Numerical and Experimental Study on the Influence of Damping Elements on the Flow and the Vibration Behavior of Industrial Steam Turbine Blades

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Long Abstract

Introduction

Industrial steam turbines are often operated at variable speeds leading to situations in which resonant excitation of blades cannot be avoided. In order to ensure the mechanical integrity of such machines, damping elements such as lacing wires or friction bolts are often used such as to provide sufficient structural damping that result in blade vibration amplitudes with alternant stresses below the fatigue limit. These damping elements are however located inside the blade passages and therefore influence the local flow field. The current study addresses the effects of damping elements on the turbine performance, the local flow field as well as the vibration behavior of the last two stages of an industrial steam turbine in a combined experimental and numerical approach.

1. Methods

A three-stage industrial steam turbine operated at variable speed is used as test vehicle. This turbine features conical friction bolts in the last rotor blade row and a lacing wire in the penultimate rotor blade row. On the experimental side, a full-scale version of the steam turbine is operated at the Institute of Thermal Turbomachinery and Machinery Laboratory (ITSM) at the University of Stuttgart. The test facility features the necessary instrumentation to measure performance, detailed aerodynamics as well as blade vibrations. A sketch of the test facility is shown in Figure 1. The data acquired includes overall performance data, locally resolved static pressures along the turbine flow path, aerodynamic probe traverses yielding steady-state data and blade vibration.

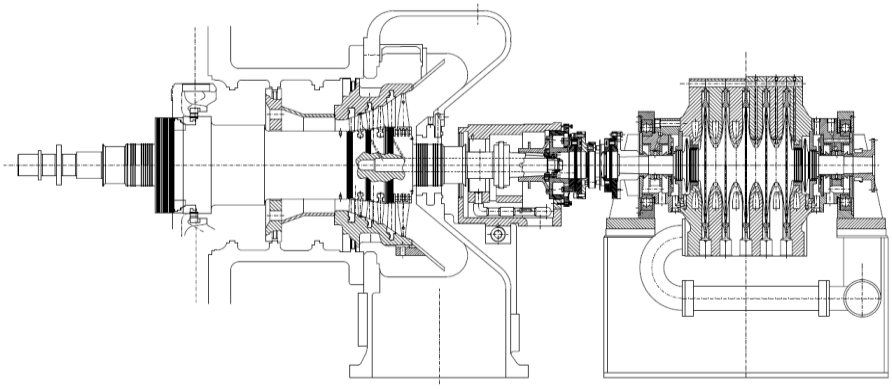

Figure 1. Full-scale industrial steam turbine test facility at ITSM

On the numerical side, the influence of the damping elements on the flow has been investigated in ANSYS CFX 15.0 using 3D full-scale RANS CFD with a Non-Equilibrium Steam (NES) model to account for condensation effects [1, 2].

The blade vibration of the last and the penultimate rotor blade rows have been calculated using a hybrid structural dynamics approach involving linear FEM (ABAQUS 6.11.2.) with the non-linear friction contact modeled in the proprietary tool DATES [3, 4].

The presentation includes an overview of relevant aerodynamic and aeromechanical phenomena in industrial steam turbines. Thereafter, the test case as well as the experimented test setup and the numerical models are presented. The effects of the damping elements on the flow and the vibration behavior are discussed in detail.

References

[1] Häfele, M., Traxinger, C., Grübel, M., Schatz, M., Vogt, D.M., Drozdowski, R., 2015, "Numerical and Experimental Study on Aerodynamic Optimization of Part-Span Connectors in the last stage of a low-pressure industrial steam turbine", J Power and Energy 229(5), pp. 465-476.

[2] Häfele, M., Traxinger, C., Schatz, M., Vogt, D.M., Drozdowski, R., 2015, "Experimental and Numerical Investigation of the Flow in a LP Industrial Steam Turbine with Part-Span Connectors", ASME Paper GT2015-42202.

[3] Drozdowski, R., Völker, L. Häfele, M., Vogt, D.M., 2015, "Experimental and Numerical Investigation of the Nonlinear Vibrational Behavior of Steam Turbine Last Stage Blades with Friction Bolt Damping Elements", ASME Paper GT2015-42244.

[4] Drozdowski, R., Völker, L., Häfele, M., Vogt, D.M., 2015, "Numerical and Experimental Analysis of LP Turbine Blades coupled with Lacing Wire"., Paper No ETC2015-105 presented at the 11th European Conference on Turbomachinery, March 23-27, 2015, Madrid, Spain.