Dynamic Characterization of 3D-Printed Damper Seals

CONTINUATION PROPOSAL

Andrew Moody, Research Assistant
Dr. Adolfo Delgado, Associate Professor

May 2019

Introduction

Balance piston seals are subjected to large pressure differential and can generate large forces directly affecting the stability of centrifugal compressors. The most common designs are labyrinth seals and textured seals such as honeycomb, hole-pattern seals, and pocketed seals including pocket damper seals (PDS) and fully partition damper seals (FPDS). Textured seals can develop larger forces and improve stability of the compressor when compared to labyrinth seals. However, these include features that are more intricate and are more expensive and required longer lead times for manufacturing.

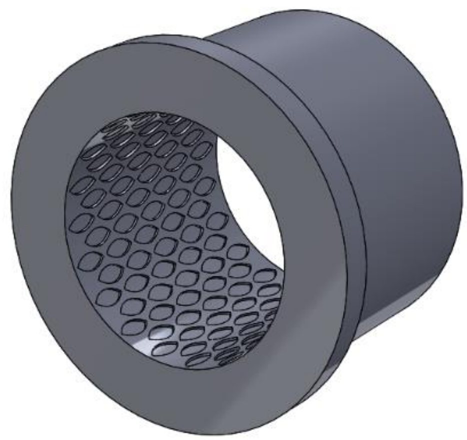

Figure 1. Damper seal design for additive manufacturing ("teardrop design does not require additional support- vertical print)

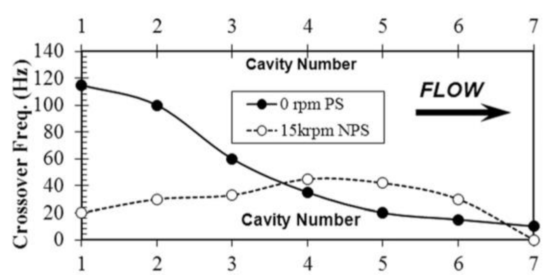

Figure 2. Crossover frequency per cavity for a fully partitioned damper seal [1]

Additive manufacturing (3D printing) represent an alternative approach to create turbomachinery components with intricate features that are more difficult (or not possible) to machine through subtractive manufacturing. This method also allows for cost-effective rapid prototyping for testing the effectiveness of multiple designs is a short period. 3D printing enables the manufacturing of new features and designs but also imposes different constrains not found in subtractive manufacturing. One of them is the limitation associated with unsupported material with angles exceeding 45 degrees from the vertical plane. This constrain makes it impractical to replicate a standard texture seal design as it would require a significant amount of post-processing to remove support material, and in turn, increase the complexity of the manufacturing process. Using a "teardrop" design pattern eliminates the need for elements and minimizes the amount of post-processing. Figure 1 shows an example of a seal following this design pattern. This design is just one example of the seal designs that will be explored.

Proposed work 2019-2020

The propose work aims to evaluate the dynamic performance of a "standard" 3D-printed seal (2 designs) and leverage this manufacturing process to test and advanced seal design. Figure 2 shows the crossover frequency per cavity for a FPDS [1]. These results indicate that the seal develops the most destabilizing forces in its first cavities. Based on these results, a variable pitch seal may improve seal performance (minimize destabilizing forces) by adjusting the area and depth of the cavity along the seal length. Table 1 presents the proposed test matrix including two seal designs, two preswirl values, three speeds and three pressure ratios. The supply pressure is limited to 20 bar (instead of 70 bars) to allow using reinforced polymer seal prototypes. The results from this low-pressure test will serve as a screening to select and refine a final design to be 3D-printed out of aluminum.

Table 1. Proposed test matrix

<table>
<tr><th>Inlet pressure [bar]</th><th>Polymer seals</th><th>Preswirl ring</th><th>Speed [krpm]</th><th>Pressure ratio [%]</th></tr>
<tr><td rowspan="12">20</td><td rowspan="6">3D constant pitch (2 designs)</td><td rowspan="3">Low</td><td>5</td><td>25, 50, 65</td></tr>
<tr><td>10</td><td>25, 50, 65</td></tr>
<tr><td>15</td><td>25, 50, 65</td></tr>
<tr><td rowspan="3">Medium</td><td>10</td><td>25, 50, 65</td></tr>
<tr><td>15</td><td>25, 50, 65</td></tr>
<tr><td>20</td><td>25, 50, 65</td></tr>
<tr><td rowspan="6">3D variable pitch</td><td rowspan="3">Low</td><td>10</td><td>25, 50, 65</td></tr>
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<tr><td>20</td><td>25, 50, 65</td></tr>
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Budget

Graduate Student Payroll, 12 months @ $2200/month	$ 26,400
Fringe Benefits	$ 5,755
Tuition and fees	$ 13,275
Test Hardware (3D printing + postprocessing)	$ 4,570
Total	$ 50,000

References

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[5] Vannini, G., Cioncolini, S, Del Vescovo, G., Rovini, M., 2013, "Labyrinth Seal and Pocket Damper Seal High Pressure Rotordynamic Test Data," J. Eng. Gas Turbines Power. 2013; 136(2):022501-022501-9.

[6] Childs, D., and Hale, K., 1994, "A Test Apparatus and Facility to Identify the Rotordynamic Coefficients of High-Speed Hydrostatic Bearings," J. Tribol., 116, pp. 337–334.

[7] Rouvas, C., and Childs, D., 1993, "A Parameter Identification Method for the Rotordynamic Coefficients of a High Reynolds Number Hydrostatic Bearing," ASME J. Vib. Acoust., 115(3), pp. 264–27