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# Measurements of heat transfer enhanced by the use of transverse vortex generators

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ABSTRACT

In the presented research, a three-fold approach was made to study the air flow in the wind tunnel featuring transverse and inclined vortex generators. In the accomplished experiments, the Reynolds number was varied from 9000 to 35,500. The aspect ratio of the rectangular channel was equal to 6.37 and pitch-to-height-ratio of the ribs was equal to 11. Two experimental techniques were employed in the research. Firstly, the steady-state liquid crystal technique was used to determine the distribution of surface temperature and subsequent evaluation of heat transfer coefficient. Secondly, the PIV (Particle Image Velocimetry) method was employed to study the flow pattern produced by transverse vortex generators, visualized using a planar beam of double-impulse laser tailored by a cylindrical lens and oil particles. Apart from the heat transfer data, the pressure drop was also measured.


## 1. Introduction

Swirl, flow destabilization and developing viscous layers are commonly regarded as three passive ways to influence heat transfer due to the presence of vortices and their generation. Their capability is to intensify heat transfer even by several hundred percent in selected cases. In order to appropriately devise the flow turbulizers fundamental knowledge is required on the issue of how different devices contribute to vortex generation, their control and of how they interact with the original or base flow and temperature field. Selection of the most appropriate vortex generators (VG) for a given task requires prior knowledge of the heat transfer and flow losses associated with the generation of a specific vortex system.

Vortices swirl fluid around their axis of rotation, they induce velocity profiles which are less stable, and their generation implies flow separation and developing viscous layers [1–3]. Vortices do not only contribute to swirl but also destabilize the flow. That is well known as the transverse vortices (TV). The Karman vortex street behind a cylinder in the cross flow is probably the best known example. The destabilization effects of longitudinal vortices (LV) are still under investigation. One of the reasons is that single LVs are more difficult to generate than TVs. Self-sustained oscillations associated with vortices have been exploited very little in general and specially for heat transfer purposes. The third mechanism, i.e. viscous layer interruption and initiation of new developing viscous layers, is implied by vortex generation (VG).

Many parameters affect the performance of rib channels equipped with turbulising ribs. These are the shape and dimensions of the channel (including constant and variable cross section channels and multiple sharp turns), the rib characteristics (including shape, size, location and thermal conductivity) and convective flow characteristics (Reynolds and Prandtl numbers). Among these parameters, the most important role is played by the rib placement and for that reason there is a considerable amount of literature on that topic for evaluation of heat transfer and friction characteristics of stationary straight channels with various forms of turbulizers.

An important issue in the experimental heat transfer investigation of ribbed channels is the adopted measuring technique. A large number of investigations have been performed by the standard technique which uses heater plates/foils and thermocouples [4,6–11,15,17,22,24,25,33–38] or the naphthalene sublimation technique [5,12,19,20,30]. The former provides accurate but discrete or regionally-averaged results; the latter requires special effort for the test section preparation and the evaluation of the local amount of naphthalene leaving the surface.

Detailed maps of the local heat transfer coefficient in channels with ribs/turbulators can be obtained also by using optical techniques, such as the infrared thermographic technique [29,31,39] and the liquid crystal (LCT) technique [14,16,26,28,40–44]. LCT techniques are less expensive than the infrared thermal imaging method. They can be classified into two categories, namely the

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