[Extended Abstract]

Experimental Prediction of Instability in Rotor Seal Systems using Output Only Data

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Introduction

Seals in turbines, centrifugal pumps or compressors are commonly used to separate different fluids and pressure levels. Because of the high rotational speeds of common turbomachines, contactless seals, such as floating ring, labyrinth or small gaps are inserted between the rotating and the stationary parts. The ever-present clearance around these contactless seals permits fluid flow through the gap. For an eccentric rotor position, the fluid-velocity distribution inside the seal becomes unsymmetrical, which entails forces on the rotor. These can culminate in stiffening, restoring, and damping effects, and in particular tangential forces, caused by the whirling fluid flow inside the seal gap. These are responsible for cross-coupling terms in the stiffness matrix. They can cause a rotor vibration, at the onset speed of instability, leading to large displacements and to a breakdown of the system, similar to the 'oil-whip' phenomenon in journal bearings. Further, the rotor-system or the seal condition can change during lifetime. Thus, an experimental diagnosis method is necessary to avoid rotor instability and to ensure safe and stable long-term operation.

A modern approach is to calculate the stability limit of the entire system using output only runup measurements. Observing the parameters during normal operation, a change of the stability limit can be detected and used as an indicator for monitoring.

The focus of this contribution is the introduction to rotor-seal system instability using a JEFFCOTT rotor model and rotordynamic seal coefficients, based on [1]. The comparison of several experimental methods at the test rig with and without additional excitation using an active magnetic bearing (AMB) gives possibilities of real turbo machinery applications.

1. Experimental Setup

The developed experimental methods are examined at the seals test rig at the Chair of Applied Mechanics, see fig.1. The main components are the flexible shaft (1) with two symmetrically arranged seals (2) in the middle. Sensors for measuring displacement and force are arranged in the seals stator housing. The fluid is injected between the two seals with a maximum pressure of 100 bar. The rotor runs with over critical speed above the first natural frequency. An Active Magnetic Bearing (3) is used as an exciter. The rotor shaft is supported by two ball bearings (4) and driven by a servo motor (5). The detailed test rig assembly and the measurement methods for seal coefficient determination is described by [2].
2. Experimental Methodology

The first presented method, as a reference, uses AMB excitation and displacement signals. The transfer function of AMB forward whirl force and the displacement has to be separated in real and imaginary parts. Finding the zero crossing frequency for several rotational speeds (still in save operation range) leads to a prediction of the onset speed of instability, as in [3].

The second method is an output only measurement without AMB excitation. During machinery runup, the spectrum of the rotor displacement signal is analyzed. A tracking filter eliminates the dominating unbalance response and let us calculate the systems damping ratio. The behavior for different rotational speeds let us predict the onset speed.

The third method is the extension of the second one using additional unbalance estimation to calculate the transfer function: rotor amplitude to exciting unbalance. Analyzing leads to the damping ratio of the rotor seal system and a prediction of the onset speed is possible.

The experimental predicted onset speed is compared each other and to simulation results, based on the bulk flow theory, see [4].

3. Conclusion

The presented experimental methods for characterizing a rotor seal systems stability limit have their usage at the stable and safe operating range. Analyzing the machineries runup behavior leads to a monitoring application at the operational speed. The usage of displacement signals at the output only cases can be easily applied on common machines.

References


