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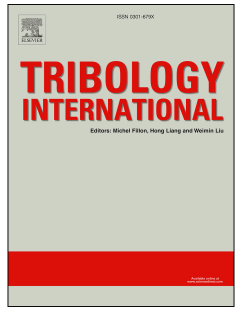

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A thermo-elasto-hydrodynamic model for air foil thrust bearings including self-induced convective cooling of the rotor disk and thermal runaway

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Abstract

A 3D thermo-elasto-hydrodynamic model for air foil thrust bearings (AFTBs) is presented. A detailed shell model is applied for the foils. The deformation of the rotor disk is modeled by axisymmetric Navier-Lamé equations taking into account thermal expansion effects. The pressure in the lubricating gap of the AFTB is calculated by the Reynolds equation and the temperature by a 3D energy equation. Particular emphasis is put on detailed thermal submodels for the bearing parts. An analytic formula is presented for the effective thermal resistance of the bump foil incorporating thermal contact resistances between the bump foil and the top foil as well as between the bump foil and the base plate. The self-induced cooling flow at the backside of the rotor disk is modeled by appropriate boundary layer equations including an eddy viscosity turbulence model. The heat flux through the tight gap between the outer part of the disk and the housing is accounted for as well. The presented model is used to reveal thermal features of AFTBs. The main finding is that load capacity increases with rotor speed only up to a critical value, above which load capacity is even found to decrease with increasing speed. This thermal runaway is proved to originate from a thermally induced bending of the disk that leads to an unfavorable gap function. Furthermore, experimentally observed beneficial effects on unit load capacity of AFTBs - as for example a forced cooling flow and a reduced number of pads - are successfully reproduced by the presented model. Finally, the relative magnitude of the different heat fluxes occuring in AFTBs is analyzed in detail.

Keywords: Air foil thrust bearing, Thermo-elasto-hydrodynamic modeling, Thermal runaway, Thin film lubrication

Nomenclature

$(\cdot)_B$	Variables associated with a bump
$(\cdot)_D$	Variables associated with the rotor disk
$(\cdot)_T$	Variables associated with the top foil
$(\cdot)_C$	Variables associated with the cooling flow region
$(\cdot)_{fr}$	Variables associated with the fresh cold air flowing into the chamber between pads
$(\cdot)_{in}$	Variables associated with the inlet surface of the lubricating gap
$(\cdot)_{out}$	Variables associated with the outlet surface of the lubricating gap
$(\cdot)_{per}$	Variables associated with the air gap at the periphery of the disk
$\dot{m}$	Mass flow
η	Dynamic viscosity
ν	Poisson's ratio for solid bodies or kinematic viscosity of air
Ω	Angular velocity of rotor disk
$\overline{z}$	Nondimensional z-coordinate, compare equation (7)
ρ	Density
σ_{ij}	Stresses in the rotor disk

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