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Heat Transfer Enhancement by Using Vortex Generators

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ABSTRACT

The efficiency of energy converters, cooling units and heat exchangers is the most important aspect for their economical success. For heat transfer enhancement in micro heat exchangers most often passive devices like roughness elements, dimples or cavities are used. For conventional converter heat exchange is enhanced by modifying the flow with bigger scale control devices like e.g. guiding plates, diverter strakes or delta shaped winglets can be found. The main physical mechanisms causing the enhancement of heat transfer is the generation and amplification of sufficiently strong longitudinal vortices which are interacting with the thermal boundary layer. The stratification of the thermal boundary layer near the heated walls is disturbed by these vortices. The convection of warmer fluid perpendicular to the heated wall and the mixing with colder fluid is intensified, and, additionally, further external momentum is transported into the inner boundary layer region. Depending on the specific technical application, flow control devices differ in their geometry, dimensions and integration. Dupond et al. [1] used compact texture like embossed vortex generators similar to dimples. Fiebig [2], Gentry et al.[3] and Jacobi et al. [4] examined experimentally the flow effects of fins and winglets to improve the heat transfer on plates and in tubes or channels. They also conducted numerical simulations considering flow control devices with varying shape and geometry to find device design criteria for heat transfer enhancement. Since vortex induced heat transfer enhancement depends strongly on shape and position of vortex generators the subject of ongoing research is to find design strategies for device shape and placement optimization. In particular, the investigation of confined channel flows with delta wing vortex generators has motivated numerous numerical and experimental studies [2]. Until now the physical mechanisms are not sufficiently understood. Thus, in order to improve the design of compact heat exchangers a better physical understanding of the generation of these flow structures is mandatory. Therefore, the task of the presented work is to analyse the interaction between vortices and the thermal boundary layer, the impact of the vortical flow structure on the heated wall and the convective transport of heat within the flow domain. In this numerical study a generic rectangular heat transfer channel with a heated upper wall is subject of the examination. Although various types of flow manipulating devices could be used for generating co- or counterrotating vortices disturbing the stratified temperature layers this consideration is restricted to delta wing vortex generators. In this case pairs of generic delta wings are used to influence the flow whereas a special local arrangement is focal point of interest: the vortex generator pairs are arranged facing one another: one pair on the hot

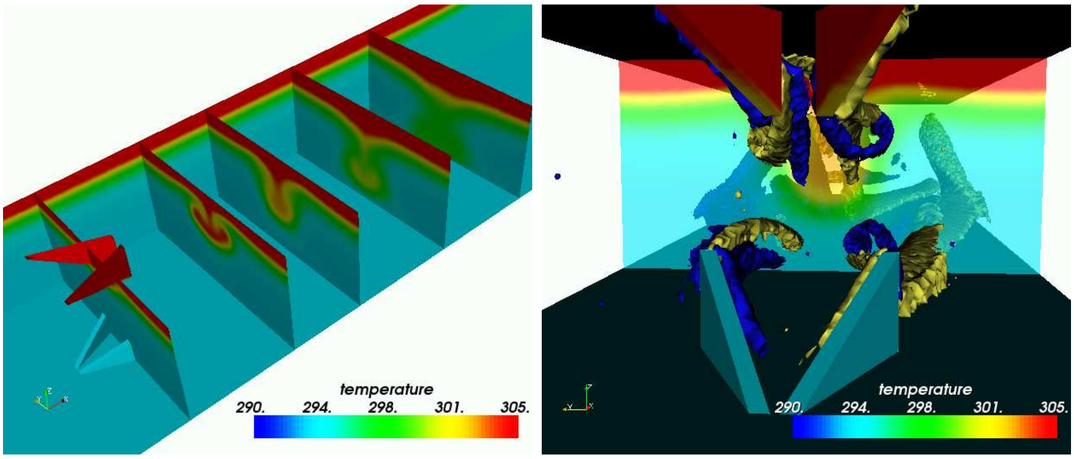

Figure 1: Vortices generated by vortex generators and their impact on the temperature field

wall, one on the cold opposite channel wall. The upper pair on the hot wall generates a so called "common flow up" pointing away from the wall flow structure, whereas the other pair induces a "common flow down" flow structure. This leads to a transport of fluid from the hot to the cold wall with the upper vortex pair feeding the lower vortex pair. The enforced vortical structure enhances the mixing of cold and warm fluid in the channel. A focal point of this consideration is the analysis of the vortical flow field and their interaction with the associated temperature field. Laminar vortical flow structure is analysed by using the Lambda2 criterion and normalized helicity to distinguish counter-rotating vortices. The heat transfer is examined by the temperature distribution and by calculation of beta-planes, suitable for the visualisation of the convective transport of momentum and heat localising the origin of mixing fluid. The usage of visualization techniques like streamline integration and advanced line integration convolution techniques yields a visual impression of the vortical structures and the associated heat transfer. A topological analysis allows a deeper understanding of the main vortical flow structures and the resulting temperature distribution. This work presents results of a comparative analysis, especially of the topological structure of vortices generated by vortex generator pairs and their interaction with the temperature field.

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