EXPERIMENTAL AND NUMERICAL STUDY OF CONTROLLED FLUTTER TESTING IN A LINEAR TURBINE BLADE CASCADE

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In this paper, results of controlled flutter testing of LSB tip profiles performed on subsonic test rig installed at the University of West Bohemia are described and compared with two different numerical methods: a commercial code (ANSYS CFX) and an in-house code (TRAF). The results confirm that the used CFD tools are capable to predict aerodynamic work exchange.

Keywords: steam turbine, last stage blades, flutter, experiment, test rig, measurement, numerical analysis, CFD, validation, blade cascade

1. Introduction

With the increase of steam turbine operational flexibility, the risk of asynchronous blade vibrations induced by flow becomes higher and higher and may lead to undesired failures of last stage blades (LSBs). For this reason, the aerodynamic and structural design of LSBs, which nowadays may be over 1 meter in length, is a critical aspect faced by designers. The Flexturbine project (EC Horizon 2020, No. 653941) gives the opportunity to design and test flutter-resistant blades for a wide range of operating conditions. As a part of this project, a subsonic test rig installed at the University of West Bohemia (UWB) is employed for a controlled flutter testing of LSB tip profiles in air flow. This kind of measurement is not possible in an actual steam turbine and the data will be used for a validation of numerical methods for various blade vibration modes.

2. Test Rig, Numerical Methods, Boundary Conditions

The test rig contains a linear cascade with eight turbine blade profiles made of carbon fibre: the four inner blades are flexibly mounted (see Fig. 1), each with two degrees of freedom (i.e. bending and torsion motions). Unsteady aerodynamic forces and moments induced by blade cascade oscillations are measured and a work exchange between the blade and the flow is estimated. Two different numerical methods were applied for the flutter assessment of blade cascade: a commercial code (ANSYS CFX) and an in-house code (TRAF). In each method, a rig geometry model with different level of complexity is used. A travelling wave mode for bending motion with vibration amplitude of 0.7 mm and torsion motion with the vibration amplitude of 0.5° was investigated at Ma = 0.42 and AOA = 0°. The aerodynamic work, which is the
main quantity to assess flutter stability, was experimentally and numerically evaluated for all the IBPAs of the two vibration test cases. The results were compared on each blade. The example of blade #6 results for the torsion motion is in Fig. 1.

![Image of test rig and blade results]

**Fig. 1:** Test section of the test rig (wind tunnel) at the University of West Bohemia and the example of measured and calculated results.

**Conclusion**

Very good agreement between all compared cases has been achieved. Minor differences appearing in the bending test case have been explained by different blade oscillation behaviour (due to the blade flexibility) during the experimental campaign with respect to the blade oscillation imposed for the numerical computations. The torsion test case, where the blade shape is not so modified by the shakers, shows perfect agreement. The overall stability of blade cascade has been observed using both numerical approaches and also in the experiments. The multi-purpose commercial code CFX confirms its flexibility in simulating aeromechanical investigations of complex geometries (including sidewalls and the actual domains up/downstream the blade cascade). On the other hand, the in-house code TRAF is basically conceived to internal flow simulations for turbomachinery environments and a few approximations in the geometry discretization are required. However, the TRAF code suite takes advantage of low computational cost and dedicated tools for flutter post-processing which speed up typical flutter analyses. The results confirm that the used flutter tools are capable to predict aerodynamic work exchange between fluid and vibrating profiles in air flows. These tools can be now used during the design phase, especially in off-design conditions required by flexible operations to avoid HCF.

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