PIV Measurements of Unsteady Vortex Behavior in the Near Wake of a Swept Wing Model

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Aircraft separation rules in international aviation are a growing handicap for the ongoing rise in passenger numbers. Because more and more airports are already working at their capacity limits the stakeholders urgently search for ways to increase the frequency of starts and landings. A safe reduction of the currently prescribed distances between following aircraft shall improve the situation. Among others there are strategies to promote the development of instabilities in the aircraft wake. The hope is to reduce the time needed to the onset of a rapid decay of the vortex strength, this way allowing shorter aircraft spacing's. However, it is still a matter of scientific research to understand the mechanisms that can lead to premature vortex decay.

In that context, results from wind tunnel experiments concerning the interaction of engine jet and vortex wake are presented. The investigation is based on stereoscopic particle image velocity measurements (PIV) downstream a swept wing half model of actual plan form with a model engine that can be mounted at different span wise positions. Through comparison between different test cases the influence of the presence and location of an engine jet on the vortical structures in the wake shortly behind the wing trailing edge are examined.

From earlier results (e.g. Fares et al., 2000 and 2003) it is known, that the vortex wake behind the wing model exhibits unsteady behavior. With respect to the relevance of the engine jet on the development of instabilities in the flow this fact is of importance. A number of wake vortex investigations based on numerical simulations make use of artificially introduced perturbations to the flow in order to evoke such instabilities. In a similar way in some experiments the flow is periodically disturbed by oscillating active or passive devices. Therefore the possible effect of the engine jet on the unsteady behavior of the vortex wake is of interest. In order to investigate the unsteady vortex movement in the wake the PIV results are processed in two ways. First a conventional time or ensemble averaging process is done. In a second run the PIV measurements are evaluated by a procedure that before the averaging process maps the individual vortex cores onto each other. This method allows discriminating the unsteady wing tip vortex movement from the underlying vortex structure and the surrounding wake flow. It helps to reduce the falsifying effect of the ensemble averaging method on the velocity data and derivatives of the vortex structure.

Results

The properties of the spiral wake, like turbulence intensity and shear stress, determine the characteristics of the flow field that winds up around the vortex core. The spiral wake shows to be influenced by the engine jet. Consequently, the presence of the engine jet has an impact on the structure of the wing-tip vortex. A number of investigations show that the structure of the wing-tip vortex is of importance for instability mechanisms. These instabilities can be amplified by perturbations through mutual induction of vortices.

The study shows that for the clean wing configuration the engine jet inboard of the trailing edge kink leads to higher wandering amplitudes of the wing-tip vortex, whereas for the high-lift case the outboard engine jet creates the strongest vortex movement. Through the combination of the ensemble and the centered averaging process the vortex center position, the wandering amplitudes, the accurate vortex structure, and the size of buffer region which contains the unsteady vortex movement can be determined.

Conclusions

The results indicate that a span wise change of the location of the engine jet modifies the stability properties of the wake flow. Depending on the engine position, the operation mode, and the wing configuration, the unsteady vortex behavior and the vortex topology are different and the interaction of wing tip and flap edge vortices is affected.

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Literature

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