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Estimation of orbits after blade loss for a multi-disk rotor

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Abstract: A flexible rotor supported by fluid-film bearings is investigated in the case of light, intermediate and heavy blade loss. In this first study, the rotor is supported by circular fluid-film bearings. The resulting rotor orbits at the bearing locations are determined for different levels of blade loss unbalance and support flexibility. This is a critical scenario for industrial rotors and usually leads to convergence problems for high unbalance forces at which the rotor approaches or even hits the bearing housing. Strategies for improving convergence as well as reducing calculation time are explored for this demanding numerical solution. The industrial rotor dynamics tool MADYN/NOLIN is chosen for modelling the fluid-film dynamics and unbalance response in case of small unbalance forces. Add-on code is developed for enabling convergence for large unbalance forces. The results are benchmarked against investigations in literature. The impact of a heavy blade loss is outlined and the resulting bearing orbits are evaluated.

Keywords: rotor dynamics, nonlinear dynamics, flexible rotor, fluid-film bearing

1. Introduction

Blade loss in a rotor is a severe condition that causes a sudden change in unbalance, which results in general to an increase of the dynamic load. An industrial rotor and its support structure need to be designed for a safe run-down in case of blade loss. For large values of unbalance, the dynamic forces are no longer negligible compared to the static load [1-3]. At this extreme condition, the linearized bearing characteristics are no longer valid and the nonlinear behaviour of the fluid-film and the bearing support become dominant.

2. Results and Discussion

We investigate the rotor deflection at the bearing locations for the simple multi-disk rotor as visualised in Fig. 1. This rotor is physically available in the lab and fully instrumented and allows for an experimental verification at a later stage. In our study, we develop a calculation procedure for achieving the numerical convergence for intermediate and heavy dynamic loads. Typical orbits for a light and intermediate dynamic load are shown in Fig. 2. These results are based on the simplified short bearing theory

$$\begin{aligned} F_t &= \frac{\eta_{\mathrm{oil}} \mathrm{B}^3 \Omega}{D\psi^2}\left[\frac{\pi}{2}\left(1-\frac{2\dot{\gamma}}{\Omega}\right)\frac{\varepsilon}{(1-\varepsilon^2)^{3/2}}+\frac{\dot{\varepsilon}}{\Omega}\frac{4\varepsilon}{(1-\varepsilon^2)^2}\right] \\ F_r &= -\frac{\eta_{\mathrm{oil}} \mathrm{B}^3 \Omega}{D\psi^2}\left[\left(1-\frac{2\dot{\gamma}}{\Omega}\right)\frac{2\varepsilon^2}{(1-\varepsilon^2)^2}+\pi\frac{\dot{\varepsilon}}{\Omega}\frac{1+2\varepsilon^2}{(1-\varepsilon^2)^{5/2}}\right] \end{aligned} \qquad (1)$$

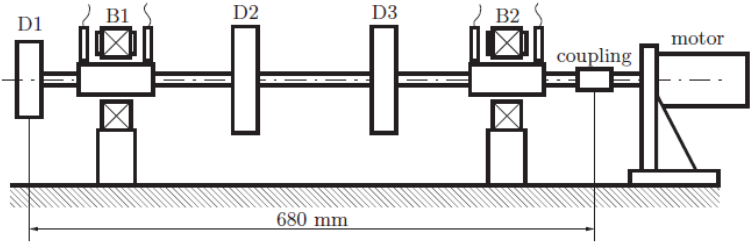

Fig. 1. Flexible, multi-disk rotor supported by two bearings.

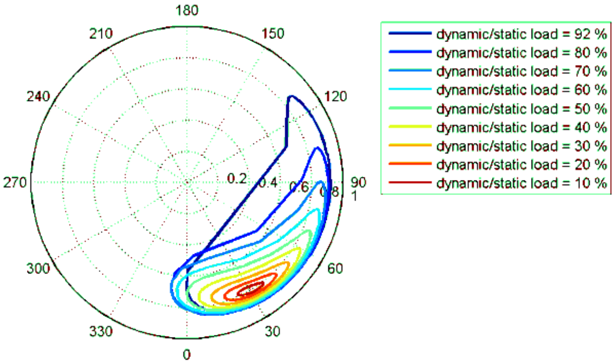

Fig. 2. Rotor orbits of a point mass in a short circular fluid-film bearing for light and intermediate unbalance.

This simplified estimation is benchmarked against a full nonlinear rotordynamic calculation using MADYN/NOLIN with improved convergence.

References

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