Local helical symmetry of vortices created by vortex generators in a low Reynolds number wall bounded flow

Velte C.M.*, Hansen M.O.L.* and Okulov V.L.*

Stereoscopic Particle Image Velocimetry (SPIV) experiments have been conducted in a low Reynolds number (free stream velocity $U_0 = 1.0$ m/s) wall bounded flow downstream of a vortex generator in order to study the flow processes generates by the device[1,2]. Vortex generators are small winglets placed on a surface with an angle of attack to the oncoming flow that are designed to redistribute the momentum in the boundary layer to prevent separation. SPIV is a non-intrusive measurement technique providing all three velocity components in a plane simultaneously at each realization. A sketch showing a triangular vortex generator pair situated in a flow and typical placement of the measurement planes in relation to the devices is shown in figure 1. A sketch of an expected fluid particle path line has also been drawn

Results show that the vortex generators give rise to longitudinal vortices possessing local helical symmetry, i.e. the following relation is satisfied along lines radially outward from the vortex core.

$$u_z + \frac{r}{l} u_\theta = u_0 \equiv const., \;\; or \;\; u_z = u_0 - \frac{r}{l} u_\theta \qquad (1)$$

u_z is the axial velocity, u_θ is the azimuthal velocity, u_0 is the velocity tangent to the helical line, r is the radius and l is the helical pitch.

The hypothesis of helical symmetry is confirmed for various sizes of vortex generators reaching from the entire thickness of the boundary layer (1.0δ) to a fraction of it (0.2δ). Figures 2 and 3 show results for rectangular devices of height δ. Figure 2 shows the mean velocity field in a plane downstream of a vortex generator pair in a counter rotating configuration. In-plane velocities are represented by arrows and the out-of-plane velocities by color contours. Only every fourth vector is shown in the figure. Testing of helical symmetry (second relation, equation 1) of a vortex generator induced vortex is shown in figure 3 and displays good agreement with the condition for helical symmetry. The data is taken from the vortex to the right in figure 2 along a line radially outward from the vortex core towards the right.

For this particular work, measurements on a single vortex generator on a flat plate has been investigated. This configuration is the subject of a parametric study, investigating the effect on the helical vortex when changing geometrical parameters of the actuating device. The effect on the pitch of the helix is of particular interest, since it characterizes the helical symmetry of the vortex. While having a non-uniform flow, due to the presence of the wall, the pitch will change with height throughout the boundary layer.

Results show that an increased angle of the device to the incoming flow decreases the pitch for device angles in the range $5° \leq \alpha \leq 30°$. It is also seen that an increased device height generally increases the pitch.

---

*Department of Mechanical Engineering, DTU, DK-2800 Lyngby, Denmark.

[1] Velte C.M. et. al., *Environ. Res. Lett.* **3**, (2008) 015006.

[2] Velte C.M. et. al., *Proceedings of The Second Conference on The Science of Making Torque from Wind*, (2007).

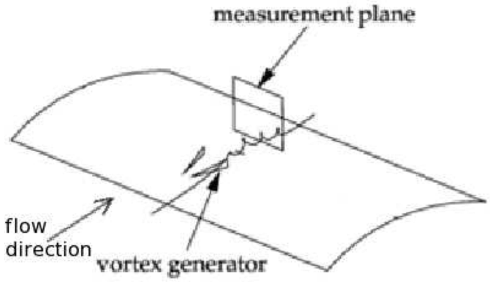

Figure 1: Sketch showing a vortex generator pair of triangular devices placed in a flow. A typical placement of the measurement planes is indicated in the figure. A sketch of an expected fluid particle path line has also been drawn.

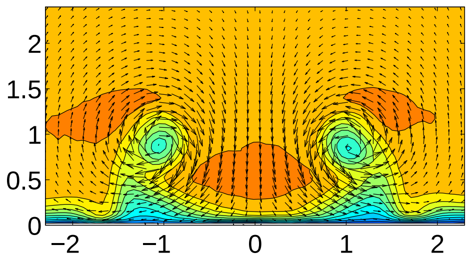

Figure 2: Velocity vector plot of the flow field downstream of a vortex generator pair in a counter rotating configuration. The arrows represent the secondary in-plane velocities and color represents the out-of-plane velocities. Every fourth vector is shown.

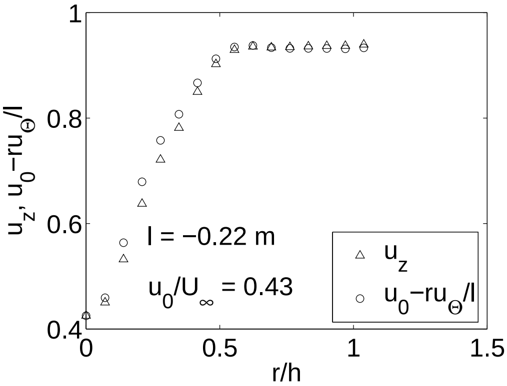

Figure 3: Testing of local helical symmetry of vortex generator induced vortices. The data is taken from the vortex to the right in figure 2 along a line radially outward from the vortex core towards the right.