BLADE OSCILLATION MECHANISM FOR AERODYNAMIC DAMPING MEASUREMENTS AT HIGH REDUCED FREQUENCIES

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ABSTRACT

Accurate prediction of aerodynamic damping is essential for flutter and forced response analysis of turbomachinery components. Reaching a high level of confidence in numerical simulations requires that the models have been validated against the experiments. Even though a number of test cases have been established over the past decades, there is still a lack of suitable detailed test data that can be used for validation purposes in particular when it comes to aero damping at high reduced frequencies which is more relevant in the context of forced response analysis. A new transonic cascade test rig, currently undergoing commissioning at KTH, has been designed with the goal to provide detailed blade surface unsteady pressure data for compressor blades profiles oscillating at high reduced frequencies. The paper provides an overview of the blade actuation system employed in the test rig and presents the result of a series of bench tests characterizing the blade vibration amplitudes achieved with this actuation system.

INTRODUCTION

One of the main challenges in the experimental setups for aero damping measurements at high reduced frequencies is how to achieve the controlled blade vibrations at high oscillation frequencies and with sufficient blade amplitudes to result in a measurable unsteady pressure fluctuation on the blade surface. The targeted reduced frequencies are in region of k~2-4, implying that in the considered transonic flow regime the blade would have to be oscillated at frequencies of 1 kHz to 2.5 kHz. Achieving such high frequencies is simply not feasible with the traditional oscillation mechanisms (mechanical, electromagnetic and hydraulic) that have been used previously in the existing oscillating cascades rigs. Therefore, the choice of the oscillation mechanism has fallen upon using piezoelectric actuators that can be embedded into the pockets machined on the surface of the blade.

The piezoelectric actuators are operated by feeding an input voltage in form of a sinus wave with a frequency corresponding to the eigen mode frequencies of the blade and in that way the natural vibration mode of the blade is excited. The employed piezoelectric actuators are Macro Fiber Composite (MFC) P1 type, with high blocking force and good performance at high frequencies. Under the applied voltage, the active piezo element elongates and since being glued to the surface, it will transfer this elongation into a force acting on the blade. An FE model has been developed to model the behavior of the blade-piezo system and to find the optimum location for the integration of the piezo patches onto the cascade blade, which results in maximum achievable vibration amplitudes for the modes of interest. Since the blade under excitation will oscillate in its natural modes of vibration it is important to characterize the blade motion by scanning the amplitude of the actual blade mode shape. This in particular since the oscillating blades will also be instrumented with unsteady pressure transduces embedded into the blade, which is expected to affect the mode shape of the blade.

RESULTS AND DISCUSSION

Blade vibration amplitudes have been measured in a bench test rig by traversing two single-point vibrometer lasers (Keyence LK-G-152), shown in Figure 1. The measurements indicate that sufficient blade amplitudes are achievable for the targeted higher modes. Figure 1 shows the measured amplitude for mode 3 (1^{st} stripe mode) at 1236 Hz, where the max amplitudes >0.6mm have been observed. The amplitude measurements have been done in the room ambient, and in next steps the blade vibration under flow conditions needs to be assessed. At a later stage, measurements with the oscillating blades instrumented with Kulite transducers will also be performed in a vacuum chamber to assess the effects of blade oscillation on pressure transducers' diaphragm and sensor readings.

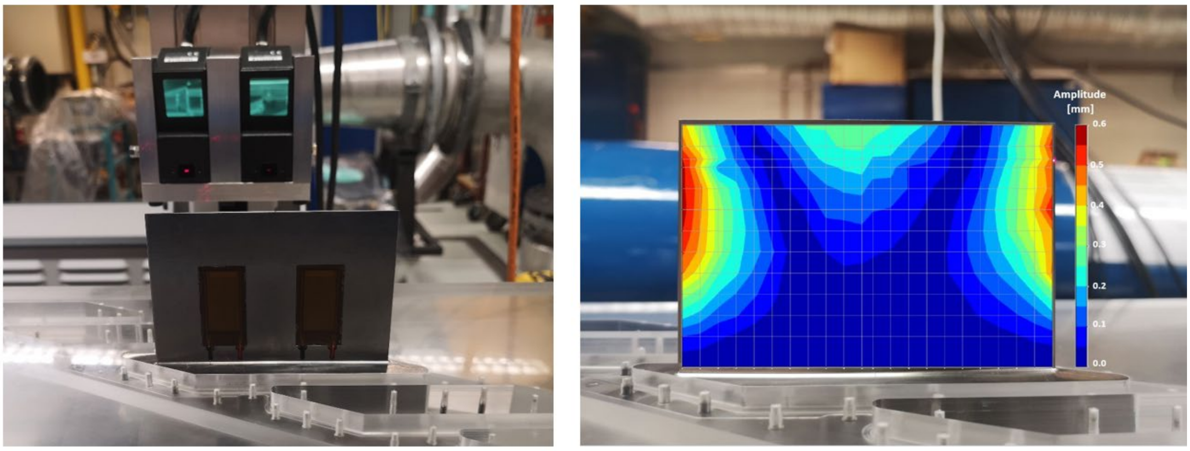

Figure 1. Bench rig for blade oscillation characterization (left); measured amplitude of the cascade blade oscillating in mode 3 @1236Hz (right)