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Advanced Measurement Techniques for Cryogenic Testing

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ABSTRACT

Future generations of aircraft will be developed applying "High Reynolds Number Design", using advanced computational aerodynamics and industry-scale cryogenic wind tunnels which enable aerodynamic optimization tests for flight Reynolds numbers on scaled models. For validation purposes and to further improve the computational techniques, accurate aerodynamic field-data must be supplied during the design process including transition locations, surface pressure distributions, velocity fields and acoustic field data. Thus, modern, image based measurement techniques commonly used in "warm" industrial wind tunnels have to be made also available for productive testing in cryogenic wind tunnels.

For example, the method of Temperature-Sensitive Paint (TSP) for transition detection at high Reynolds numbers in a cryogenic wind tunnel (cryoTSP) has been optimized within the last years and is now ready to use for productive testing (Fig.1). In the European Transonic Windtunnel (ETW), cryoTSP now has substituted a highly sophisticated, cryogenic infrared camera. Transition patterns gathered by cryoTSP on full models at transonic Mach numbers, as well as on half models in high lift configuration at low speed Mach numbers (Fig.2), clearly can show the complex structure of laminar-to-turbulent boundary layer transition and further exhibit additional information about transition zone length and underlying instability.

The acquisition of surface pressure distributions using Pressure-Sensitive Paint (PSP) today has become a valuable and reliable method in warm wind-tunnel testing. Availability of the PSP method for cryogenic wind tunnels (cryoPSP) is highly recommended and research has been undertaken to make this technique work under the specific conditions given in cryogenic testing. First, qualitatively results have been gathered (Fig.3) and some major problems, like accurate oxygen injection into the nitrogen-driven wind tunnel, are solved.

The measuring of the velocity field by use of the Particle Image Velocimetry (PIV) meanwhile is a standard wind tunnel testing tool since years. However, the extension to cryogenic testing (cryoPIV) is not effortless and a system to be used in the ETW is under development. Successful cryoPIV measurement was performed in the cryogenic,

low-speed wind tunnel DNW-KKK in Cologne (Fig.4). The implementation of PIV to the ETW wind tunnel, as an important item requires an appropriate seeding of the flow, suited for the cryogenic temperatures. Results of seeding tests exist and the implementation of the appropriate laser technique in ETW is investigated.

The necessity to detect sound sources in high lift configuration testing recommends the application of acoustic measurement by means of microphone arrays. Hence, this technique has to be made available for cryogenic wind tunnels as well. Image Pattern Correlation Technique (IPCT) for deformation measurement, and the Background Oriented Schlieren Method (BOS), used to detect density gradients in the flow, are already tested in the ETW wind tunnel and are available for cryogenic measurement. An automated evaluation of image based test results and integrative assembly and presentation of the different field data can help to improve aerodynamic interpretation (Digital Mock-Up).

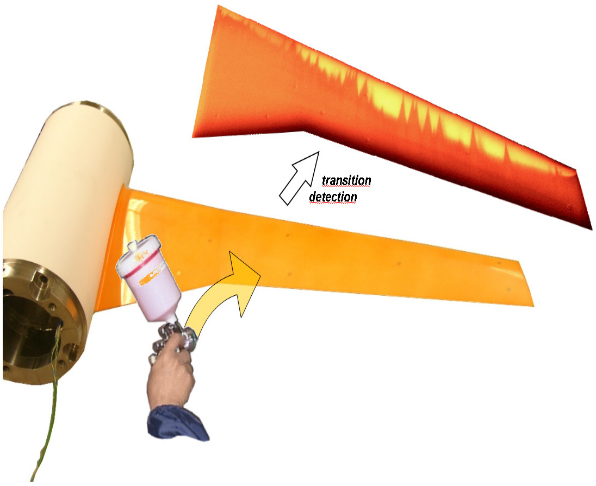

Figure 1: The method of Temperature-Sensitive Paint for transition detection has been established as a standard technique in the ETW cryogenic wind tunnel (cryoTSP). Transition patterns on upper wing is colour coded.

Figure 2: Transition patterns on a half model wing tested in the ETW wind tunnel by means of cryoTSP. Dark areas represent turbulent, and bright areas laminar boundary layer state.

Figure 3: Pressure distribution on a full model's wing tested in ETW as a result of the first application of cryoPSP. Dark areas represent low pressure, bright areas represent high pressure.

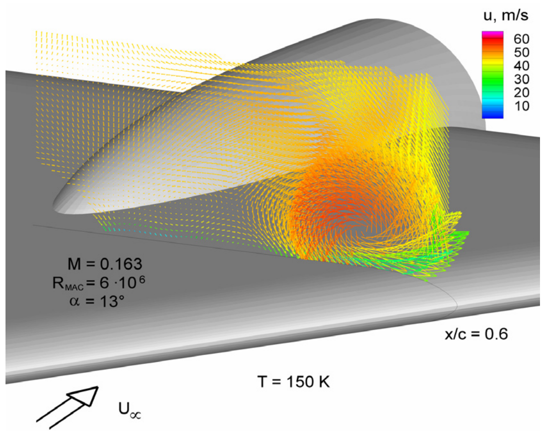

Figure 4: Time averaged in-plane velocities (vectors) and out-of plane velocities (vector colour) above a delta wing obtained in the cryogenic wind tunnel DNW- KKK at T = 150 K, applying Stereo-cryoPIV.