

Application of image based measurement techniques for the investigation of aeroengine performance on a commercial aircraft in ground operation

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Among the objectives of the DLR-project SAMURAI (Synergy of Advanced Measurement techniques for Unsteady and high Reynolds number Aerodynamic Investigations) the investigation of the flow and sound field upstream and downstream of a full scale aeroengine is aimed at providing important reference data required for reliable modeling and prediction [1]. In this regard a wide variety of contactless and non-invasive laser optical and acoustic measurement techniques have matured in recent years to allow their application on full scale aircraft. In 2013 a measurement campaign involved the DLR research aircraft A320-ATRA (Advanced technology research aircraft) inside a sound-attenuating hangar of Lufthansa Technik at Hamburg Airport (Fig.1). Within this campaign four image-based measurement techniques were applied in parallel to acquire data for the IAE V2527 engines operating at conditions varying between idle and take-off [1]:

- PIV: stereoscopic particle image velocimetry of the engine intake and exhaust jet
- BOS: high frame rate background oriented Schlieren of the exhaust jet in combination with acoustic array measurements
- PROPAC: projected pattern deformation correlation technique for the measurement of fan blade deformation under load
- MODE: marker-based optical deformation measurements to the obtain reference position of the aircraft during the engine runs

The objective of the ground tests was to establish a combined measurement data base to locate the zones within the engine exhaust flow where large, turbulent fluctuations in velocity and density produce noise. Simultaneous application of PIV, BOS and acoustic array techniques were carried out in front and behind the aircraft jet engine, for the characterization of inlet flow disturbance due to ground vortex formation, the turbulent free jet flow field as well as engine's core and jet noise. Furthermore the PROPAC technique was applied to determine the fan blade deformation and vibration. The acquired data serves as a basis for validation of numerical simulations that aim at predicting engine performance and noise emission.



Figure 1: Measurement hardware within the hangar

The installed ground test instrumentation was operated in parallel to facilitate a simultaneous acquisition of various flow field parameters using different diagnostic approaches (instantaneous velocity, sound pressure and fluctuation, density fluctuations and fan blade deformation). The diagnostics were applied non-invasively to the aircraft and aeroengine, that is, the ground test hardware neither required modifications to the aircraft airframe or engines nor had any direct connection to the aircraft which significantly eased the certification and test approval procedure. Nonetheless parts of the test equipment had to be installed within the danger (safety) area of the engines and required numerous certification and approval steps. To reduce the risk of foreign object damage to the engine during operation all components were securely fastened to the concrete foundation of the test facility (hangar) by means of anchor bolts or approved adhesives.

Figure 1 provides an impression of the installation of the measurement hardware within the hangar. The acoustic array consisting of 240 microphones is visible in the foreground extending the entire length of the aircraft. Four high-speed cameras for use BOS imaging are visible on the left. Further in the background supports for stereo PIV cameras and MODE are visible. Alongside the aft fuselage a series of retro reflecting panels with dot pattern serves as background for the BOS technique. Hardware immediately in front of the engine is dedicated to PROPAC blade deformation measurement.

Figure 2 presents a visualization of the density gradients downstream of the engine obtained with the BOS technique. The paper focuses on the implementation and use of the laser optical measurement techniques PIV and BOS in this challenging, full scale application.

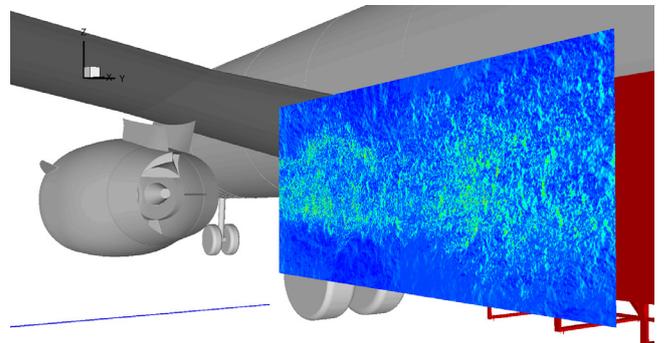


Figure 2: High-speed BOS result of the density gradient field downstream of the engine acquired at a frame rate of 2 kHz. The field of view covers about 4×1.5 m² and was acquired by four high-speed camera operated in parallel

[1] http://www.dlr.de/as/en/desktopdefault.aspx/tabid-183/251_read-33607/

[2] http://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10204/296_read-8278/year-all/#gallery/12408