Numerical and Experimental Investigations on Preload Effects in Air Foil Journal Bearings

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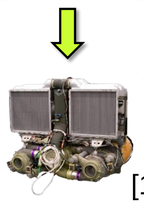
Introduction

- A detailed **elasto-gasdynamic** model of a **preloaded** three-pad air foil journal bearing is presented.
- The influence of the assembly preload on the **static bearing hysteresis** as well as on the **aerodynamic bearing performance** is investigated.
- For the purpose of model validation, **hysteresis measurements** are accomplished.

Applications

- Air cycle machines, turbo chargers, turbo compressors for fuel cell applications, etc.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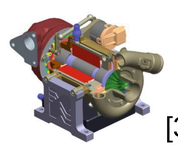
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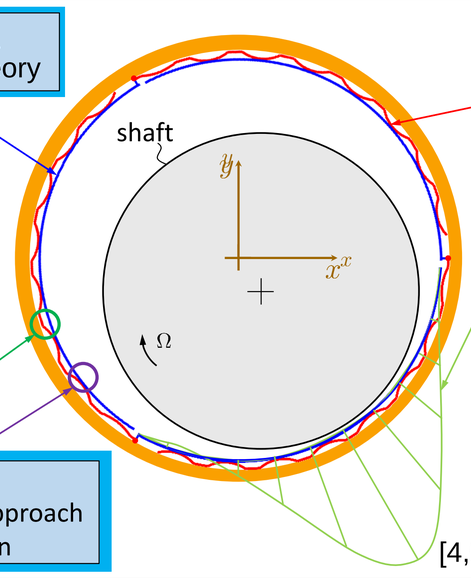
Elasto-Gasdynamic Model

Elastic top foil deformation:
→ Nonlinear *Beamshell* theory

Elastic bump foil deformation:
→ Nonlinear *Beamshell* theory



Contacts:
→ Augmented Lagrange approach
→ Coulomb's law of friction

Pressure Distribution:

$$\frac{1}{1+\varepsilon_{t_i}}\frac{\partial}{\partial s_t}\left(\frac{1}{1+\varepsilon_{t_i}}\frac{\rho_i h_i^3}{\eta}\frac{\partial p_i}{\partial s_t}\right)+\frac{\partial}{\partial z}\left(\frac{\rho_i h_i^3}{\eta}\frac{\partial p_i}{\partial z}\right)=-\frac{6 r_R \Omega}{1+\varepsilon_{t_i}}\frac{\partial(\rho_i h_i)}{\partial s_t} \qquad \forall i=1,2,3$$

Gasdynamic

$$(N\cos(\varphi)+Q\sin(\varphi))' = -p_x(1+\varepsilon)$$
$$(N\sin(\varphi)-Q\cos(\varphi))' = -p_y(1+\varepsilon)$$
$$M' = (1+\varepsilon)Q-\gamma N - m(1+\varepsilon)$$

Elasto-

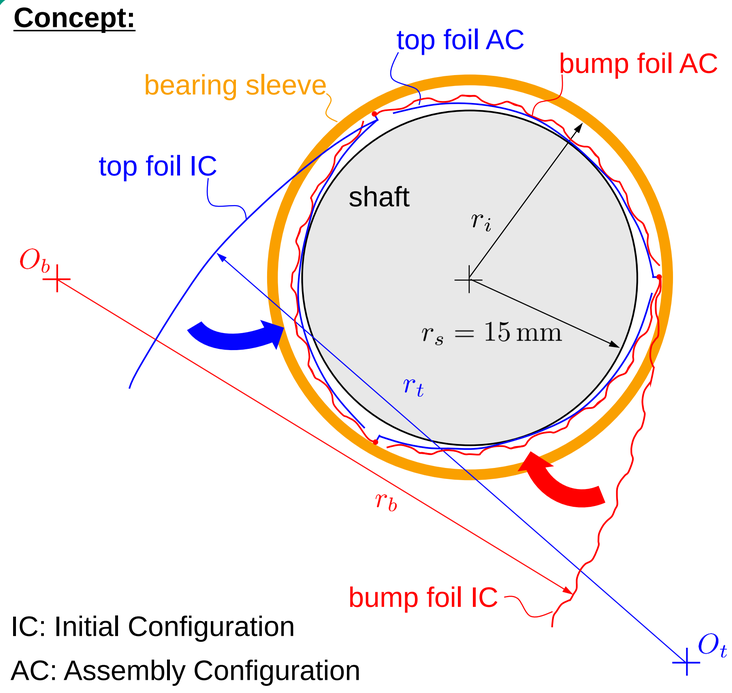
[4,5]

Assembly Preload:

- Objective:
  => Reduction of synchronous and subsynchronous vibration amplitudes

- Solution:
  => Increasing the elastic foil structural stiffness for moderate shaft displacements
  => Increasing the elastic foil structural damping

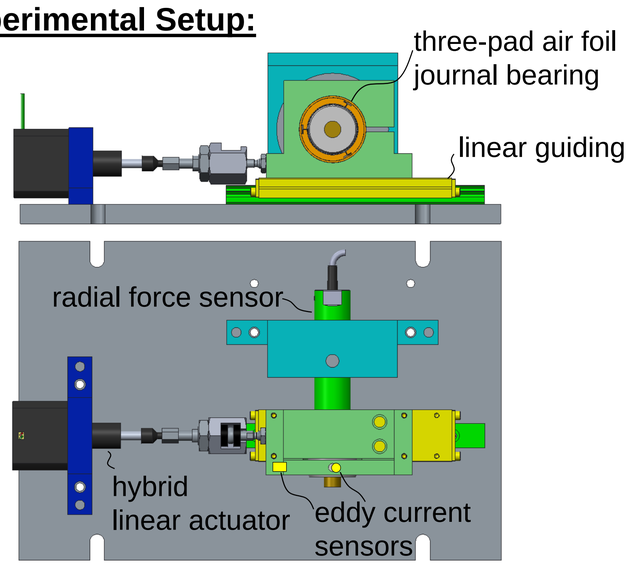
Concept:



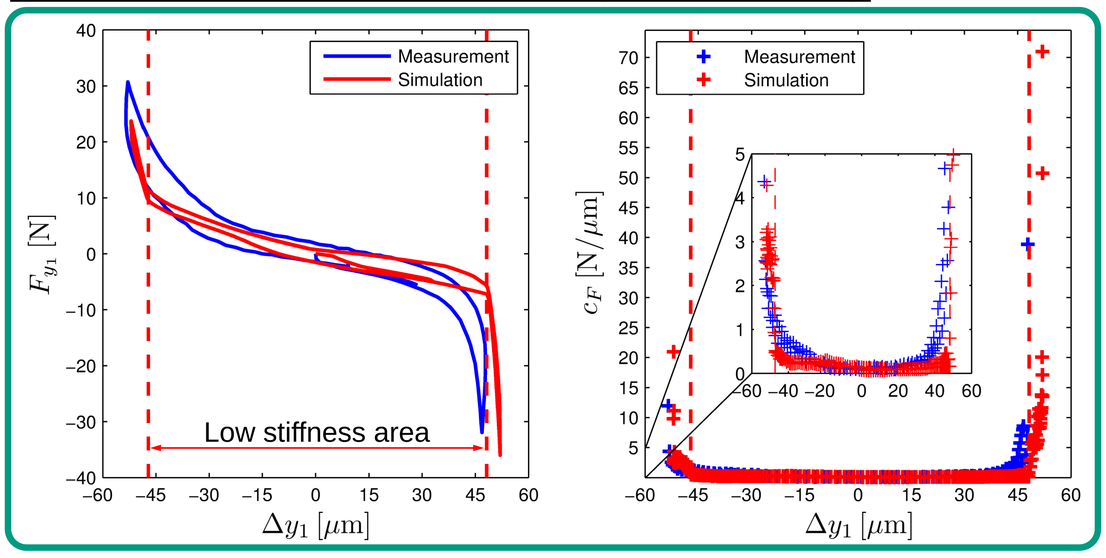
IC: Initial Configuration
AC: Assembly Configuration

Experimental Model Validation

Experimental Setup:



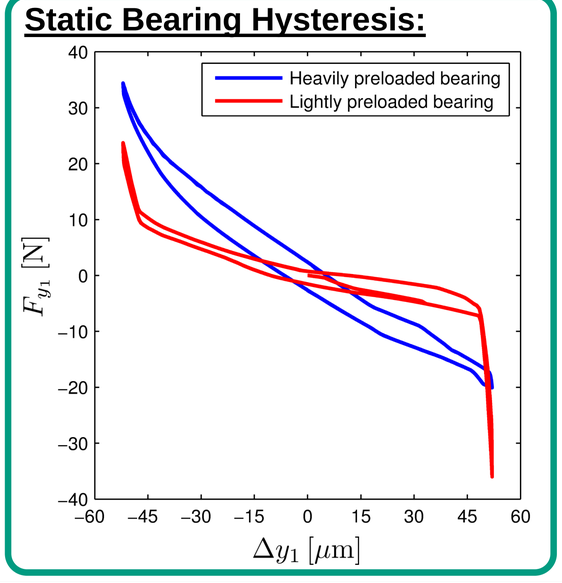
Measurement and Simulation Results (Force, Stiffness):



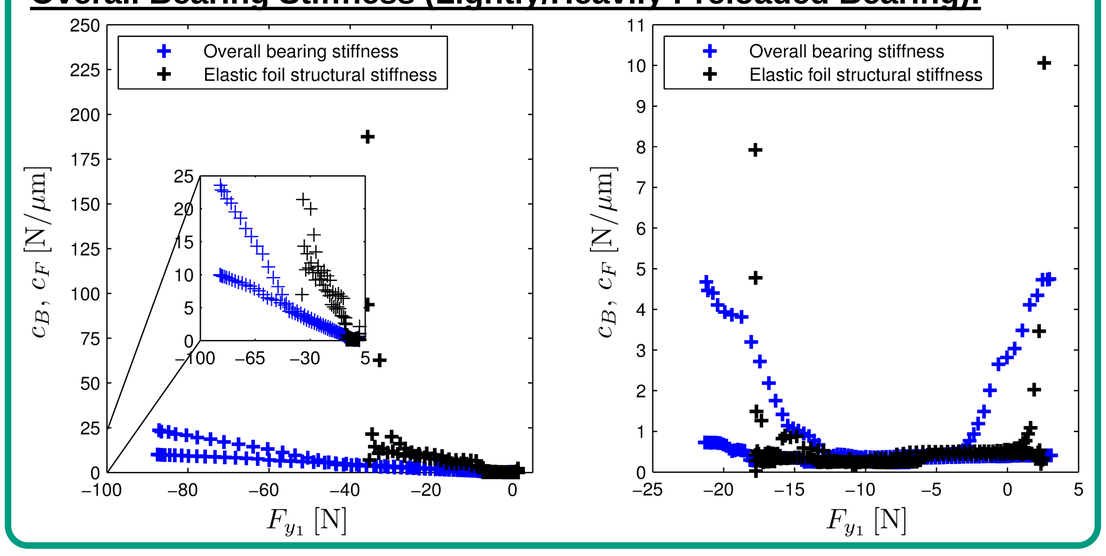
- **Good agreement** between measurement and simulation
- Slight differences in the **friction loss**:
  => Uncertainty in **the coefficient of friction**
  => Friction between **top foil** and **shaft** is neglected
- Slight differences in the **stiffness**:
  => Manufacturing and assembly **deviations**

Preload Effects

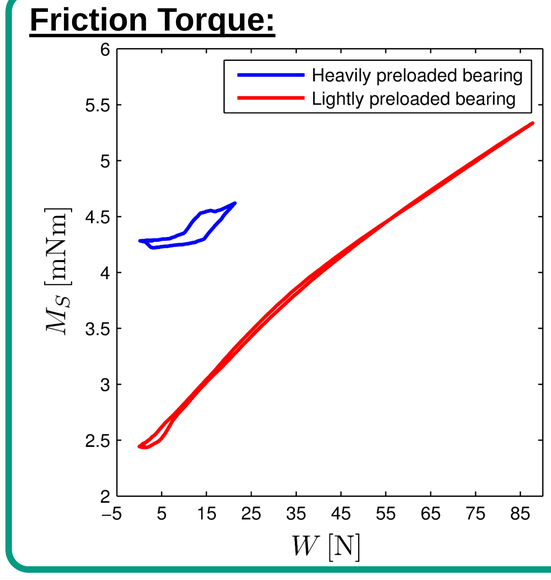
Static Bearing Hysteresis:



Overall Bearing Stiffness (Lightly/Heavily Preloaded Bearing):



Friction Torque:



[1] UTC Aerospace Systems. *Thermal Management Systems, Air Management Systems*. 2017 [cited 2017 30.05.2017]; Available from: http://utcaerospacesystems.com/cap/products/Pages/thermal-management-systems.aspx.
[2] Keun, R. and A. Zachary. *BUMP-TYPE FOIL BEARINGS AND FLEXURE PIVOT TILTING PAD BEARINGS FOR OIL-FREE AUTOMOTIVE TURBOCHARGERS: HIGHLIGHTS IN ROTORDYNAMIC PERFORMANCE*. in *ASME Turbo Expo 2015: Turbine Technical Conference and Exposition*. 2015. Montréal, Canada: American Society of Mechanical Engineers.
[3] Metz, D., et al., *Luftversorgung für Brennstoffzellen.* MTZ-Motortechnische Zeitschrift, 2013. 74(4): p. 316-319.
[4] Mahner, M., et al. *Elastogasdynamic Model for Air Foil Journal Bearings: Hysteresis Prediction Including Preloading Effects*. in *STLE 71st Annual Meeting and Exhibition*. 2016. Las Vegas, Nevada, USA.
[5] Lehn, A., M. Mahner, and B. Schweizer, *Elasto-gasdynamic modeling of air foil thrust bearings with a two-dimensional shell model for top and bump foil.* Tribology International, 2016. 100: p. 48-59.