ASSESSMENT OF STEREOSCOPIC MEASUREMENT FOR THE STUDY OF BLADE VIBRATIONS

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ABSTRACT

Aeroelastic instabilities arising from complex fluid–structure interactions remain one of the major challenges in turbomachinery design and operation. Accurate experimental characterization of these phenomena therefore requires advanced measurement techniques capable of capturing blade vibrations with high spatial and temporal resolution. This paper presents a new measurement technique applied to the study of non-synchronous vibration (NSV), high-speed stereoscopy, to complement existing systems — namely tip-timing, strain gauges, and high-speed camera coupled with stroboscopy. The study describes the experimental protocol, calibration procedures, and data processing methodology, while comparing the performance and relevance of stereoscopy with conventional techniques. The results highlight the essential role of careful calibration and the complementary use of several measurement systems to fully understand aeroelastic behaviour. The measurements provide complementary three-dimensional information with high spatial and temporal resolution on blade deformation during NSV events and demonstrate the potential of high-speed stereoscopy for future aeroelastic investigations.

INTRODUCTION

A thorough comprehension of aeroelastic instabilities, including flutter, non-synchronous vibration (NSV) [1] and rotating stall, remains a major challenge for the safe operation of turbomachinery. Their underlying mechanisms remain only partially understood, limiting the predictive capabilities of current numerical methods. Although open experimental datasets such as the ECL5 Ultra-High Bypass Ratio (UHBR) fan [2] already provide detailed information on aeroelastic behaviors, obtaining a comprehensive three-dimensional description of blade deformation during rapidly evolving NSV events remains challenging. The development of complementary experimental measurement techniques is therefore essential to improve the understanding of these phenomena [3] and to provide reliable datasets for the validation of advanced aeroelastic models.

Several studies have demonstrated the potential of stereoscopic imaging for turbomachinery applications. Goessling and Seume [4] investigated its applicability to blade vibration measurements, while Klinner *et al.* [5] highlighted the remaining challenges associated with highly curved blade geometries, reporting pattern distortions of up to 12% of the image height and an estimated triangulation error of 0.5 mm. More recently, Brunow *et al.* [6] applied stereoscopy to UHBR fan blades, obtaining results consistent with strain-gauge measurements.

This paper investigates the capability of high-speed stereoscopy to provide accurate three-dimensional measurements of blade deformation during aeroelastic instabilities, using NSV as a representative test case.

RESULTS AND DISCUSSION

The proposed stereoscopic system consists of two synchronized Phantom high-speed cameras. Following stereo calibration and marker tracking, the three-dimensional displacement fields were obtained over the visible blade surface. Figure 1 presents the standard deviation of the out-of-plane displacement component measured under part-speed operating conditions. The reconstructed field reveals a region of increased vibration amplitude near the blade tip and leading edge, consistent with the expected aeroelastic response under these operating conditions. The proposed approach provides spatially resolved three-dimensional displacement fields over the blade surface. Such measurements constitute a valuable complement to strain gauges and tip-timing for the investigation of aeroelastic instabilities.

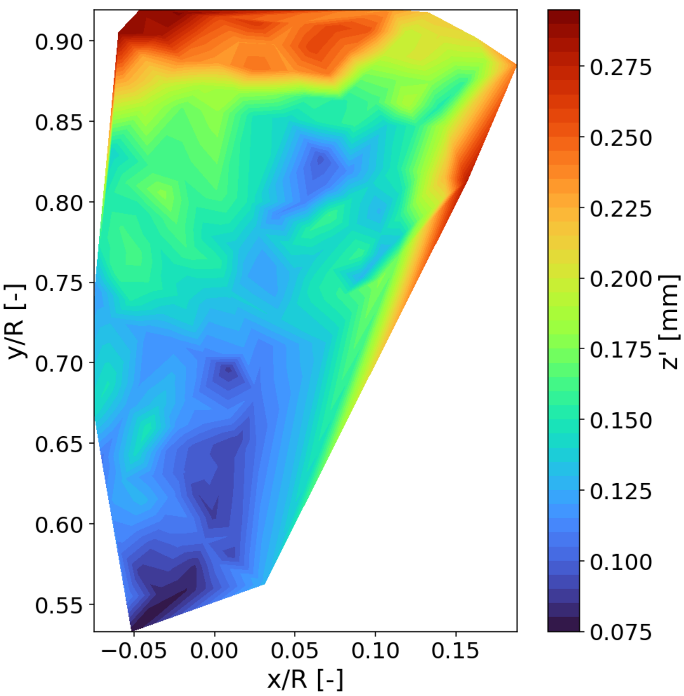

Figure 1. Standard deviation of the reconstructed out-of-plane displacement over the blade surface under part-speed operating conditions.

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