FLUID MECHANICS

V3V™ System

2008 Award Winner

Smoothly Contoured Ramp with Vortex Generators

Application Note V3V-005

Separated flows are of particular interest in the field of fluid mechanics due to their prevalent nature in a wide variety of engineering applications, for example in civil engineering, the flow downstream of a dam or bridge pillion, in aerospace engineering, the flow on the suction side of an airfoil approaching the stall condition, or in chemical engineering in a host of mixing applications where turbulent flow is an effective mechanism in efficient amalgamation. In addition, the use of vortex generators to increase the streamwise vorticity within a separating boundary layer, increasing the fluid momentum near the surface and thus delaying separation, are being used and investigated more and more frequently.

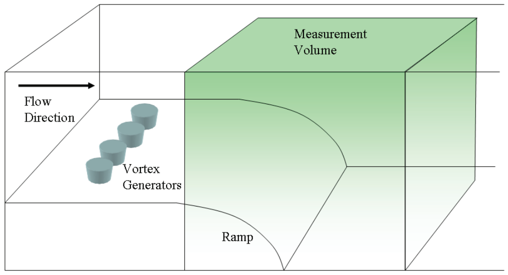

Fig. 1: Schematic of experimental setup and measurement volume.

In this experiment, the separated flow over a backward-facing smoothly contoured ramp was investigated in order to determine the effects of adding vortex generators before the separation point. A schematic of the experimental setup and the measurement volume can be seen in Fig. 1. The water tunnel had a square cross-section with side length of 150 mm. The ramp was 40 mm high and 80 mm long.

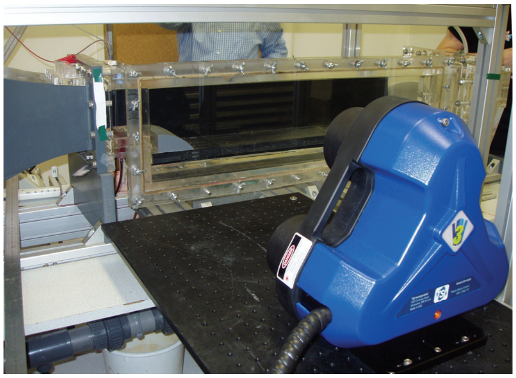

Fig. 2: Experimental setup showing the position of the 3D camera in relation to the measurement volume. The laser cone entered the water tunnel from the top.

The TSI V3V (Volumetric 3-Component Velocimetry) system was used to analyze the resulting flow structure (Fig. 2). The flow was illuminated by a model YAG120-BSL 120 mJ dual-head pulsed Nd:YAG laser operating at 7.25 Hz and 532 nm wavelength. Light cone optics were used at the exit of the laser to shape the beam into an illuminating cone. The laser cone was formed with two -25 mm cylindrical lenses mounted at 90° to each other. These cylindrical lenses diverged the beam in the horizontal and vertical directions to illuminate a volume approximately 140 mm × 100 mm × 100 mm. The model V3V-8000 3D camera probe consists of three apertures and a total of 12 million pixels. The camera was aligned and calibrated with the CCD a distance of approximately 800 mm from the back plane of the measurement volume.

The data capture was synchronized with the model 610035 synchronizer. The images were streamed to the model HYPER2 *HyperStreaming*™ computer, and subsequently analyzed.

The freestream velocity was 11.5 cm/s and was seeded with polycrystalline particles. Two image captures were taken with a Δt of 1500 μs, and volumetric velocity fields were obtained through unique particle identification, triplet

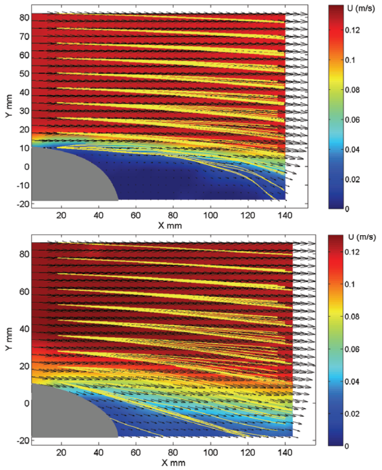

Fig. 3: Planar streamwise velocity showing the difference between no vortex generators (top) and with vortex generators (bottom).

matching, and particle tracking algorithms in TSI's *INSIGHT* V3V™ software. A 2D slice from the V3V data showing the streamwise velocity field taken near the center of the tunnel can be seen in Fig. 3. The top plot shows the results of the flow without the vortex generators, and the bottom plot shows the results with the vortex generators. Notice that the region of faster moving streamwise velocity is drawn down toward the downstream recirculation zone sooner (spatially) for the case where the vortex generators are present.

The average of 20 instantaneous captures of the V3V data can be seen in Fig. 4. Each instantaneous capture yielded between 10,000 and 15,000 independent vectors. In the plots, the yellow isosurfaces represent the z-vorticity, and the red and blue isosurfaces represent opposite signs of x-vorticity (streamwise). Notice that the presence of the vortex generators has the effect of diminishing the z-vorticity and increasing the presence of streamwise vorticity. In particular, in the case with the vortex generators (right), there exists two strips of opposite-signed vorticity near the center of the tunnel (z = -780 mm) which represent the flow "curling around" the vortex generators and increasing the interaction between faster moving fluid above, and slower moving fluid below. In addition, a region of negative (blue) streamwise vorticity is induced along the near wall between approximately x = 70 mm and x = 140 mm.

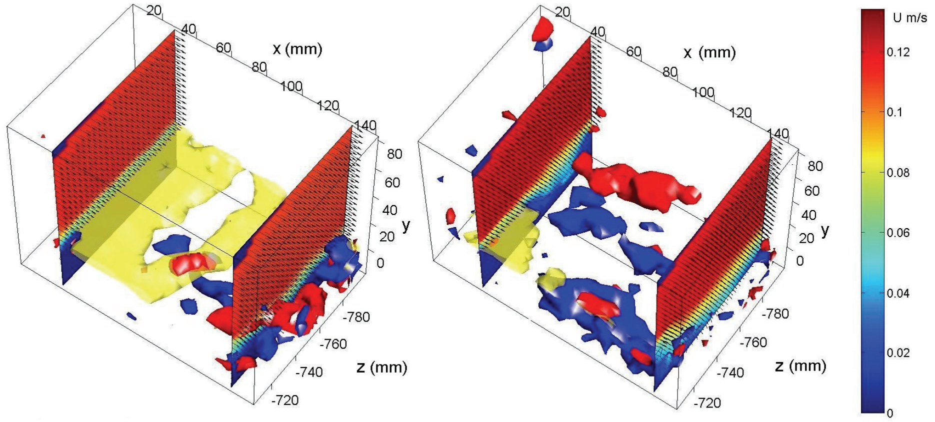

Fig. 4: Volumetric 3-component velocity field of the flow downstream of the slope without vortex generators (left) and with vortex generators (right). The yellow isosurface represents z-vorticity (-10 1/s), the red (+1.8 1/s) and blue (-1.8 1/s) isosurfaces represent opposite signs of x-vorticity, and the slices represent the streamwise velocity.

In this study, the flow structure downstream of a smoothly contoured backward-facing ramp with vortex generators, was examined with the TSI V3V system. Instantaneous volumetric velocity fields were obtained, and the results were compared to the case without vortex generators. The V3V data were compared with standard 2D PIV data, and the results matched quite well.

Acknowledgement

This data was taken with the cooperation and facilities of École Supérieure de Physique et de Chimie Industrielles, Paris.

Reference

Duriez T; Aider J L; Wesfreid J E, "Base Flow Modification by Streamwise Vortices. Application to the Control of Separated Flows" *2006 ASME Joint U.S.-European Fluids Engineering Summer Meeting, FEDSM 2006,* 2006.

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P/N 5001129 Rev. B Printed in U.S.A