PERFORMING FULL-FIELD DEFORMATION MEASUREMENTS ON AN ROTATING TURBOFAN USING DIGITAL IMAGE CORRELATION

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ABSTRACT

In this work, required steps to enable digital image correlation for the testing on a fan in operation is presented and evaluated. This includes the development of adapted test setups and data analysis methods. The test setup is developed for a scaled fan test rig. The measurement throughout a surface is used to determine the change in stagger angle at different radial positions, the modal vibration amplitudes, and the agreement between the measured vibration pattern and the calculated mode shape. A virtual test case is used to determine the measurement uncertainties of the respective measured variables. The measurement results are compared with numerical calculations and reference measurement techniques. The results encourage wider application of the measurement technology in research test benches, real engine fans, and blades of other turbomachinery components.

INTRODUCTION

The design of turbomachinery requires a variety of experimental methods to characterize different arising phenomena. These are also required to derive and calibrate simulation models. One of the challenges in designing turbofan engines is the service life of the fan, which is subject to static deformation and vibrations during operation. This requires precise and comprehensive measurements of the blades during operation. Digital image correlation (DIC) is an optical testing technique measuring surface deformations. Due to the non-invasive nature of the testing technology and the time-resolved and spatial measurement of deformations, this testing technology has great potential for analyzing fan blades. The application in turbomachinery poses particular challenges due to the rotation of the blades, high requirements for measurement accuracy, and difficulties in optical access.

RESULTS AND DISCUSSION

The paper presents a new approach to measure full-field deformation using DIC. The instrumentation consists of a high-speed stereo camera setup with a synchronized high-speed laser. Motion blur is eliminated using short laser pulses. A dot pattern made of fluorescent paint ensures good contrast in the obtained images and thus a good correlation.

The data analysis method is adapted such that an analysis of the spatial measurement in the rotor coordinate system is possible. Deviations caused by camera movements are reduced by means of recalibration. Uncertainties are assessed using a virtual test case that represents the scene and allows the uncertainty quantification using ground truth data.

The resulting static deformation, synchronous and non-synchronous vibration of the DIC measurement is compared to numerical simulations and reference measurements using strain gauges and a blade tip timing system.

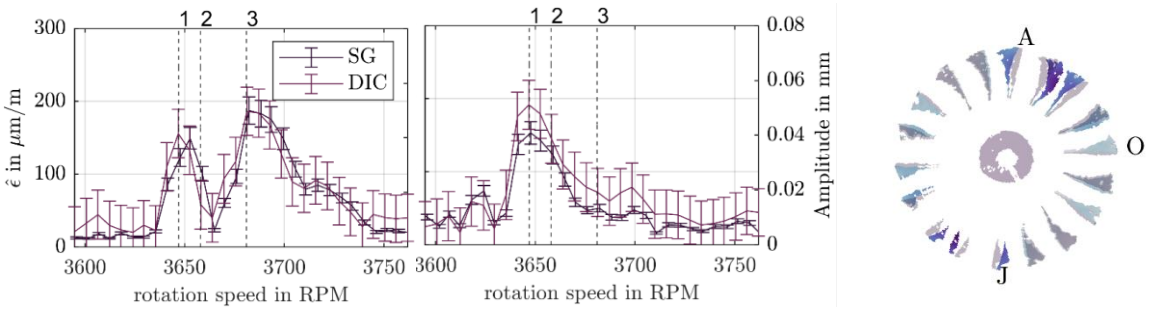

Figure 1: Measured synchronous vibration of SG and DIC (70% blade height) at Mode 2, EO10 resonance and 10 kts crosswind velocity,
left: blade A, middle: blade O, right: spatial vibration pattern at 3681 RPM

Results of synchronous vibration of Mode 2 in resonance with EO10 crosswind excitation are shown in Fig. 1 and compared to strain gauge measurements for to different blades.