. Therefore, the total entropy production rate denoted by $\dot{S}_{\text{gen}}$ is the sum of entropy productions associated with heat conduction and fluid friction. However, among all the variational principles in thermodynamics, Prigogine's minimum entropy generation principle is still the most debated one [5]. Accordingly, the entropy generation minimization approach, widely applied to modeling and optimization of thermal systems that owe their thermodynamic imperfection to heat transfer, mass transfer, and fluid flow irreversibilities, demonstrates some inconsistencies and paradoxes in applications of heat exchanger designs [6]. This is because the focus of the entropy generation minimization approach is on the heat-work conversion processes, while in heat exchanger designs the rate and efficiency of heat transfer are more concerned. By analogy with the electrical conduction, Guo et al. [7,8] defined a new physical concept, entransy, which describes the heat transfer ability. Based on the entransy, the heat transfer efficiency can be defined and the optimization design of heat exchanger can be discussed. It is found that in the irreversible processes the entransy is dissipated and the heat transport capability attenuates [9]. The more dissipation of the entransy implies the higher degree of irreversibility in heat transfer

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* Corresponding author. Tel.: +86 531 993000 6503; fax: +86 531 88399598.
E-mail address: mingtian@sdu.edu.cn (M. Xu).

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