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Investigation of Heat Transfer Enhancement using Vortex Generators

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Abstract: *In most of the engineering applications it is heat exchange mechanisms that limit the performance of the overall system and thus considerable effort has been devoted to increase heat transfer rates by introducing effective transport enhancement devices or techniques. Recent research has shown that mixing in non-turbulent flows can be greatly enhanced by initiation of complex particle motions caused by chaotic advection. Transport enhancement schemes can take a variety of forms, from the 'passive' addition of flow obstacles, to the 'active' modulation of the driving flow rate. An essential step in a large number of industrial processes is the removal of heat from a wall to a flowing fluid stream. In most of these applications the design is such that the temperature on the heated wall remains constant with required heat flux. In order to satisfy the constant wall-temperature requirement, two approaches can be adopted: the Reynolds number of the flow can be increased while keeping the geometry fixed; or the geometry can be modified so as to increase mixing while maintaining low Reynolds number. It is typically the case that with either of these remedies the requisite increase in heat transfer co-efficient can be obtained, and thus the distinction between the two choice is determined solely by the optimality criteria used to evaluate the overall system performance. Here we will investigate the performance enhancement by analyzing the delta wing type vortex generators.*

Keywords: *Delta wing, Heat transfer enhancement, vortex generators.*

1. INTRODUCTION AND THEORETICAL ASPECT

The longitudinal vortices generated on the channel walls shown in Fig. 1 are representative of a wide class of engineering heat exchange enhancement techniques. These longitudinal vertical structures are found in channel confined flows where they are generated by the protrusions within the channel/ duct and they can lead to the development of chaotic flow regimes. Protrusions from a heat transfer surface, designed to generate vortices, are termed as vortex generators (VGs) capable of generating longitudinal vortices. Vortex breakdown remains a significant and intriguing phenomenon that can have detrimental or beneficial effects, depending on the application [1]. These generated longitudinal vortices persist over long distances in the flow direction and diffuse slowly in while traversing downstream causing significant increase in heat transfer. VGs that primarily generate longitudinal vortices are especially suited for heat transfer applications that can be analyzed by Lagrangian approach to study the behavior of motion of fluid particles chaotic particle paths may naturally appear or may be expressly made to appear in an interacting vortex field by superposition of an external motion. The process of chaotic mixing leads to efficient transport of scalars such as heat and species concentration in fluids [3]. An attractive feature of chaotic advection, which differentiates it from turbulent flow, is that it can be brought in even for low Reynolds number flows.

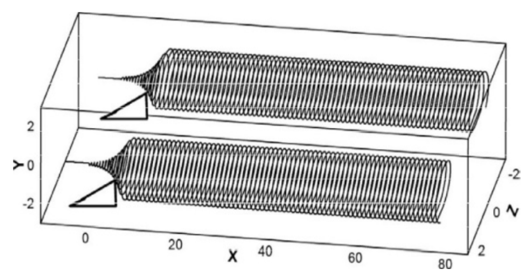


Fig. 1: Trajectories of two particles in the field of twin vortex system.

Experimental study reveals where a vortex filament is created by stretching of vorticity through suction. The coherent structure of the vortex is observed to be only the spiraling motion. However, when a translating flow is superimposed, vortex filament with a helical motion gets generated. The chaotic particle behavior is found in many practical applications, where the existence of chaotic path lines, effect arising due to secondary effect of vortex generation[2] is predicted using Lagrangian approach of tracking individual fluid particles. The Lagrangian dynamical system approach is used in the design of industrial devices, such as stirred tanks, micro-biological flows, combustors, micro-channels and micro-mixers. In most domestic and commercial refrigeration systems, frost forms on the air-side surface of the air-to-refrigerant heat exchanger. An array of delta-wing vortex generators is applied to a plain-fin-and-tube heat exchanger with a fin spacing of 8.5 mm. Heat transfer and pressure drop performance are measured to determine the effectiveness of the vortex generator under frosting conditions [5].

Flow through an interrupted or enhanced heat exchanger passage is complicated and may cause the natural formation f vortices that can enhance local heat transfer by several hundred percent. Vortex-induced heat transfer enhancement exploits this effect through the deliberate generation of large-scale longitudinal vortices in the flow [6]. Numerical results [7] reveal that cross-averaged absolute vorticity flux in the main flow direction can reflect the intensity of the secondary flow; a significant relationship between this cross-averaged absolute vorticity flux and span-averaged Nusselt number exists for the case studied. A benchmark dataset [8] can be used as base for related experiment.

C.B. Allision [9] found that the winglet surface had 87% of the heat transfer capacity but only 53% of the pressure drop of the louvre fin surface. In general, the vortex system may either be fixed or moving. However, the stream wise vortices generated by fixed protrusions commonly called vortex generators (VGs) mounted on fins of heat exchangers form a system of fixed vortex filaments. On the other hand, if the vortices of a given physical system are not fixed, the consequences may lead to vortex merging.

2. ANALYSIS

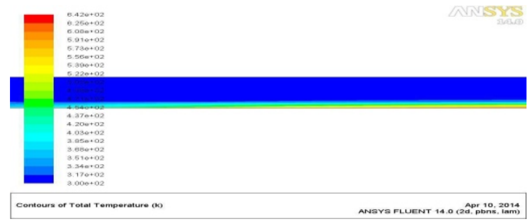
Analysis has been done for flow over a flat plate with and without vortex generator. Geometry was created for following dimensions.

Flat plate of length: 800 mm

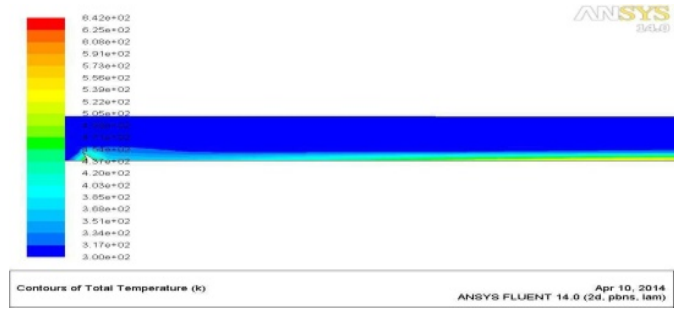
Delta wing vortex generator distance from leading edge: 10 mm Delta wing dimensions: 1.5X1.5X2.0

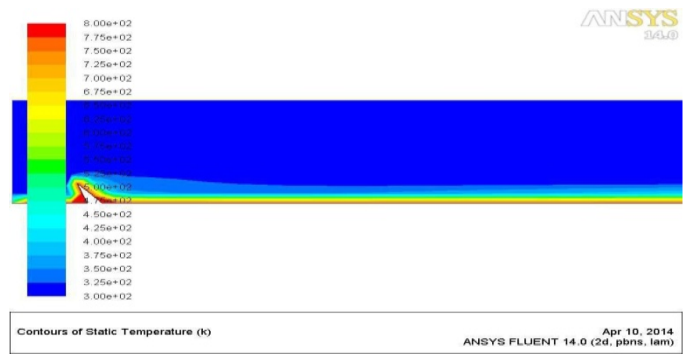
Meshing:
A rectangular domain was considered for the analysis
Material property:
Material: water
Density: 1000 kg/m^3
Viscosity: 1 kg m/s
Boundary conditions:
Inlet velocity condition: 2 m/s, 1atm
Solution Scheme was considered as SIMPLE and relevance of 10-6 was considered for analysis. Each case was given 20000 iterations and solution was obtained.

Case 1 (without vortex generators)



Case 2(with vortex generators)





3. DISCUSSION

As mentioned in the introduction section, in most cases, the secondary flow is used to enhance convective heat transfer. It was demonstrated through flow visualization that the proposed delta-winglet orientation generated distinct coherent stream wise vortices. In case one without vortex generator, we can see the temperature variation in the figure. In case two, with vortex generator, we can see the variation of temperature distribution. The variation can be attributed to the disturbance generated inside and outside the thermal boundary layer, thereby altering the temperature distribution.

4. RESULT

On comparing the results of temperature distribution for both the cases we conclude that using vortex generators heat transfer can be enhanced with some pressure drop due to obstruction. A series of vortex generators or a CFD/CFU arrangement can be used for better results.

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