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[Extended Abstract]

Design of a static test rig for advanced seals and air bearing testing

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Introduction

The increasing share of renewables on the electrical grid, makes the supply side of the grid less predictable than it used to be. Large fluctuations may occur, which are to be compensated by the more traditional sources of electricity, like gas turbines. Today's gas turbines are, however, designed for high performance operation in a base-load regime and they are not well equipped for quickly changing load requirements. Flexible operation cycles are limited by the tight clearance between rotor and stator and to avoid rubbing during ramp up. Cyclic operations, additionally, lead to significant temperature gradients which consequently cause high axial and radial displacements of turbine parts. Novel technologies thus need to be introduced to balance demand peaks by providing flexible operation, while still increasing the performance of gas turbines. Such new requirements especially affect current sealing concepts. Hence, advanced seal design concepts need to be invented, optimized and tested at engine-like conditions to match the latest requirements on turbomachinery.

Adaptive seals present a promising approach to allow transient operations and reduced leakage flows. They ensure minimal clearances and can handle a wide range of operating conditions. The seal is spring-mounted allowing it to follow the rotor's axial and radial movements. Small feedholes are present on the seal's surface to always ensure a minimal clearance between the rotor and seal. The feedholes inject high-pressure air in the rotor/stator gap, effectively creating a thin air film between both components. Performance of these so called air bearings and, thus, design and optimization have been the subject of various studies. Of special interest here are: the stiffness, damping, load carrying capacity, flow rate and stability of the air bearing [1].

To understand the dynamic characteristics of air bearings it is first of all necessary to thoroughly study its static characteristics [2]. There are only few researchers investigating static characteristics with an experimental approach. Nishio et al. [3] investigated the stiffness and damping characteristics of air bearings for feedhole diameters of less than 0.05 mm. Fourka et al. [4] developed a numerical approach to predict the stability of air bearings, which was supported by some experimental test results. A similar research approach with a similar test facility was developed by Franssen et al. [5]. All mentioned test facilities allow the investigation of the load capacity, but there has been no study covering the exact pressure distribution on the air bearing surface. Such measurements are, however, of great interest since the pressure in the end translates back to the air bearing's stiffness, which guarantees a non-contact operation of the seal. Also, for the sake of validating and improving the numerical codes [6–9] used for simulating the behavior of adaptive seals it would be helpful to have accurate pressure distributions available.

This paper presents the design and operation of a new advanced seals test facility. The rig was developed to investigate aerodynamic characteristics of advanced seals with a specific focus on the air bearing flow. Precise measurement techniques are implemented to get high quality test data. The key capabilities of the test rig include:

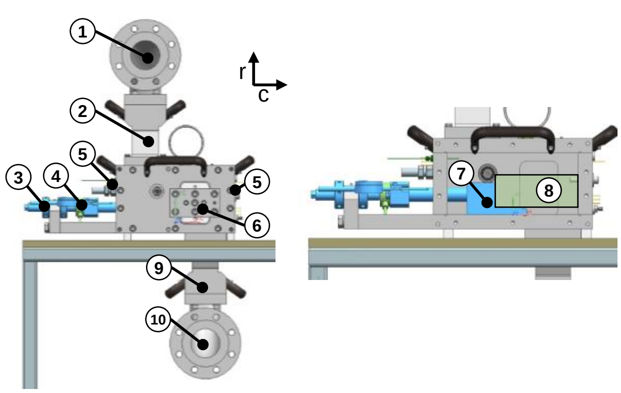
- High resolution pressure measurements on the bearing faces
- Accurate setting of the clearance between rotor and seal face
- Possibility to set the eccentricity and tilt of the air bearing
- Accurate mass flow measurements
- Force measurements

Test Rig Overview

The test facility is shown in Fig. 1. The rig is connected to our local compressor plant, which can provide a maximum mass flow rate of 750 g/s and a maximum pressure of 10 bar. Both the inlet and outlet pressure can be controlled, allowing for the rig to be run at various Reynolds and Mach numbers, representing realistic gas turbine conditions. A 2D segment of an advanced seal or air bearing face can be fitted into the rig. The setup allows for the horizontal and vertical gap adjustment to simulate different axial and radial clearances, respectively. The horizontal movement can be controlled during the experiment by a traverse mechanism, whereas setting the vertical gap requires a quick rig disassembly.

In terms of instrumentation, several proximity probes are used to measure the horizontal gap between the seal and rotor surface. The mass flow rate is measured by a mass flow meter, installed upstream of the test rig. Great care has been taken to design an absolutely air tight test rig setup, which is necessary for getting accurate measurements on the seal leakage flow. Compressed air enters the test rig through an inlet duct that was optimized to achieve a homogeneous inlet flow field. Various pressure tapings on the bearing face allow a comprehensive study of the pressure distribution. By performing CFD calculations in advance the optimum locations for pressure tapings were determined to capture the important flow features. Additionally, a load cell was installed to get a direct measurement of the load capacity. The rig was designed so that different test models can be conveniently exchanged and tested.

The detailed rig design and sample results will be reported in the final paper.



1 Air Inlet
2 Extended duct for an uniform inflow
3 Traversing mechanism for axial adjustments
4 Force measurement unit
5 Outgoing cable channels
6 Sidewall sealing mechanism
7 Slider
8 Blackbox for test built
9 Extended duct otimized outlet channel
10 Air outlet

Figure 1. Test facility setup

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