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THE INFLUENCES OF THERMAL EFFECTS INDUCED BY THE LIGHT-RUB AGAINST THE BRUSH SEAL TO THE ROTORDYNAMICS OF TURBO MACHINES

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ABSTRACT

Brush seals find increasing use in turbomachinery substituting conventional labyrinth seals thanks to their excellent leakage characteristics and convenient integration. Brush seals have very small clearances during operation. In case of contacts between rotor and brush seals, contact forces will be low due to the compliant behaviour of the bristles. While short term contacts between seal and rotor have no significant influence on the rotordynamics, longer-lasting rub can lead to thermally induced rotor-vibrations, also known as the Newkirk-effect. Light partial rub and the subsequently dissipated heat that enters into the shaft may yield a thermal bow performing spiral-vibrations regarding rotating coordinates. Depending on thermal coefficients and rotating speed, this thermal bow may effect instable behaviour with high amplitudes and a possible damage of the machine. At the Chair of Engineering Design and Product Reliability at Berlin Institute of Technology investigations of light partial rub of a rotor against a brush seal are conducted. A test rig is under construction in order to validate the numerically calculated parameters. Investigations are setting up on a thermoelastic model, developed by Kellenberger for a real rotor model. The goals of the investigations are to verify and to extend the model for brush seals and finally to formulate guidelines for the safe use of brush seals in turbomachinery concerning rotordynamics. The difficulty of defining stability statements is to quantify the required thermal parameters. Hence, the three dimensional temperature distribution inside the rotor, which depends on the rotating speed as well, must be known. In order to calculate this temperature distribution the three dimensional Laplace-Equation in cylindrical coordinates is solved for the different convection coefficients by means of Finite-Volume-discretization. Subsequently the required parameters are calculated by numerical integration of the 3-D-structure. The stiffness of the brush seal with respect to a partial rub is calculated using beam theory and continuous elastic support. This paper shows the numerical results of the 3-D temperature distribution, the numerically identified parameters that drive the thermal bow and stability charts regarding spiral vibrations for a chosen brush seal configuration.

NOMENCLATURE

$c_{u,d,l,r,f,b,C}$ Conduction coefficients of the FVM
d Diameter
h Width of the brush seal
p Factor for the entering heat
q Factor for the outflowing heat
r_T Complex coordinate of thermal deflection at the hot spot
A_O Overlap area
I_{yy} Second moment of area around the y-axis
M_y Moment around the y-axis
dS Surface differential
dV Volume differential
$\dot{Q}$ Heat flow
$\dot{W}$ Power loss