KEYNOTE LECTURE

INVESTIGATIONS OF HELICOPTER ROTOR BLADE TIP VORTICES IN WIND TUNNELS AND IN FLIGHT

Prof. Ing. hab Markus Raffel

Head of Department
German Aerospace Center
Institute of Aerodynamics and Flow Technology
Helicopters Bunsenstr. 10
37073 Göttingen, Germany

Prof. Markus Raffel is currently the Head of Department of German Aerospace Center, Institute of Aerodynamics and Flow Technology. He received his degree in Mechanical Engineering in 1990 from the Technical university of Karlsruhe and his doctorate in 1993 from the University of Hannover, Germany. He started working on Particle image velocimetry at German Aerospace centre (DLR) Gottingen in 1991 with emphasis on the development of PIV recording technique in high-speed flows. He has also applied the method to a number of aerodynamic problems mainly in the context of rotorcraft investigations.

ABSTRACT

The advancement of measurement systems and technology perpetuates experimental aerodynamics, which incorporates particle image velocimetry (PIV) and background oriented schlieren (BOS) techniques in helicopter aerodynamics. Unsteady and complex features of helicopter flows present a vast number of specific challenges to experimentalists, including transonic flow, concentrated vortices and dynamic stall. To illustrate this some recent PIV applications will be described, using the examples of blade tip vortex investigations. The potential of combining PIV with complementary optical measurement techniques will be outlined considering large and full scale applications. Based on some recent trends, a glimpse into the future of PIV in helicopter aerodynamics will be ventured. The lecture will also describe BOS methods to detect and trace density gradients of helicopter tip vorticies in the field, on large geometrical scales without having to use sophisticated optical equipment. Major aspects of large-scale imaging using natural backgrounds will be reviewed in relation to full-scale helicopter testing. A handheld sensor system that consists of two standard single-lens reflex cameras will be described. The cameras are fixed in a paraxial configuration that can be operated from the ground as well as from aboard an airplane or helicopter for in-flight visualizations. The feasibility and fidelity of in-flight BOS applications will be demonstrated and compared to subscale and large-scale wind tunnel experiments. Additionally, three-dimensional localization of vortices will be presented for the case of full scale helicopters under flight conditions. A BOS measurement system consisting of ten cameras was used with a natural background to visualize the vortices of the helicopter under maneuvering flight. Vortex filaments could be visualized and extracted up to a vortex age of 360°. A three-dimensional reconstruction of the main part of the vortex system was carried out for the first time using triangulation-based stereo-photogrammetry, demonstrating the potential of the multi-camera BOS measurement technique for the analysis of blade-vortex interaction effects in rotorcraft.