BLADE PRESSURE LOADING and torque measurement in a transonic linear cascade

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| **Jan Lepicovsky, David Šimurda, Jindřich Hála**Institute of Thermomechanics, Czech Academy of Sciences, Dolejškova 5, Prague, Czech Republic | **Petr Šidlof, Martin Štěpán**Technical University of Liberec, NTI FM, Studentská 2, Liberec, Czech Republic | Put author/affiliation here | Put author/affiliation here |

Abstract

Experimental results of a transonic compressor blade pressure loadings and blade shaft torque measurements are presented in this paper. Data were acquired for the cascade middle blade being set to a number of incidence angle offsets to simulate phases of a blade flutter oscillatory motion.

introduction

Strive for higher performance and enhanced operation flexibility of newly designed turbomachines will augment undesired flutter phenomena in stages with long slender blades. The Institute of Thermomechanics of the Czech Academy of Sciences instigated an advanced research program on blade flutter research in order to enhance the understanding of blade flutter onset conditions for off-design operation regimes. A new innovative test facility for blade forced flutter research in transonic flow regimes was designed and built in the High-Speed Laboratory of the Institute of Thermomechanics. The facility test section consists of five blades arranged in a linear cascade. The test facility operation range is up to inlet Mach number of 1.2 and the forced frequency of test blade oscillation up to 400 Hz (Lepicovsky et al., 2022).

RESULTS and DISCUSSION

The reported results are for an airfoil developed for a transonic compressor rotor blade (Schreber & Starken, 1984). The first series of steady flow tests was focused on wall pressure distributions upstream and downstream of the cascade to characterize the cascade inlet flowfield. The purpose of this study is to assess the dynamic effects on blade pressure loading while the blade is in oscillatory flutter motion. Consequently, a strict cascade inlet flow periodicity is not an imperative here. Notwithstanding, an effort is being made to keep the inlet flow periodicity uniform.

Three of the five blades were densely instrumented with conventional static taps as well as with miniature pressure transducers. The instrumentation trenches on the airfoil were made on the blade passive side. Consequently, there are only 0.5 mm taps on the active side of the blade that do not disturb the flow in the boundary layer. It is quite a challenge to insert miniature pressure transducers in thin airfoils. The transducers were inserted with sensing diaphragms oriented in the plane perpendicular to the blade pitching axis to eliminate distortion of pressure signals by acceleration effects.

A blade deflects periodically from a design incidence angle once the blade oscillatory motion is set in force. A steady state simulation of the blade deflection impact on the flowfield alteration was made by setting the middle blade incidence angle to offsets of up to plus and minus 3 degrees.

The tests were conducted for the inlet Mach numbers of 0.9 and 1.09. The results of blade pressure loadings for the inlet Mach number of 1.09 and the incidence angle offsets plus/minus 2 degrees are shown in the first three diagrams in Figure 1. As seen here the blade is undergoing a huge change of its loading during the simulated motion period between the upper and lower dead centres.

Shafts of three middle blades were instrumented with strain gauges to detect torque moments being inserted on the blades. Results of torque measurements for the inlet Mach number of 1.07 and the middle blade (BL-3) being gradually set to incidence offsets from -3 deg through +3 deg are shown in the fourth diagram in Figure 1.

The final paper will present a correlation between the blade loadings and the corresponding measured torque values. Computational results of blade loadings for selected incidence angle

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| **Figure 1. Blade pressure loading and torque moment** |



References

Lepicovsky J., Šimurda D., Šidlof P., Luxa M. (2022), Exploratory Experiments for Simple Approximation of Blade Flutter Aerodynamic Loading, *Proc. of ASME Turbo Expo 2022, Paper GT2022-833351.*

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