Experimental characterization of wingtip vortices using smoke flow visualizations

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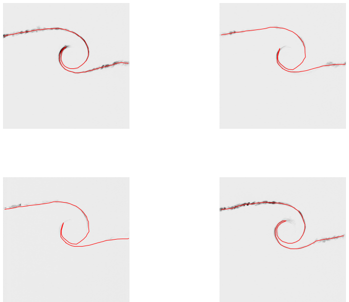
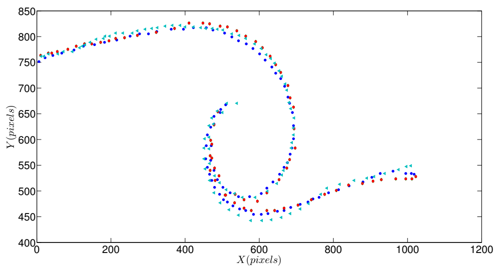
In order to predict the axial development of the wingtip vortices strength an accurate theoretical model is required. Several experimental techniques have been used to that end, e.g. PIV or hotwire anemometry, but they imply a significant cost and effort. For this reason, we have carried out experiments using the smoke-wire technique to visualize smoke streaks in six planes perpendicular to the main stream flow direction. Using this visualization technique, we obtained quantitative information regarding the vortex velocity field by means of Batchelor's model [1], which only depends on two free parameters, i.e. the vortex strength, S, and the virtual origin, z_0. Results for two chord based Reynolds numbers have been compared with those provided by del Pino et at. [2], finding good agreement.



(a)



(b)

FIG. 1. Smoke and curve fitting (a) and experimental points (b) for Re=10^5.

Trailing vortices have a strong influence on the air traffic control of airport runways. Aeronautical engineers are still searching for different strategies to breakdown these wingtip vortices in order to increase the traffic of aircraft in airports.

The origin of the idea behind this experimental study was formulated by Meaner and Villermaux [3]. In this manuscript, the authors describe how the advection of a passive scalar blob in the deformation field of an axisymmetric vortex is a simple mixing protocol.

Our experimental system is based on the smoke-wire technique. This allows us to visualize the airflow intersection of streak lines generated by the smoke-wire and the control plane highlighted by a laser sheet. We show in figure 1 (a) the results of four different experiments two chords behind the wing model together with the local curve fitting in red line. In figure 1 (b) we show a cloud of experimental points for the same four cases. We can observe that the shape of the spiral is similar for different tests. This fact confirms a good experimental procedure.

One can obtain a quantitative description of the velocity field in the roll-up process by means of a smoke-wire system together with a set of differential ordinary equations. To that end, a set of N equally-spaced numerical points can be aligned along the line from where streak lines departure. Experimental smoke and numerical streaks are compared, finding slight differences between the real flow pattern and the one adjusted using Batchelor's model. Thus, one can estimate the vortex strength S.

As a conclusion, the final values of S and z_0 obtained by this experimental method have been compared with those provided by del Pino et at. [2] using the stereo-PIV technique. We find a reasonably good agreement between the techniques. The values given in this work also detect the weak influence of the Reynolds number on the parameters which characterize Batchelor's model in the near-field of the wingtip vortex. In addition, results for each control plane have been gathered, finding the difference between global and local curve fittings.

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