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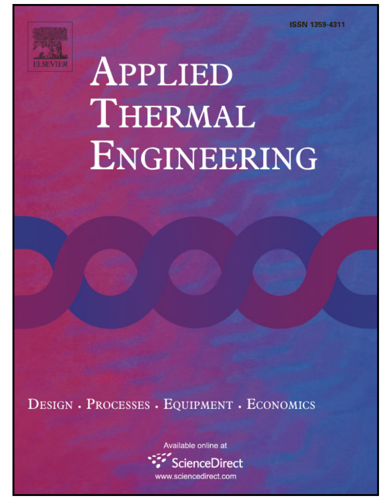

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Numerical investigation of thermohydraulic performance of air to water double-pipe heat exchanger with helical fins.

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ABSTRACT:

In this work, the thermohydraulic performance of a proposed design of an air-to-water double pipe heat exchanger with helical fins on the annulus gas side, is numerically studied. Three-dimensional computational fluid dynamics (CFD) simulations are performed, using the FLUENT software in order to investigate the gas side fluid flow, turbulence, heat transfer, and power consumption for different configurations of the heat exchanger. CFD performance analysis is conducted under turbulent flow conditions for configurations with helical fin spacings in the range of 0.05–0.2 m. The numerical model is first verified against experimental data available in the literature, for a double-pipe heat exchanger with longitudinal fins. Then, longitudinal fins are considered as a reference configuration and a comparative analysis of the thermohydraulic performances of the different helical fin configurations and the reference configuration is conducted. The flow field characteristics of the helical fin configurations are clearly demonstrated and discussed. Key design parameters such as the heat transfer coefficient, pressure drop, and thermal performance enhancement factor are evaluated to predict the overall performance of the heat exchangers. Results show that the use of helical fins significantly enhances the heat transfer rate for the same unit weight, but it also increases the pressure drop. The overall compactness and performance of the heat exchanger improve through the use of helical fins, and within the scope of the present investigation, the helical fin configuration with a fin spacing of 0.1 m provides the optimal thermohydraulic performance. Therefore, the present study helps to reveal and expand the potential of helical fins in providing an enhanced overall performance of this type of heat exchanger as well as in limiting its material cost for design engineers and manufacturers.

1. INTRODUCTION:

Double pipe heat exchangers are extensively used in various industrial processes and research fronts; for example, they are used in air coolers and in waste heat recovery and conversion systems and for heating in chemical processes. Recently, various techniques have been employed for heat transfer enhancement in the aforementioned applications; these techniques can be beneficial from a practical viewpoint and their implementation may result in energy savings, time savings, an increase in thermal ratings, and extension of the work life of the equipment [1].

A simple gas-to-liquid double-pipe heat exchanger consists of two pairs of concentric pipes; here, fluids usually flow through the exchanger in opposite directions (counter-current flow). Generally, in gas-to-liquid heat exchangers, the heat transfer coefficient on the liquid side is one order of magnitude higher than that on the gas side, which, in turn, limits the heat transfer rate [2]. To increase the heat transfer capacity, the heat transfer surface area is increased by using extended surfaces termed fins on the gas side; this improves the convective heat transfer by decreasing the thermal resistance on the gas side, but at the cost of an increase in the pressure drop [3]. The type and geometry of the fins are a determining factors for enhancement of the thermohydraulic performance of gas-to-liquid heat exchangers, and the use of fins can increase the heat transfer surface area by a factor of 5–30 depending on the application [4].

Literature on fin and tube heat exchangers is vast, where fins of various types and geometries have been reported to be used to enhance the heat transfer and effectiveness of these exchangers. A description of representative physical conditions considered in such works is provided herein. Ahmad et al. [5] numerically investigated the heat transfer performance of a double-pipe heat exchanger with longitudinal exponential fins in the annulus. Sheikholeslami et al. [6] experimentally studied the thermohydraulic performances of a double-pipe water-to-air heat exchanger equipped with discontinuous helical turbulators and reported that the thermal performance is an increasing function of the open area ratio but a decreasing function of the pitch ratio. Zhang et al. [7] experimentally and numerically studied the fluid flow characteristics on the annulus side of a double-pipe heat exchanger with one helical fin and pin fins and measured the three-dimensional velocity components by using a laser Doppler anemometer; their results improved the understanding of flow in a double-pipe heat exchanger with helical and pin fins.. Cavazzuti et al. [8] presented a systematic method for the optimization of a finned concentric pipes heat exchanger for industrial recuperative burners; the aim of this optimization was maximization of the heat transfer of the recuperative heat exchanger under cost, compactness, and pressure drop constraints. In their proposed method, the OpenFOAM software was used for computational fluid dynamics (CFD) simulations; the optimum configurations were found to enhance the heat transfer capacity of the recuperative heat exchanger by up to 10.8%. Kumar et al. [9] presented a CFD comparison of thermalhydraulic performances of various fin patterns for an air-cooled heat exchanger; their results suggested that the capital and operating costs of the air-cooled heat exchanger could be minimized by using circular fins, but plate fins might be more appropriate for achieving a more compact configuration. Torabi et al. [10] conducted a numerical comparative study of longitudinal fins of rectangular, trapezoidal, and concave parabolic profiles with multiple nonlinearities; they established the performance characteristics of these fins for different thermal conductivities, emissivities, and convection–conduction parameters. Sahiti et al. [11] experimentally studied the heat transfer and pressure drop characteristics of a double-pipe pin fin heat exchanger and developed a mathematical for its optimization; the model was based on minimization of entropy generation for different