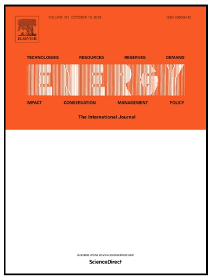
Accepted Manuscript



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PII: S0360-5442(18)31961-3

DOI: 10.1016/j.energy.2018.09.189

Reference: EGY 13883

To appear in: *Energy*

Received Date: 20 July 2018

Accepted Date: 28 September 2018

Please cite this article as: Chaoyang Wang, Ming Liu, Yongliang Zhao, Zhu Wang, Junjie Yan, Thermodynamics analysis on a heat exchanger unit during the transient processes based on the second law, *Energy* (2018), doi: 10.1016/j.energy.2018.09.189

Thermodynamics analysis on a heat exchanger unit during the transient processes based on the second law

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ABSTRACT

Diminishing fossil fuel resources have intensified the need for energy saving. Heat transfer is a basic method of energy delivery and convention, and heat transfer during the transient processes may be affected by the dynamic performance of heaters. Analysis of the heater performances during the transient process based on the second law of thermodynamics may show the room for the improvement in energy saving. Variations of boundaries, such as the flow rates and temperatures of the work fluids, may affect the dynamic behaviors of heaters. The variation rates, formats and ranges of the inlet work fluids flow rates and temperatures on the irreversibility and exergy delivery characteristic are discussed in this paper. The average exergy efficiency ($\eta_{E,avg}$) of the heater during the transient process with different operational parameters are presented and compared. The results show that, in the identical variation range, the maximum difference in $\eta_{E,avg}$ with different flow rates and temperature variation rates of the cold work fluid are 0.3% and 0.4%, respectively. With step variation format, the maximum difference in $\eta_{E,avg}$ for the different variation ranges of the cold work fluid is 0.85%.

***Keywords*:** Heat exchanger; Energy saving; Transient processes; Entropy generation; Exergetic efficiency

1 Introduction

Energy saving is a key method to prolong the usage time of fossil resources. Most fossil resources, such as coal and natural gas, are converted to thermal energy to generation electricity, supply heat, and conduct chemical processes. Heat transfer process is the main method for thermal energy delivery from one work fluid to another. Recuperative heaters are widely used in these processes [1-3]. The heat transfer characteristics of the heater can be evaluated by calculating its energy and exergy efficiencies. Design parameters, such as materials and structure sizes, may affect the heat transfer performances of the heater. Moreover, operational parameters, such as work-fluid inlet flow rates and temperatures, may greatly influence the behaviors of the heater. The operational parameters affect not only the heat transfer characteristics in stationary states but also the dynamic performances of the heater. To improve the energy usage efficiency of the heater, the optimizations of the design and operational parameters are studied for many years. Frequent transient operations highlight the need to investigate the dynamic behaviors of the thermal devices [4-11]. To reveal the mechanism of the energy conversion and the irreversibility of the heat transfer during the transient process, basic research on the dynamic behaviors of the heater and the analysis based on the second law of the thermodynamics is necessary.

Numerous researchers have investigated the optimization of the heater design. Bejan [12-14] studied the structural designs for a variety of heat exchangers, and the entropy generation minimization method was proposed and used for the heater design. Mishra et al. [15] proposed the plate-fin heat exchanger design using genetic algorithm. The optimizations aimed to minimize the number of entropy generation units for the specified heat duty under given space restrictions. Guo and Huai [16] proposed component-based optimization, and a system-based optimization design was implemented based on the main heat exchanger which works as a component of a regenerative Brayton cycle system. Huang et al. [17] investigated the optimal design of vertical ground heat exchangers by using entropy generation minimization method and genetic algorithms. Chen et al. [18-21] studied the constructal design and operation optimizations for various types of heaters based on heat transfer theory. Wang et al. [22] performed irreversibility analysis for optimization design of plate-fin heat exchangers using a multi-objective cuckoo search