A Numerical Design Tool for Textured Hydrodynamic Bearings

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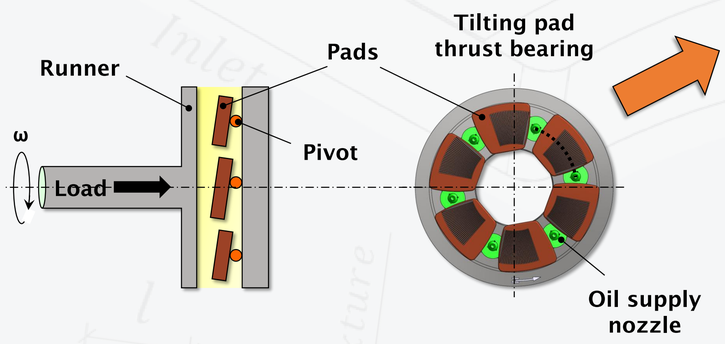
INTRODUCTION



Artificial surface textures are capable of enhancing the tribological performance of lubricated contacts. However, as the optimum texture geometry highly depends on the application and even operating conditions, a careful design of surface textures is crucial.

This project is aimed at developing a robust and fast numerical texture design tool for tilting pad thrust bearings. A purposely developed bearing test rig is used to validate the numerical model.

CONCLUSIONS

Applying special discretization schemes to handle discontinuities, employing parallel computing, strategically utilizing Broyden's method and using results form the equivalent untextured bearing can significantly reduce the computation time of numerical tools to study textured surfaces.

These advanced modelling techniques make a computational optimization of texture designs possible in minutes and facilitate the application of surface texturing for hydrodynamic bearings.

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NUMERICAL MODEL

INPUT *.txt file → START

FILM THICKNESS

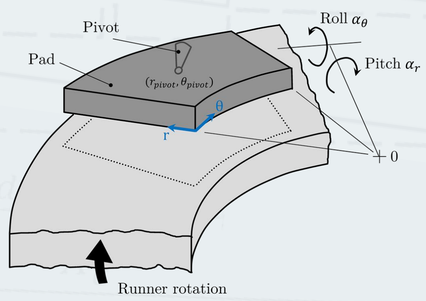
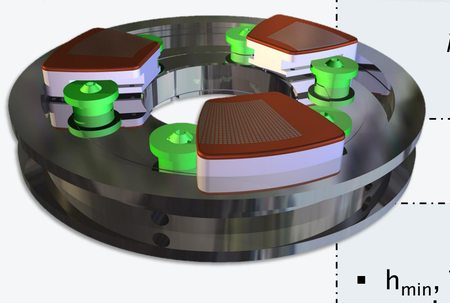
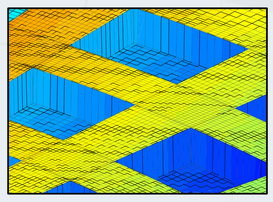


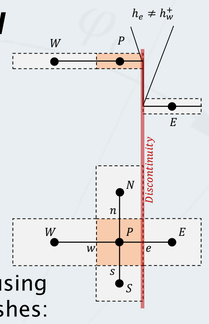
Illustration adopted from: Etsion, I. Analysis of the Gas-lubricated Flat-sector-pad Thrust Bearing. 1976

$$h(\theta,r) = h_p + r\sin(\theta_p - \theta)\sin\alpha_r + [r_p - r\cos(\theta_p - \theta)]\sin\alpha_\theta$$



MESH



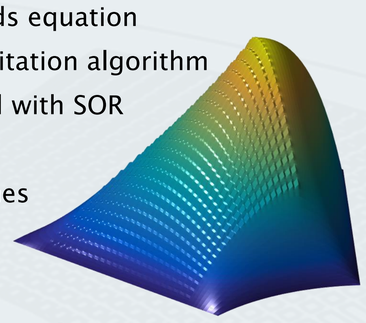


Reduced computation time and enhanced accuracy by using non-uniform & adaptive meshes:

- Different mesh sizes for different contact areas
- Placement of additional points around discontinuities
- Mesh can be aligned with texture edges

PRESSURE DISTRIBUTION

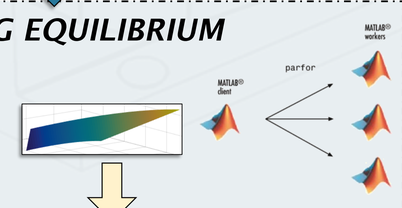
- Based on 2D Reynolds equation
- Mass-conserving cavitation algorithm
- Gauss-Seidel method with SOR
- FVM with special discretization schemes for discontinuities & concentrated inertia



$$\frac{\partial}{\partial r}\left(r\frac{\rho h^3}{\eta}\frac{\partial p}{\partial r}\right) + \frac{1}{r}\frac{\partial}{\partial\theta}\left(\frac{\rho h^3}{\eta}\frac{\partial p}{\partial\theta}\right) = 6\omega r\frac{\partial(\Theta\rho h)}{\partial\theta}$$

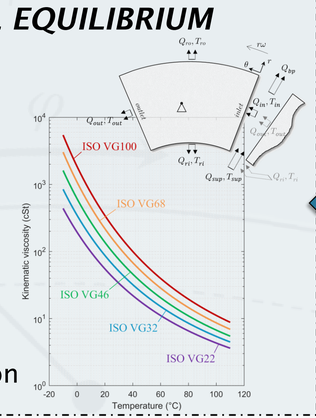
BEARING EQUILIBRIUM

- Multicore computation of Jacobian
- Use of equivalent untextured results
- Optimized solution strategy based on Newton-Raphson, Broyden and continuation method



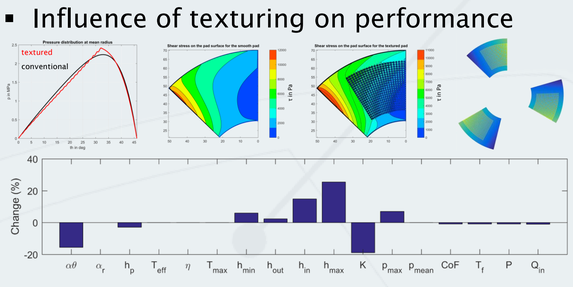
THERMAL EQUILIBRIUM

- Iterative, effective temperature method
- Hot-oil-carry-over effect
- McCoull and Walther's temperature/ viscosity relation



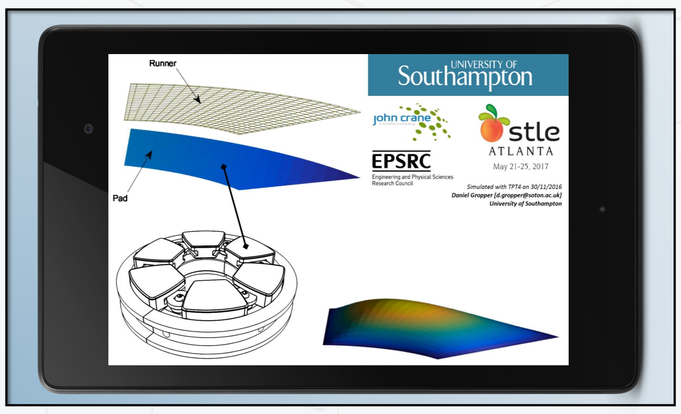
BEARING PERFORMANCE

- h_{min}, T_{max}, Friction torque, pitch & roll angles etc.
- Influence of texturing on performance

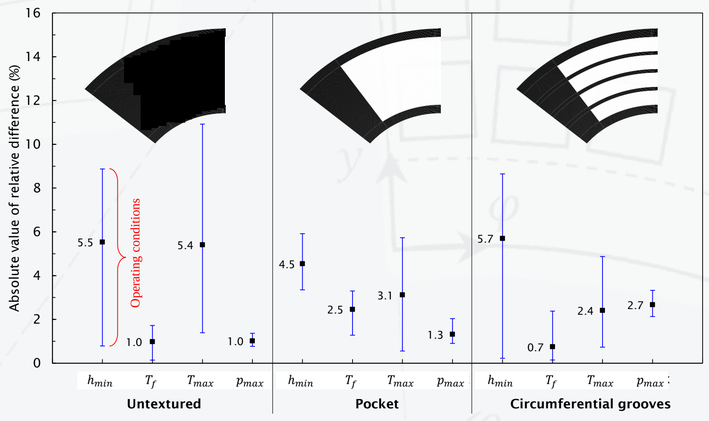


END → OUTPUT *.csv file

NEAR REAL-TIME ANALYSIS

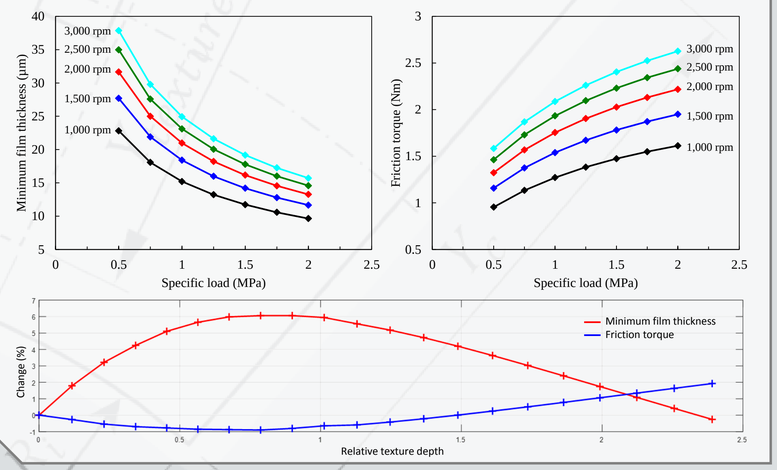


VALIDATION USING CFD



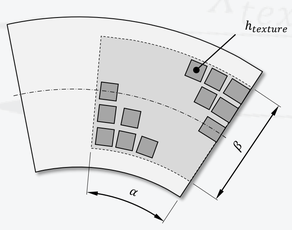
CFD data from: Zouzoulas V, Papadopoulos CI.; Tribology International. 2017.

PARAMETRIC STUDIES

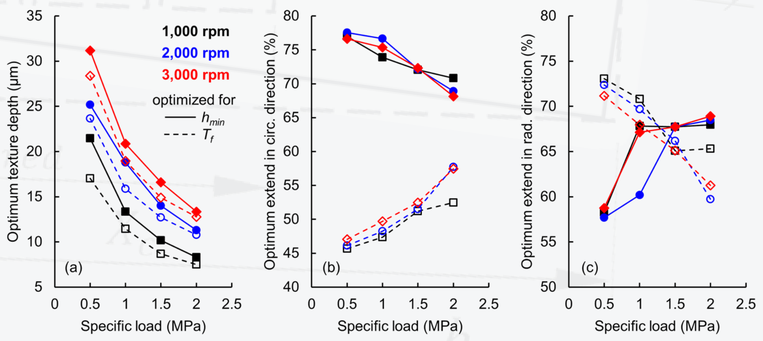


TEXTURE DESIGN OPTIMIZATION

- Nonlinear constrained optimization using interior point algorithm
- Optimization of texture depth, circumferential and radial texture extend

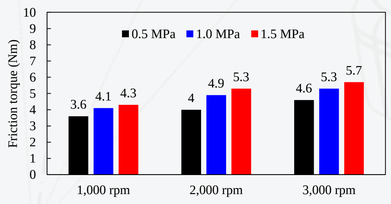


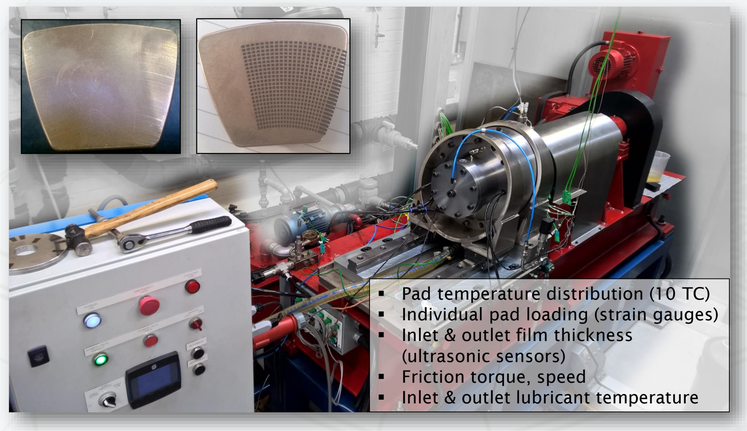
Application ⇨ **Texture design**



EXPERIMENTS ON BEARING TEST RIG

- Influence of texturing under HD operation & validation of numerical model
- Influence of texturing during start-up and shut-down





- Pad temperature distribution (10 TC)
- Individual pad loading (strain gauges)
- Inlet & outlet film thickness (ultrasonic sensors)
- Friction torque, speed
- Inlet & outlet lubricant temperature

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