Dissipated Energy and Boundary Condition Effects associated to dry friction dynamics

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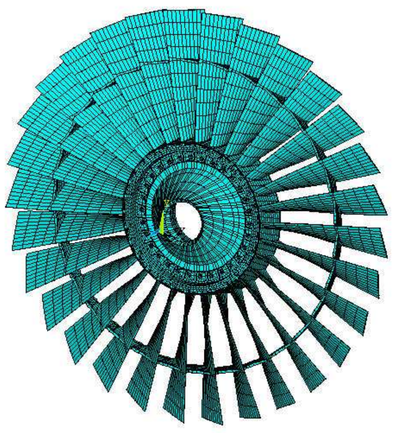
Objective

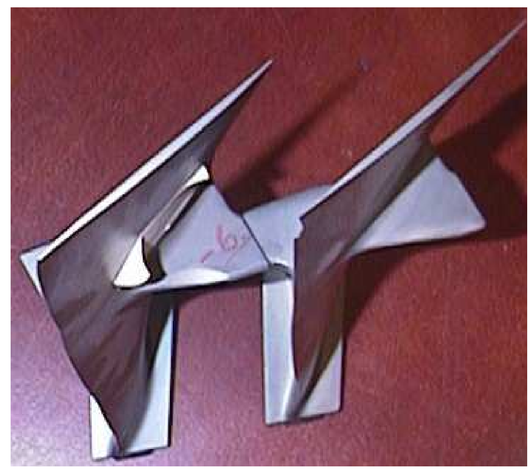
Dynamics of Shrouded Bladed Discs Assemblies in Turbomachines



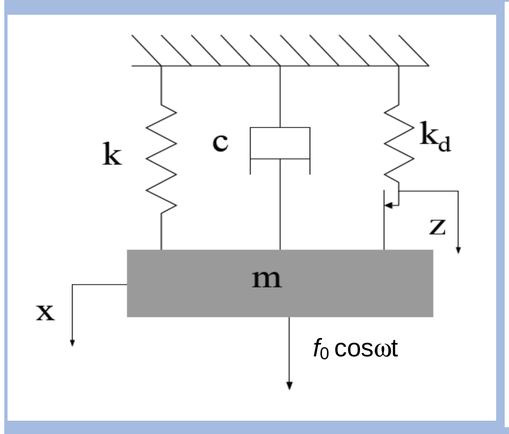
Aim: Physical causes explaining flattening phenomenon of Frequency Response Function peaks of systems in presence of dry friction effects.

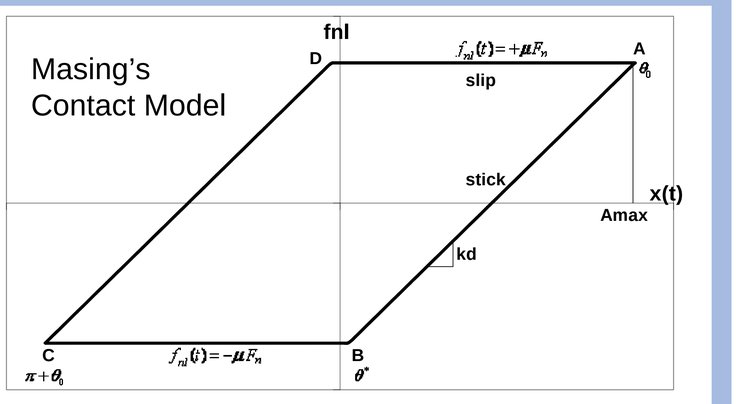
Assumptions:

- Energy dissipated by dry friction
- Changes in contact states during stick/slip motions



1 DOF System and Multiharmonic Balance Method





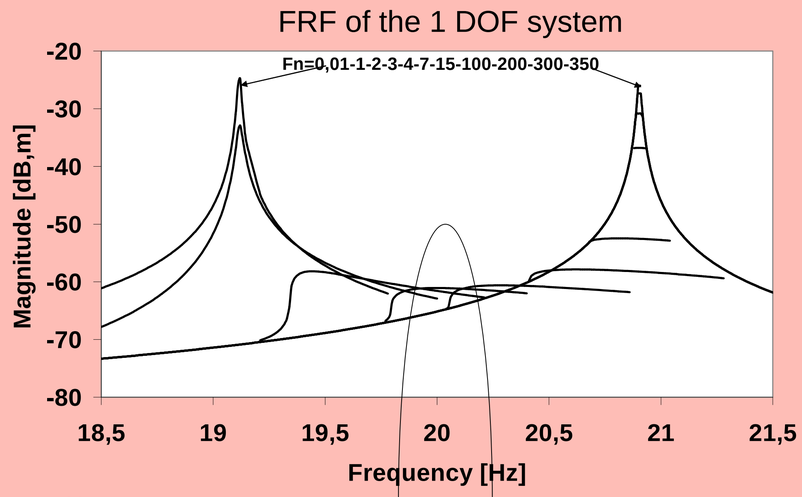
Relative displacement y = x - z

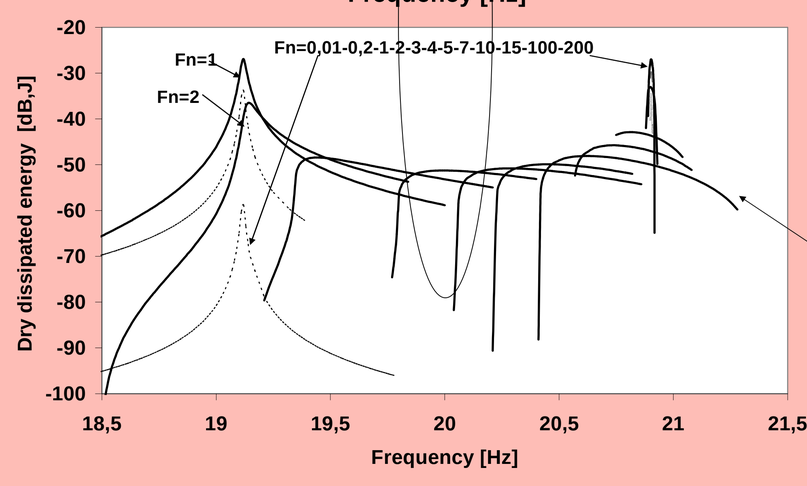
Non linear Force $$f_{nl}(t) = \begin{cases} \mu F_n + k_d(x(t) - A_{max}) & \theta_0 < \theta < \theta^* \\ -\mu F_n & \theta^* < \theta < \pi + \theta_0 \end{cases}$$

The Multiharmonic Balance Method (MHBM) considers the total displacement and the dry friction force as a superposition of harmonic components dependent upon the pulsation of excitation

$$x(t) = \sum_{n=1}^{N} a_n \cos(n\theta) + b_n \sin(n\theta) \qquad f_{nl}(t) = \sum_{n=1}^{N} fc_n(\theta)\cos(n\theta) + fs_n(\theta)\sin(n\theta)$$

Energy dissipated by dry friction hypothesis





Lowest magnitude for the lowest dissipated energy by dry friction

$$E_{dry} = \int_T f_{nl}(t).\dot{y}.dt$$

Changes in contact state due to Stick/Slip Behavior

- **Assessment of forces in the 1 DOF system with MHBM truncated to 1rst harmonic**

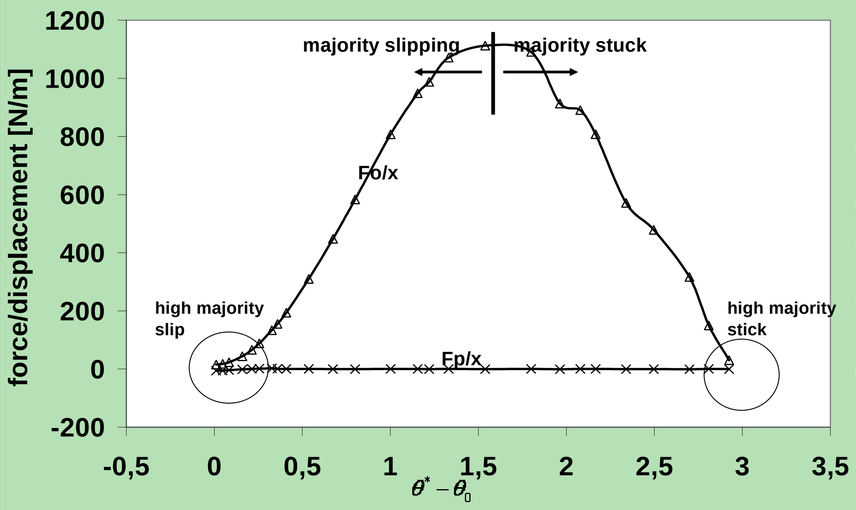
Nonlinear force for maximum displacement: $F_{nl} = fc_b.A_{max} + fs_b.A_{max}$

In phase forces : $F_p = F_{spring} + F_{inertia} + F_{nonlinear\sin}$

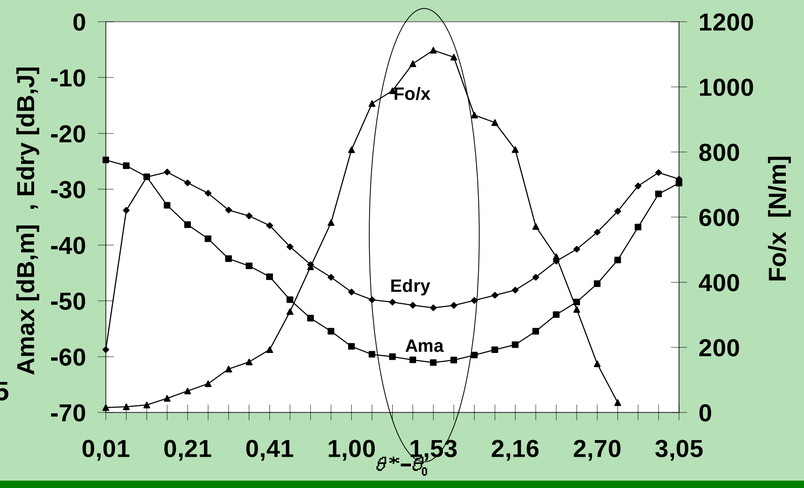
Out of phase forces : $F_p = F_{viscousdamper} + F_{nonlinear\cos}$

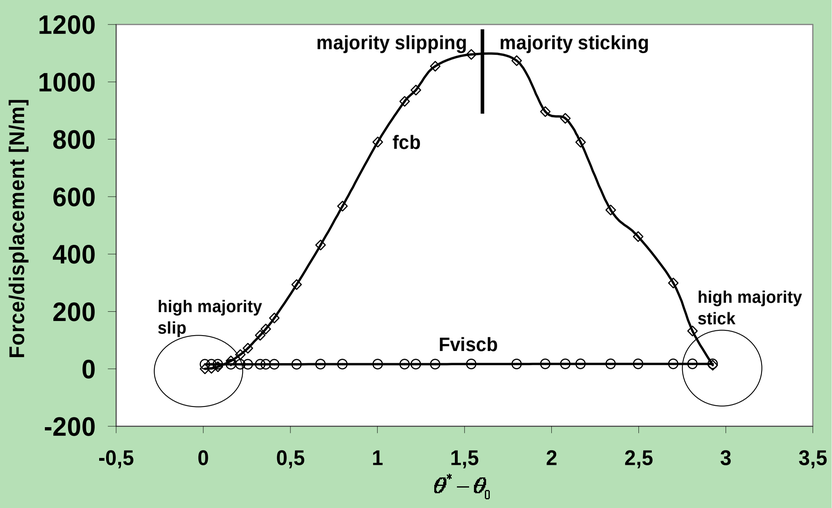
In phase forces per displacement unit : $F_{p/x} = k - m\Omega^2 + fs_b$

Out of phase forces per displacement unit: $F_{o/x} = -F_{viscb} + fc_b$



Lowest magnitude for the highest out of phase component of force and the lowest dissipated energy by dry friction





CONCLUSION

Peak flattening cannot be associated neither to an increase in dissipated energy induced by dry friction nor to an increase in total dissipated energy (dry friction and viscous damping). The analysis of forces acting on the system at resonance shows that when contact moves toward stick/slip states, the out of phase force per displacement unit increases, implying a vibration amplitudes reduction. The half-stuck and half-slip contact state minimises amplitudes.

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