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Numerical results of the influence of thermal effects on the turbo machine rotordynamics induced by light-rubs against a brush seal

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ABSTRACT

Brush seals are an efficient alternative for labyrinth seals in turbomachinery. Brush seals show on the one hand a better leakage reduction in relation to their axial length and hence allow a shorter design of the machinery. On the other hand, the particularly small gap between bristles and the engine shaft increases the risk of rotor-stator-contact. The flexible brush seals induces basically light-rubs that in some cases might lead to spiral vibrations and thermal mechanical instabilities.

Spiral vibrations are caused by a thermal deflection of the rotor induced by a heat flow into the shaft. To predict areas of instabilites during the design process a tool was developed at the Berlin Institute of Technology. The model combines a rotor dynamic model and a thermal model. The thermal system is reduced using a stationary solution, so that the final system, on which the stability analysis is performed, is comparable to the established Kellenberger model.

The paper presents the numerical model for the predictions of unstable regions depending on rotational speed. This is illustrated by means of an example of an axial compressor manufactured by MAN Diesel & Turbo.

1. Introduction

Replacing labyrinth seals in turbo-machines with brush seals allows a significant reduction in axial length of the seal while maintaining the leakage characteristics. Hence, brush seals allow a wider range of possibilities in rotor design, for example to shift the eigenfrequencies of the rotor away from the operating speed or to reduce the leakage in order to increase the efficiency of the machine. As brush seals provide a comparably low stiffness due to the flexible bristles, the clearance to the rotor can be reduced to almost zero. But a small gap raises the probability of a contact between the rotor and the seal, leading to rub induced vibrations of the machine. Since the contact stiffness of the brush seal is small compared to the rotor stiffness, hard rubbing can be neglected and the friction can lead to the known Newkirk-effect [12]: The power loss due to friction at the contact-line between seal and rotor heats up the rotor asymmetrically. The non-uniform temperature distribution bends the rotor in direction of rotor's rubbing point. The rubbing point changes its circumferential position over time while the vibration amplitude changes as well. That combination leads to the typical spiral orbits observable in rotating coordinates that are sometimes increasing in an unstable manner.

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