Recent developments in background oriented schlieren methods for rotor blade tip vortex measurements

Kolja Kindler[1], Erik Goldhahn[2], Friedrich Leopold[3], Markus Raffel[1]

1: German Aerospace Center (DLR), Institute of Aerodynamics and Flow Technology, Germany, kolja.kindler@dlr.de, markus.raffel@dlr.de

2: University of Hannover, Institute for Turbo Machinery and Fluid Dynamic (TFD), Hannover, Germany, goldhahn@tfd.uni-hannover.de

3: Institute Franco-Allemand de Recherche de Saint-Luis (ISL), Saint-Luis, France, Leopold@isl.tm.fr

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Compressible blade tip vortices (BTV) of rotary wings have been subject of numerous investigations and their importance for the understanding of the helicopter flow field has clearly been drawn. Due to its great impact on the dynamics of the flow field, the investigation of the BTV is directly linked to issues of flow control and aeroacoustic optimization. However, despite of the velocity field data of the BTV, additional density information for vortex modeling is desirable.

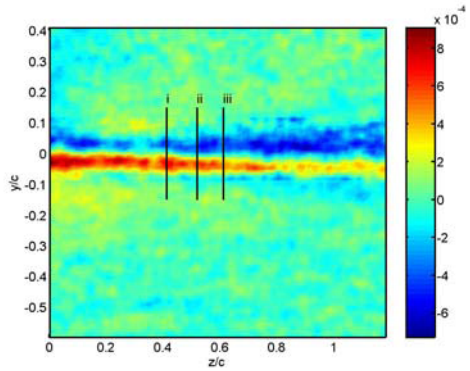

Fig. 1 Image displacement of the y-component of the BTV.

In this work we briefly describe the set up of an airborne background oriented optical stereoscopic schlieren (BOSS) system for helicopter flight tests as well as preliminary experimental results of background oriented optical tomography (BOOT) of a 0.4 Mach scaled rotor model investigation. The tomographic approach enabled us computing an estimate of the tip vortex density field. This method is demonstrated to yield reasonable scales of the vortex core diameter. The advantages and applicability of the filtered back-projection method for rotor investigations will be discussed.

A background oriented schlieren result is shown in Figure 1. The main deflections are observed in the y-component, while the chordwise x-component turns out to be fairly noisy. However, the vortex is fully developed at the trailing edge and starts to spread increasing its core radius at approximately z = 0.5c. We note that due to limitations of the light intensity mainly determining the exposure time, the BOS data is biased by smear effects of the blade. The area of cohesive positive in-plane deflection magnitude closely above the blade tip is probably an artefact of smearing (0,-0.1) in Figure 1 corresponds to the position of the trailing edge of the blade tip. Therefore, the instantaneous BOS results imply a spatial average of approximately 5° and additionally a conditional average is calculated from series of ten images in order to enhance the signal. These averaged fields are evaluated by means of filtered back-projection at three different chord-wise positions. Considering these averaging effects smearing the narrow vortex core, we expect the density to be underestimated by the back-projection scheme in addition to effects of the limited spatial resolution.

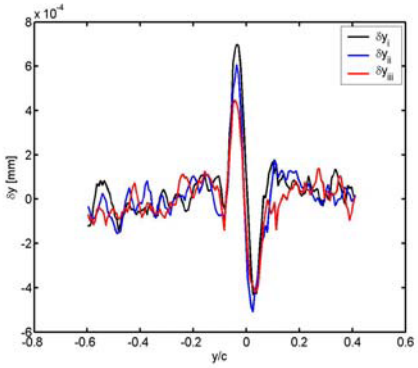

Figure 2: 2C-PIV result example

Fig. 2 Image displacement of the y-component at the three positions given in Figure 1.

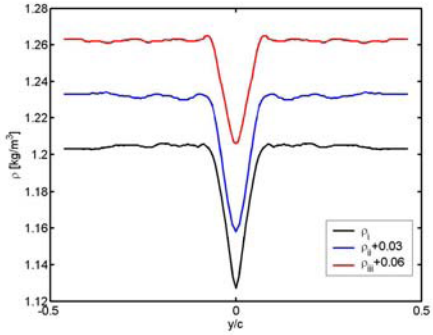

Fig. 3 Example of a BOOT result of the BTV