Continuation Proposal: Project **PRESSING NEEDS FOR SEALS SOFTWARE DEVELOPMENT/UPDATE** (Year III)

AN IMPROVED BULK FLOW MODEL FOR DRY AND WET GAS POCKET DAMPER SEALS

Dr. Luis San Andrés, Mast-Childs Chair Professor
Dr. Jing Yang, Post-Doctoral Research Associate
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SIGNIFICANCE

Since their invention in 1991 [1], pocket damper seals (PDS) that generate a large effective damping coefficient are applied in high performance turbomachinery, in particular centrifugal compressors. Figure 1 displays a photograph of a typical PDS for a commercial application.

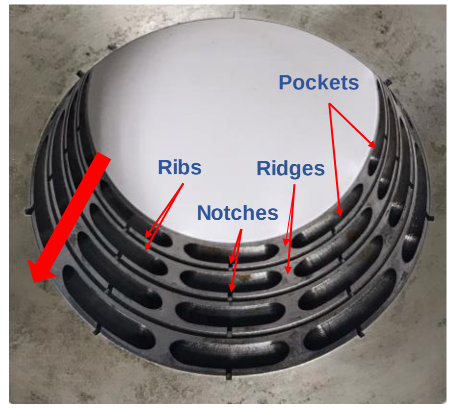


Fig. 1 Photograph of an eight-rib, eight-pocket damper seal.

Current and upcoming multiple-phase pump and compression systems in subsea production facilities must demonstrate long term operation and continuous availability. Sealing systems such as plain seals and labyrinth seals produce persistent subsynchronous rotor vibrations in these subsea systems. Recently, however, a *wet* compressor incorporating a PDS operated stably where a labyrinth seal could not [2]. The pockets apparently stopped the circulation of trapped liquid.

The bulk-flow model (BFM) is a time-efficient way to predict the leakage and dynamic force coefficients for PDSs. In 1999, Li and San Andrés [3] developed *PD_Seal*®, a one-control-volume BFM for PDSs. The BFM predicted leakage agrees with the test data for a two-rib, four-pocket PDS [4]. The predicted dynamic force coefficients deviate from test results by up to 30%, yet meeting approximately industrial application needs. Note the BFM has not been revised or updated since 1999. Further, a BFM for PDSs operating with two-phase flow is not available. Thus, it is urgent to improve and develop a better and proven BFM for both dry gas and wet gas seals.

RECENT EXPERIENCE ON PDS AT THE TL

Ertas et al. [5] high shaft speed test data for three distinct gas seals, one being a fully partitioned eight-rib PDS, constitute the benchmark for any predictive model. Ref. [6] correlates BFM and computational fluid dynamics (CFD) predictions against the experimental results, as shown in Fig, 2 for the dynamic direct stiffness and damping coefficients vs. excitation frequency ratio. The BFM under predicts both force coefficients. There is a 100% or larger difference with the test data for excitation frequencies ranging from 0.1 to 1× rotor speed.

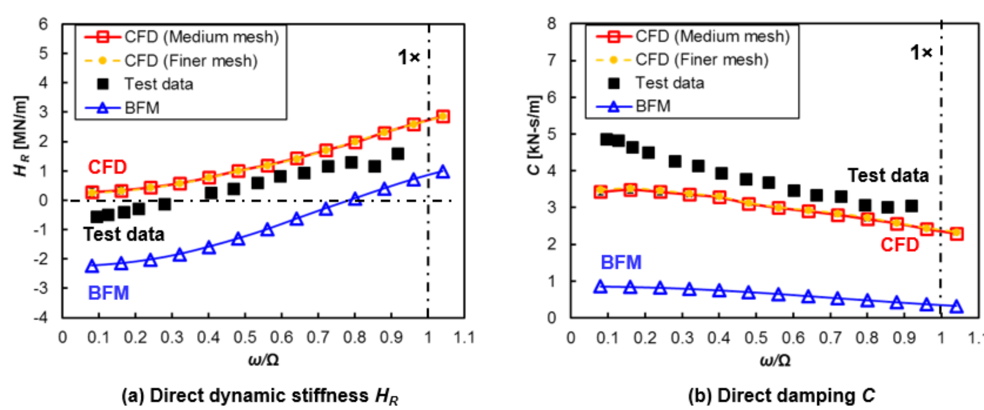
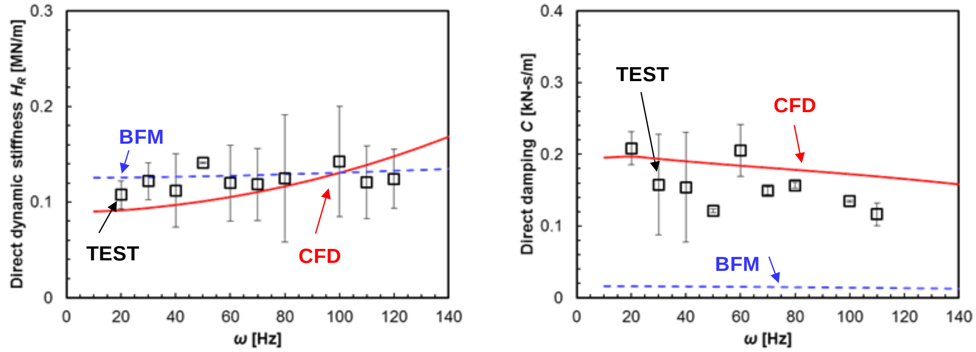


Fig. 2 BFM and CFD predicted, and test force coefficients for a pocket damper seal vs. frequency ratio (ω/Ω). (a) Direct dynamic stiffness H_R, (b) Direct damping *C*. Test data from Ref. [5]. Fully partitioned PDS, clearance C_r = 0.3 mm, supply pressure P_S = 6.9 bar, rotor speed 15,000 rpm (Ω*R* = 134 m/s).

On another case for a four-rib, eight-pocket fully partitioned PDS [7], the supply pressure is 2.3 bar and the rotor speed is null. Fig. 3

displays the BFM and CFD predicted and experimental seal force coefficients vs. frequency. The BFM stiffness matches well the test result, but the BFM damping is almost null, well below the test result and CFD prediction.

The accuracy deficiency of the tool *PD_Seal*® severely limits the engineered application of PDSs.



(a) Direct dynamic stiffness H_R (b) Direct damping C

Fig. 3 BFM and CFD and test force coefficients for a PDS vs. frequency ratio (ω/Ω). (a) Direct stiffness H_R, (b) direct damping C. Test data from Ref. [7].

PROPOSED WORK 2019-2020

The proposed work will improve the existing BFM tool *PD_Seal*® to better predict the leakage and dynamic force coefficients of a PDS (or a labyrinth seal) operating with either a pure gas or a wet gas. Specific tasks include:

1. For gas operation near or above choke conditions, debug the code and update the model for choke flow.
2. For a wet PDS, employ a two-component flow, homogeneous mixture applied strictly as a BFM enhancement [8].
3. Validate the BFM predicted leakage and dynamic force coefficients for dry and a wet gas PDS against test data.

The research is important to advance accurate predictive tools to design, troubleshoot and validate the operation of PDSs applied into high performance compressors and steam turbines. The deliverable will include a new GUI for the computational program with examples of validation.

BUDGET FROM TRC FOR 2019-2020

Support for research associate (40 h/week) x $ 5,000 x 50% effort during 12 months	$ 30,000
Fringe benefits (16.8%) and medical insurance ($747/month)	$ 9,522
Support for a undergraduate student $2,500 x 50% effort during 10 months	$ 6,250
High performance research computing center fees and personal computer upgrade	$ 1,728
Travel & registration to technical conference	$ 2,500
Total Cost	**$ 50,000**

REFERENCES

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[6] Yang, J., San Andrés, L., and Lu, X., 2019, "Leakage and Dynamic Force Coefficients of a Pocket Damper Seal Under Wet Gas Condition: Tests vs. Predictions," ASME Paper No. GT2019-90331.

[7] Yang, J., San Andrés, L., and Lu, X., 2019, "On the Leakage and Dynamic Force Coefficients of a Novel Stepped Shaft Pocket Damper Seal: Experimental and Numerical Results," TRC-SEAL-02-19, Annual Progress Report to the Turbomachinery Research Consortium, Mechanical Engineering Department, TAMU, College Station, TX.

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