Dynamic Performance of Liquid Annular Seals in the Transition Regime

NEW PROPOSAL

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Introduction

During liquid annular seal experiments conducted at Turbomachinery Laboratory [1], a significant drop in direct stiffness was identified for certain operating conditions. Figure 1 shows the seal direct stiffness as a function of pressure drop from smooth seal experiments at speeds ranging from 2 to 8 krpm. The original purpose of the tests was to evaluate the effect of pre-swirl on the static and dynamic performance of smooth annular seals. While the negative stiffness was identified and associated with a flow regime transition, it was not thoroughly investigated since it was not part of the original project scope.

A drop in direct stiffness may lead to significant issues as the natural frequency of the system may decrease drastically. In a centered position annular seals develop stiffness mainly due to the Lomakin effect [2], which arises in the turbulent and laminar flow regimes where the wall friction factor drops with increasing Reynolds number [3]. Smith et al. [4] and Ekeberg et al. [5] reported pump supersynchronous vibration and could not define the source for this behavior. Figure 2 show the unstable supersyncronous motion for both cases.

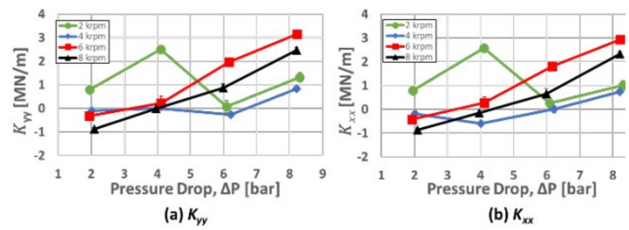

Figure 1. Direct stiffness of oil seal as a function of pressure drop [1].

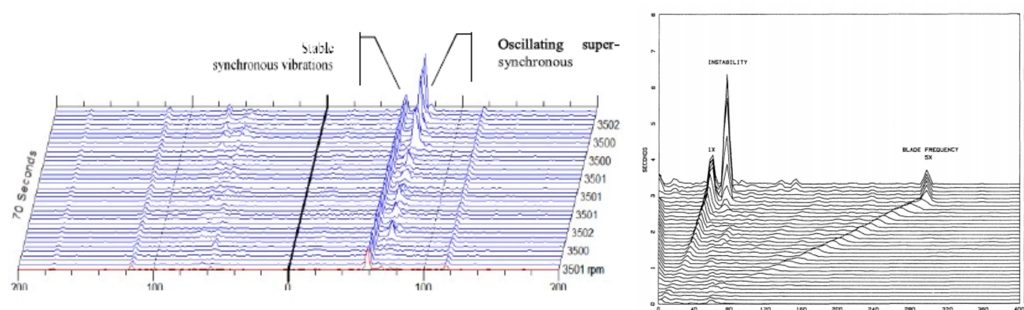

Figure 2 Unstable supersynchronous motion [4,5].

Proposed work

The proposed work aims to evaluate the dynamic performance of the same oil seal tested in Ref. [1] including additional instrumentation to identify the flow regimes within the seal cavity. Table 1 presents the proposed test matrix that will focus on collect as many points as possible at the transition regime and in the laminar and turbulent regions rig next to this threshold. These tests, following well-established parameter identification methodologies, will provide the full set of force coefficients (stiffness *K*, damping *C*, virtual mass *M*) characterizing the seal dynamic load performance as it transitions multiple flow regimes. Figure 3 shows the test results from Ref. [1] showing a sudden drop in stiffness across the transitional regime. The figure also shows the proposed test conditions to evaluate this phenomenon.

Table 1. Proposed test matrix

ΔP* [bar]	Preswirl ring	Speed [krpm]
1.5-8 (0.5-1 bar increments)	Low	2
		4
		6
		8
	High	2
		4
		6
		8

*: May be adjusted to capture flow regime transition

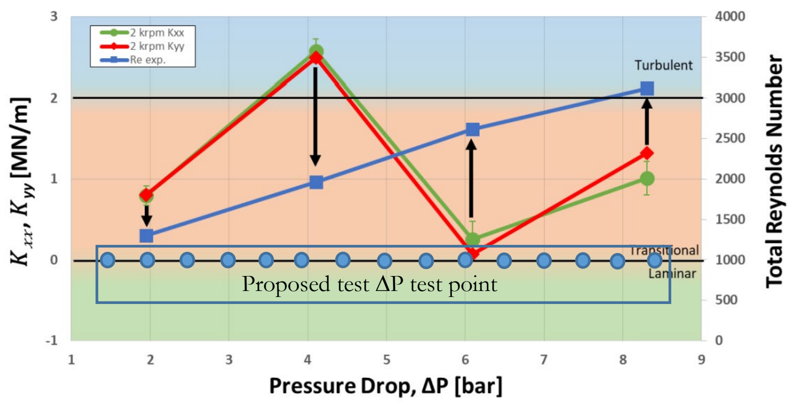

Figure 3. Kyy and Kxx vs. ΔP for ω = 2 krpm and ϵ0 = 0.00 overlaid with Reynolds Numbers [1].

Figure 3. Picture and 3D Model of controlled-motion test rig including sensor locations and detailing main components.

Budget

Graduate Student Payroll, 12 months @ $2200/month	$ 26,400
Fringe Benefits	$ 5,755
Tuition and fees	$ 13,275
Lab supplies	$ 4,570
Total	$ 50,000

References

[1] Bullock, J., 2019, "The Effects of Imposed Pre-swirl on the Static and Rotordynamic Performance for Smooth Annular liquid Seals, M.S. Thesis in Mechanical Engineering, Texas A&M University in College Station, TX.

[2] Childs, D., "Potentially Severe Rotordynamic Consequences of Operating a Pump with Balance-Piston Annular seal in the Transition Regime," to be submitted to the 2022 ASME TurboExpo Conference.

[3] Lomakin, A., 1958, "Calculation of Critical Number of Revolutions and the Conditions Necessary for Dynamic Stability of Rotors in High-Pressure Hdraulic Machines When Taking Into Account Forces Originating in Sealings," J. for Power and Mechanical Engineering (In Russian), **14**.

[4] Ekeberg, I., Bibet, P.-J., Knudsen, H., Torbergsen, E., Kjellnes, F., Angeltveit, R., and K. Klepsvik, "Design and Verification Testing Of Balance Piston for High-Viscosity Multiphase Pumps, Proceedings, 47th Turbomachinery & 34th Pump Symposia, Houston, TX, George R. Brown Convention Center

[5] Smith, D., Price, S., and F. Kunz (1996), "Centrifugal Pump Vibration Caused by Supersynchronous Shaft Instability," Proceedings, 13th Pump Users Symposium, Organized by the Turbomachinery Laboratory, Texas A&M University, pp. 47-60.