XXIII Cycle, DIMEAS
2017 - 2020

EXPERTISE models, EXperiments and high PERformance computing for Turbine mechanical Integrity and Structural dynamics in Europe

Effect of wear on the dynamics of structures with friction contacts

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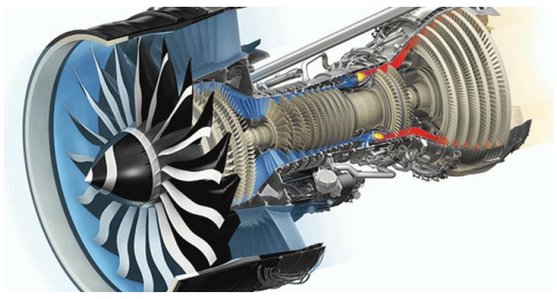
Objectives

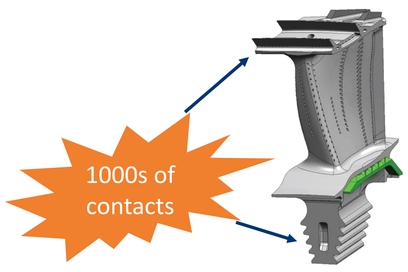
To develop and validate models to predict the effect of wear on the contact surfaces and their ability to dissipate energy by damping. Thereby affecting dynamics of structures with friction contacts. The validated models to be embedded in non-linear solvers for forced response of turbine components.

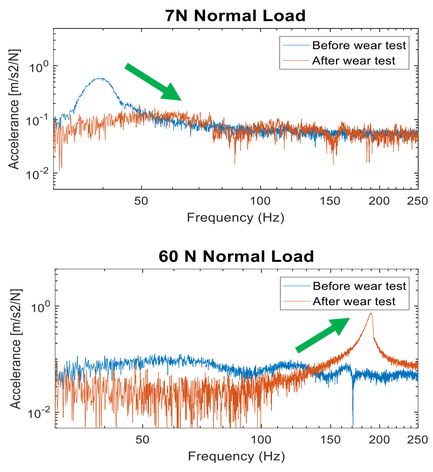
Expected Outcome

- Experimental data set from wear test rig to characterize wear rate of a single friction contact
- Develop numerical solver for the forced response of structures with contacts
- Develop test rig for the forced response of structure with friction contacts
- Comparison of experiments with predicted numerical results

Motivation







Wear affects Dynamics!

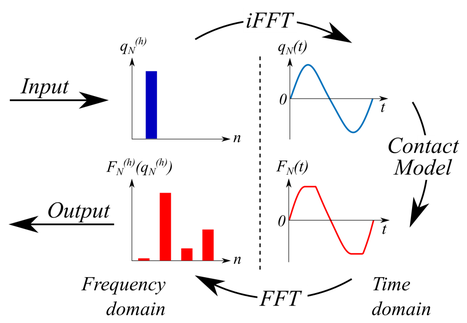
Methodology

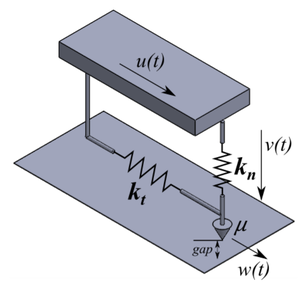
Time domain
$$\mathbf{M}\begin{Bmatrix}\ddot{\mathbf{q}}_\mathbf{L}\\ \ddot{\mathbf{q}}_\mathbf{N}\end{Bmatrix}+\mathbf{C}\begin{Bmatrix}\dot{\mathbf{q}}_\mathbf{L}\\ \dot{\mathbf{q}}_\mathbf{N}\end{Bmatrix}+\mathbf{K}\begin{Bmatrix}\mathbf{q}_\mathbf{L}\\ \mathbf{q}_\mathbf{N}\end{Bmatrix}=\begin{Bmatrix}\mathbf{F}_\mathbf{E}\\ \mathbf{0}\end{Bmatrix}+\begin{Bmatrix}\mathbf{0}\\ \mathbf{F}_\mathbf{N}(\mathbf{q}_\mathbf{N})\end{Bmatrix}\quad\begin{matrix}\mathbf{q}_\mathbf{L}\\ \mathbf{q}_\mathbf{N}\end{matrix}\quad\left|\begin{matrix}\text{Linear DOFs}\\ \text{Non-linear DOFs}\end{matrix}\right.$$

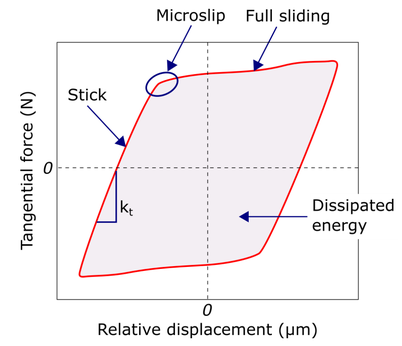
Frequency domain
$$\mathbf{q}(t)=\sum_{h=0}^{H}\mathbf{q}^{(h)}e^{ih\omega t};\ \mathbf{F}(t)=\sum_{h=0}^{H}\mathbf{F}^{(h)}e^{ih\omega t}\quad with\ h=0..H$$

Harmonic Balance Method (HBM)
$$(\mathbf{K}-h^2\omega^2\mathbf{M}+ih\omega\mathbf{C})\begin{Bmatrix}\mathbf{q}_\mathbf{L}{}^{(h)}\\ \mathbf{q}_\mathbf{N}{}^{(h)}\end{Bmatrix}=\begin{Bmatrix}\mathbf{F}_\mathbf{E}{}^{(h)}\\ \mathbf{0}\end{Bmatrix}+\begin{Bmatrix}\mathbf{0}\\ \mathbf{F}_\mathbf{N}{}^{(h)}(\mathbf{q}_\mathbf{N}{}^{(h)})\end{Bmatrix}$$

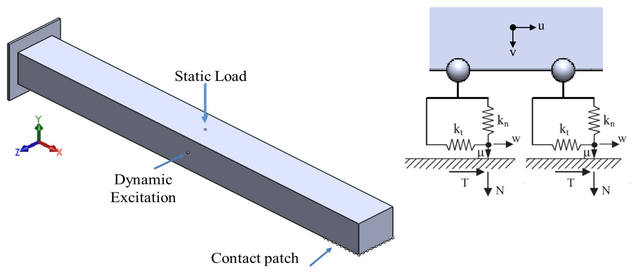
Wear energy approach
$$\boldsymbol{v_w}=\frac{\boldsymbol{Z_w}}{\boldsymbol{A}}\boldsymbol{\alpha E};\ \boldsymbol{Z_w}=\frac{\boldsymbol{R}}{\boldsymbol{max}(\boldsymbol{\Delta h_{ij}})};\quad\mathbf{v}(t)=\sum_{h=0}^{H}\hat{\mathbf{v}}^{(h)}e^{ih\omega t}-\mathbf{v}_w$$

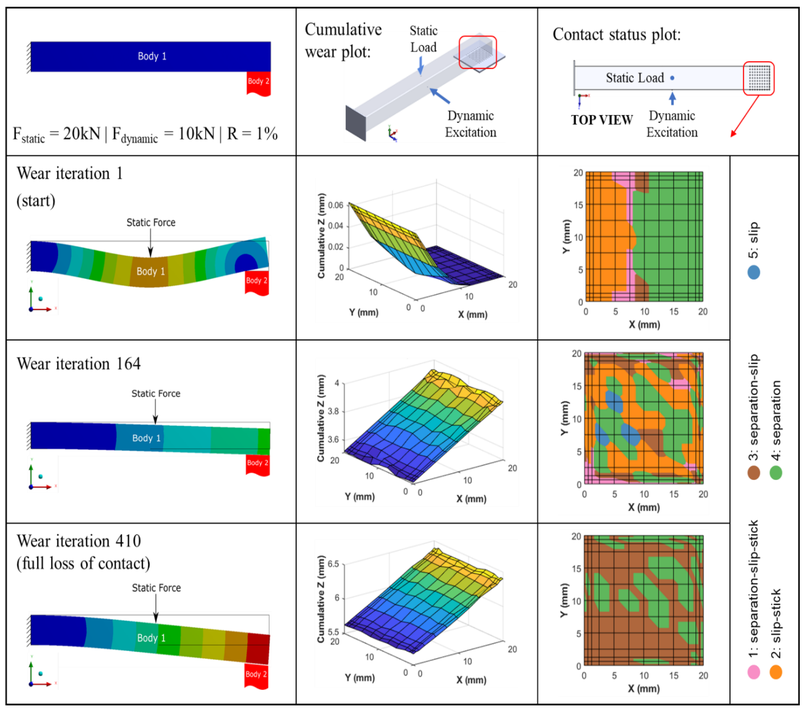


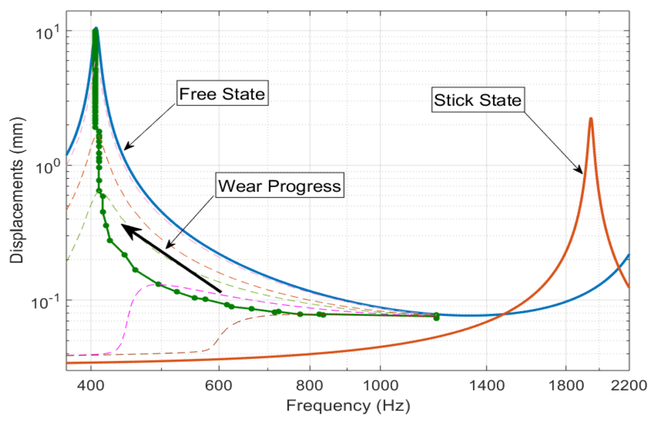


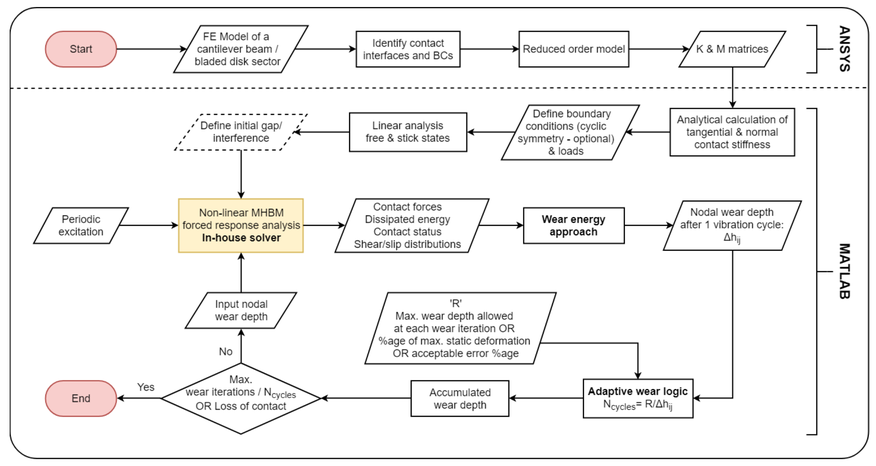


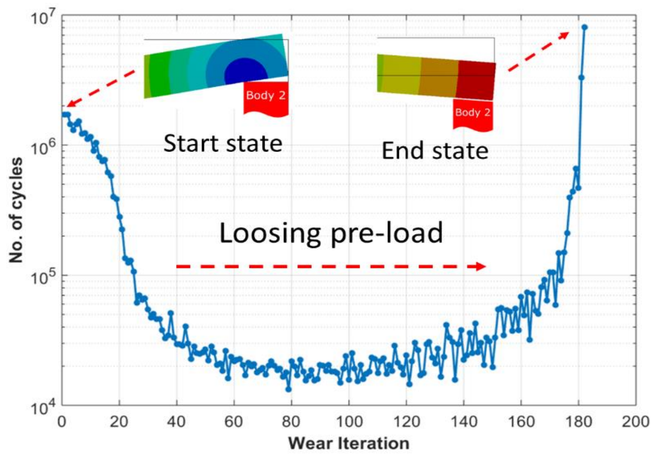
Test Case 1

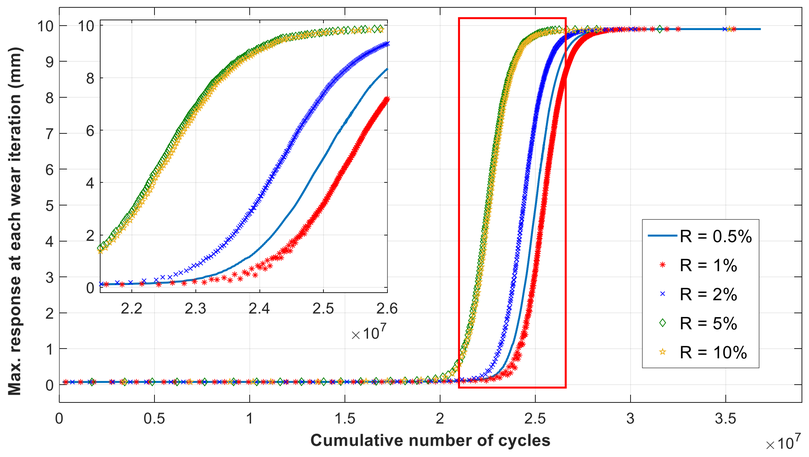




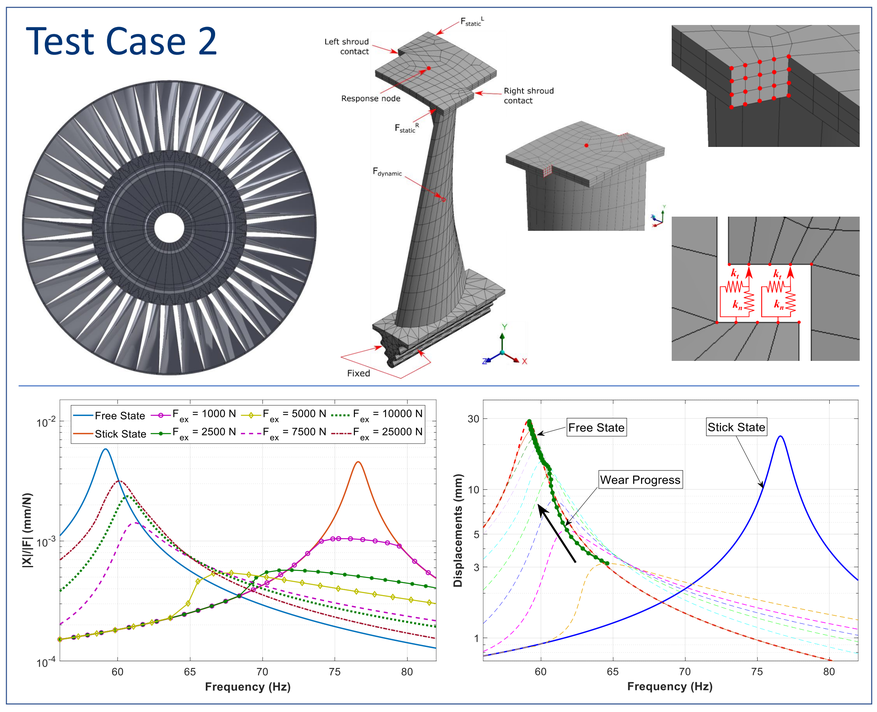




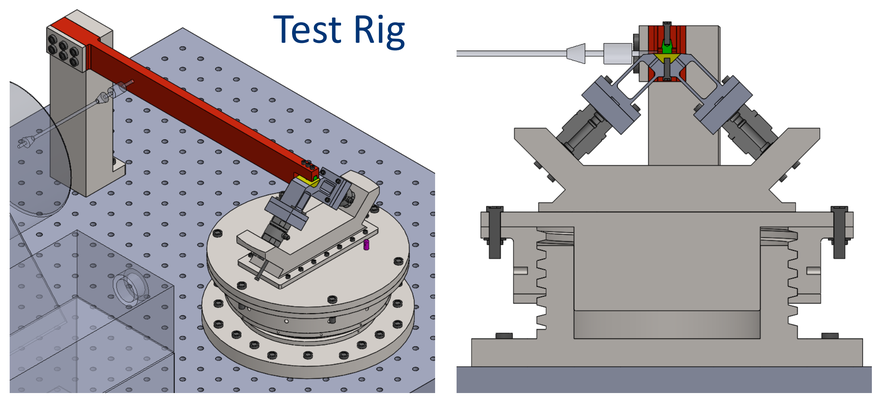




Test Case 2



Test Rig



Future work

- Perform wear tests on the ‘wear test rig’
- Build ‘forced response test rig’ and run the experiments
- Validation of experimental results with numerical predictions

Secondments:

BAKER HUGHES a GE company

University of Stuttgart Germany