A Quantitative Flow Visualisation of a Point Source Disturbance in a Swept Wing Boundary Layer

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Since the earliest days of fluid mechanics research, flow visualisation has been a useful tool in gaining a qualitative insight into complex flow phenomena. However traditional visualisation techniques are limited in application and give little or no quantitative data for advanced analysis. In order to fill this void a combination of accurate Hot-Wire Anemometry (HWA) techniques and modern data acquisition has been used to develop a new quantitative visualisation during a series of experiments conducted in the low speed wind tunnel at the department of Thermo and Fluid Dynamics, Chalmers University of Technology. A comprehensive system for automated traversing (5-axis) and data acquisition has been designed and developed for this task (*figure 1*).

Flow visualisation lends itself to the study of the complex three-dimensional (3D) phenomena associated with transitional flows. Whilst much work has been devoted to the theoretical, numerical and experimental study of the stability of two-dimensional (2D) boundary layers, there remains a gap in information concerning the stability of 3D boundary layers due to the inherent complexity of the breakdown process. Point source disturbances are also 3D in nature and present a difficult task for prediction and simulation. The developed HWA visualisation technique offers a possibility for an advanced analysis whilst retaining the advantages of traditional visualisation methods.

In this investigation the instability resulting from such a point source disturbance, on the surface of a wing model, is studied three dimensionally using the developed technique. Traces within the boundary layer are obtained in a 3D mesh over the surface of the wing. Data acquisition was triggered on the initial disturbance to give a lock in phase. At each point the traces sampled were ensemble averaged to give a single period of the oscillation. These are then assembled to form a four-dimensional (4D) spatial and temporal matrix (x, y, z, t). The waveforms are then separated into the discrete scans of which they consist and in this fashion a number of 3D "frame" matrices are obtained. Iso-surfaces of fluctuating velocity are plotted for each frame and displayed in sequence to obtain a dynamic visualisation of the process (see still shots in *figure 2*). Three wing configurations were studied (straight, 30^0 of sweep and 45^0 of sweep) to determine the effect of a swept leading edge on the process of transition.

The transition process was shown for each configuration to progress through the generation of super harmonics and it was seen that T-S instabilities were dominant. For the straight configuration symmetrical Λ-structures were formed. Cross flow components in the swept configurations lead to unsymmetrical structures and a significant change in the process of transition. The visualisation technique was highly successful and provides a great deal of quantitative data, which can be extracted to gain a detailed knowledge of the 3D development of the disturbance.

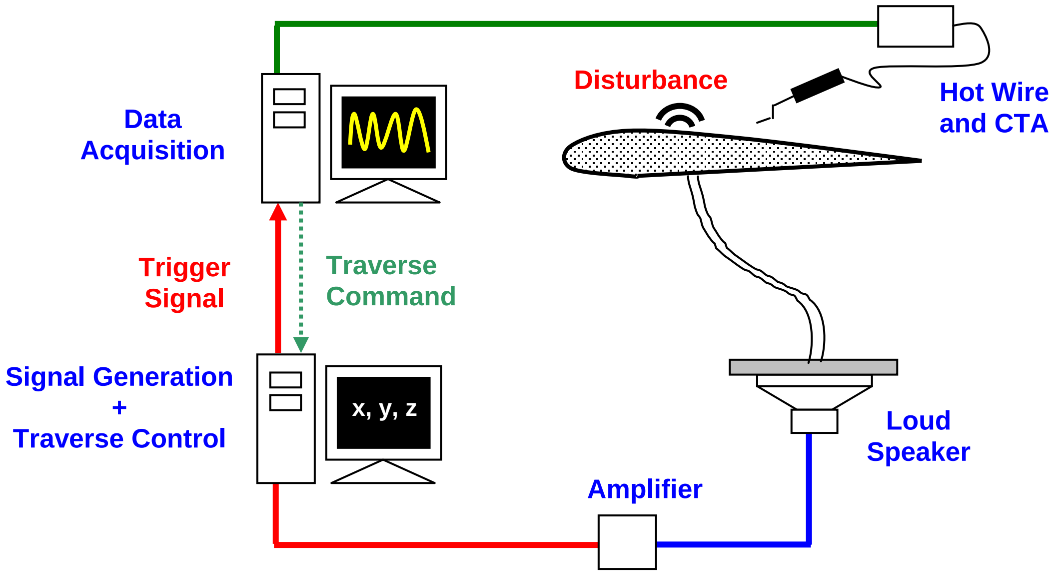

Figure 1: *Schematic Representation of Experimental Set-up*

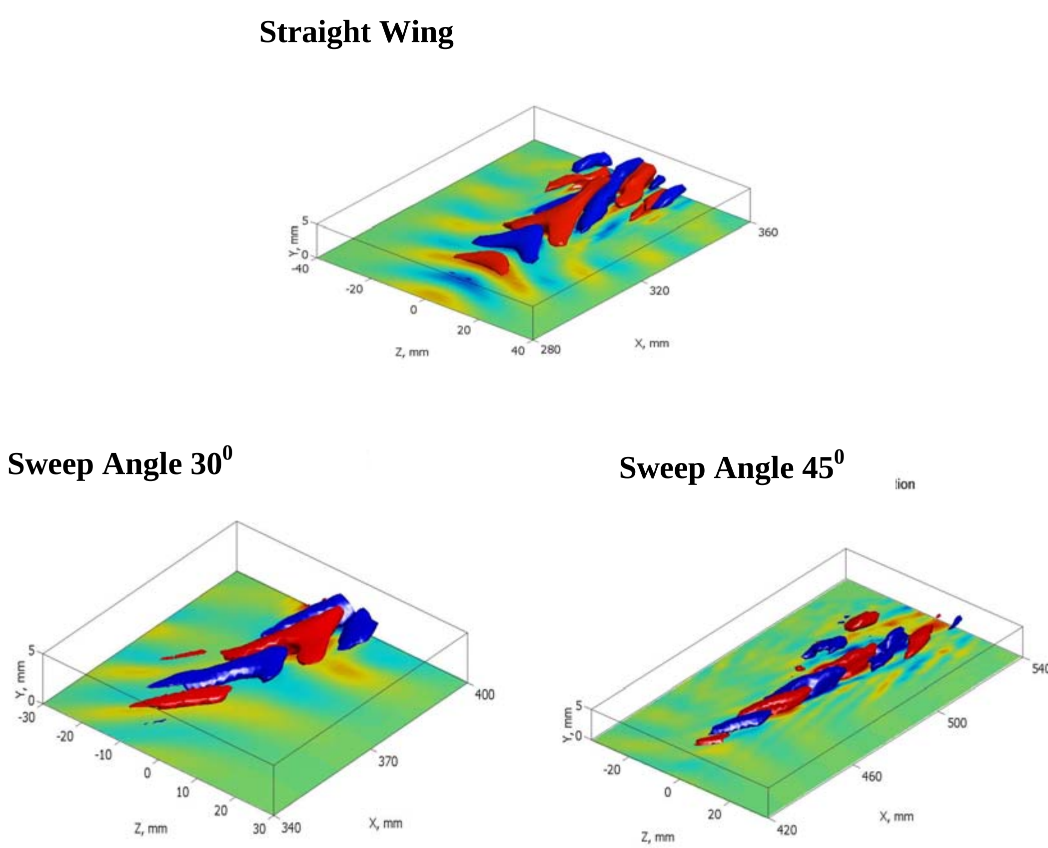

Figure 2: *Still shots from visualisations for all three configurations*