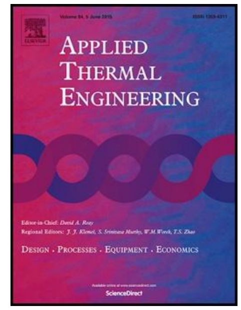

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Thermal-hydraulic performance optimization of inline and staggered fin-tube compact heat exchangers applying longitudinal vortex generators

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HIGHLIGHT

- Simple approach based on trigonometric decomposition to treat the constraints.
- The optimum ratio between the vortex generator height and fin-pitch is 0.6.
- Heat transfer for staggered tube arrangement is more pronounced than for inline.
- The optimum vortex generator shapes are similar to rectangular-winglet.
- Optimum configurations are more influenced by tube arrangement than by *Re* number.

ABSTRACT

Optimization is now recognized as essential in the design of modern compact heat exchanger since the augmentation of heat transfer applying longitudinal vortex generator depends on different interacting parameters such as its streamwise and spanwise locations, attack and roll angles and shape. For this work, an optimization procedure based on the SIMPLEX method was conducted through a fluid-solid conjugated heat transfer modeling considering a fin-tube compact heat exchanger with two rows of tubes in staggered and inline arrangements, in order to find an optimum configuration of the vortex generators for two objective functions related to Colburn factor (j) and Friction factor (f). Two Reynolds numbers (250 and 650), performing as a function of fin-pitch, were evaluated. Moreover, a simple approach based on trigonometric decomposition to treat the constraints is presented, which allows great flexibility to vortex generators to cover the design space solution. Seven independent input parameters for each vortex generator in optimization procedure were considered, totaling fourteen independent variables. The results indicate that this work optimized configuration for the vortex generators achieved higher heat transfer augmentation than those in previous works in the open literature, for both objective functions, Reynolds number and tube arrangements, and it is more pronounced for staggered tube arrangement than for inline tube arrangement. Moreover, suitable vortex generator shapes to maximize the objective functions are more similar to rectangular-winglet type than delta-winglet type, and the optimum ratio between the vortex generator height and fin-pitch is 0.6. Although several trends could be defined for the optimum points, optimized configurations of the vortex generators were found to be different for each Reynolds number, tube arrangement and objective functions, indicating strong asymmetry between the vortex generators to achieve higher heat transfer augmentation.

Keywords: Heat exchanger, Heat Transfer Augmentation, Vortex Generator, SIMPLEX Method, Optimization

1. Introduction

Compact Heat Exchangers are widely applied to several engineering fields, such as automotive and chemical industries, heating, residential air-conditioning and refrigeration. For applications in which the physical space available and weight are concerns, for example for automotive and aerospace industries, the search for solutions that could increase the ratio between heat transfer and pressure drop has become a key part during the thermal system development process. It is known that the heat exchanger performance could be enhanced providing a decrease of the airside convection resistance, which is usually dominant due to the thermo-physical properties of the air. Vortex Generators (VG), such as wing and winglet types, are passive enhancement technique able to provide this effect and to improve the heat transfer performance in fin-tube heat exchangers. In this passive technique, the heat transfer surface is intentionally modified to introduce secondary vortices into the main flow [1-3]. Although the surface total area of the heat transfer is not significantly changed due to the VG surface, the fluid flow dynamics may be strongly disturbed. In fact, VG not only disturbs the flow field and disrupts the growth of the boundary layer, but also causes fluid swirling and heavy exchange of the fluid core and walls, leading to enhancement of heat

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