Dynamic Characterization of 3D-Printed Damper Seals

CONTINUATION PROPOSAL

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June 2020

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 expensive when compared to labyrinth seals and require longer lead times for manufacturing.

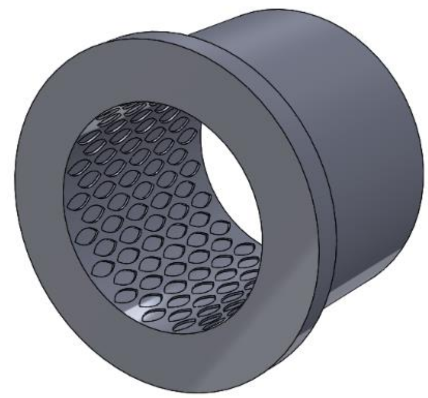

Figure 1. Damper seal design for additive manufacturing ("teardrop design does not require additional support- vertical print)

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.

Project Status

The first phase of the project aimed at evaluating the dynamic performance of 3D-printed seals at 20 bar (~300 psi). The first step was selecting and procuring a suitable printer, followed by performing trial prints to evaluate the capability of the printer. The selected printer, a Mark Forged Mark-2, is capable of embedding carbon fibers on the print such as to increase material strength in two directions. The next step was to assess the printer capabilities and design multiple seal patterns. Figure 2 shows the proposed seal designs including a variable size diamond pattern, a uniform scallop pattern and a multi-lobe configuration.

The scope of the first phase included testing these designs at multiple speed and pressure ratios. Unfortunately, it was now possible to complete seal the testing this year.

Proposed work 2020-2021

The next phase of the project will focus on completing the original test matrix including three seal designs, and developing and testing two additional seal configurations. Table 1 shows the updated test matrix. These new designs will focus on seal features that minimize deflection, cross-coupling forces and leakage. The deliverables will include force coefficients and leakage at each of the operating conditions for all the seals.

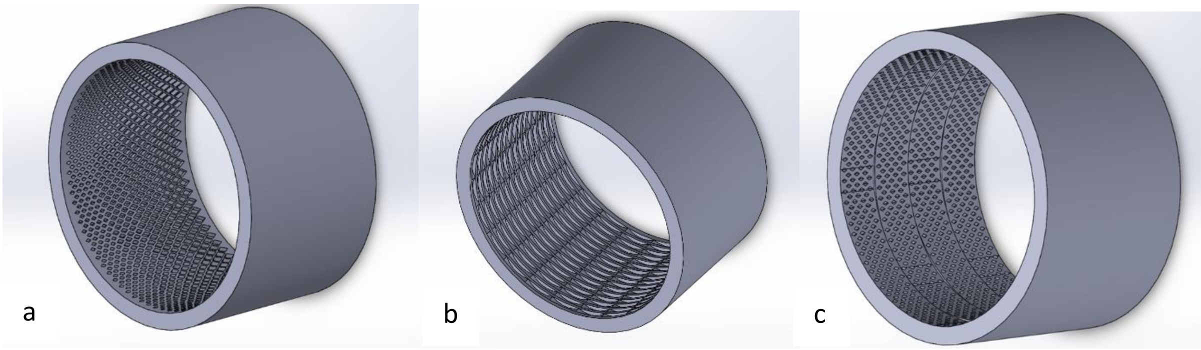

Figure 2. Proposed annular seal geometries (a) variable hole size, (b) scallop, (c) Multi-lobe rings

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Table 1. Proposed test matrix

Inlet pressure [bar]	Polymer seals	Pre-swirl ring	Speed [krpm]	Pressure ratio [%]
20	3D constant pitch (2 designs)	Low	10	25, 50, 65
			15	
			20	
		Medium	10	
			15	
			20	
	3D variable pitch (2 designs)	Low	10	
			15	
			20	
		Medium	10	
			15	
			20	
	3D Best Design (Leveraging previous test results)	Low	10	
			15	
			20	
		Medium	10	
			15	
			20	

Budget

Graduate Student Payroll, 12 months @ $2200/month	$ 26,400
Fringe Benefits	$ 3,127
Tuition and fees	$ 17,186
Test Hardware (3D printing + postprocessing)	$ 3,287
Total	$ 50,000