An Experimental and Computational Investigation of the Rotordynamic Coefficients of a Labyrinth Seal
(New)

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Introduction and Background

There is a plethora of experimental investigations aimed at measuring the rotordynamic coefficients of a labyrinth seal (Wright, 1978; Benckert and Wachter, 1980; Wright, 1983; Nelson et al., 1986; Bolleter et al., 1987; Wagner et al., 2009; Ertas et al., 2012; Vannini et al., 2014; Arthur and Childs, 2015). Almost always, however, some information needed for the computational fluid dynamic (CFD) simulation is missing either because it was not measured or because it was not reported. The chance of being able to obtain all the data needed for the CFD simulation decreases as the time interval between the experiment and the computational simulation increases, even if both activities are conducted in the same laboratory.

Significant advances were made recently in the CFD rotordynamic analysis of labyrinth seals using the Reynolds-averaged Navier–Stokes (RANS) equations (Moore, 2003; Athavale and Przekwas, 2004). Inspite of the progress, there are still differences between the experiments and computations. Because the RANS models are dependent on the turbulence model, attempts were made to use instead Large Eddy Simulations (LES) in order to numerically solve the larger turbulent scales (Tyacke et al., 2011) rather than to model them. The computational cost of the LES simulations, however, exceeds that of the RANS simulations by at least an order of magnitude, making LES undesirable for design. We have shown that a careful RANS simulation yields similar results to LES (Liliedahl et al., 2011), but a much smaller computational cost. Irrespective whether one uses RANS or LES solvers, the CFD computations must be verified and validated. While the verification is done typically by proving the solution is grid independent, the validation must be done against experimental results. Ideally the generation of experimental and computational data for validation should be done simultaneously, to make sure that all required data are measured and available for the numerical simulation.

The goal of this two-year project is to concurrently conduct an experimental and computational investigation that will both measure and predict the rotordynamic coefficients of a labyrinth seal. In the first step, the CFD simulation using geometries and operating conditions representative of centrifugal compressor applications will be used to help design the experiment and required test set up. Specifically, the simulations will assist in determining the instrumentation location. In addition, the information required for the CFD simulation will be identified and communicated to the experimental investigators.
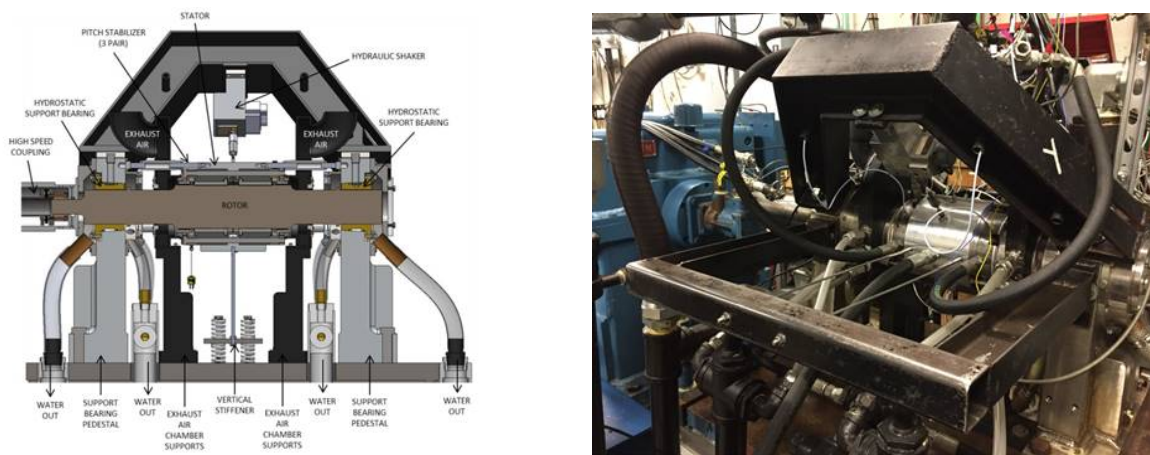

Figure 1: Annular seal test rig: cross section view and picture.

The second step consists of testing the selected seal geometry in the component-level seal test rig (Childs and Hale, 1994), shown in Fig. 1. This facility is capable of testing annular seals up to 5 inches in diameter, at speeds up to 20,000 rpm with a maximum supply pressure of 70 bar, and multiple pressure

ratios by controlling seal discharge pressure. Static and dynamic tests will be conducted to identify the seal force coefficients. The measurements will include flow velocity, temperature, static and dynamic pressures, acceleration, displacement and input force.

In the third step, measured parameters will be directly compared to CFD simulations. The benchmarked CFD model will then be used to optimize labyrinth seal and swirl brake geometries leveraging additive manufacturing.

Deliverables

2018-2019

1. Computational grids, UNS3D input files, simulation results.

2. Labyrinth seal design, proposed test matrix and measurements.

2019-2020

1. Operating conditions and experimental measurements of the labyrinth seal.

2. Updated computational grids, updated UNS3D input files, simulation results, and accuracy assessment for the simulations of the labyrinth seal.

3. Comparisons between experimental and computational results.

Costs 2018-2019

Support for graduate student (20 hours/week)	$26,400
Fringe benefits and insurance	$5,755
Tuition and fees	$13,275
Software	$400
Hardware	$4,170
Total	$50,000

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