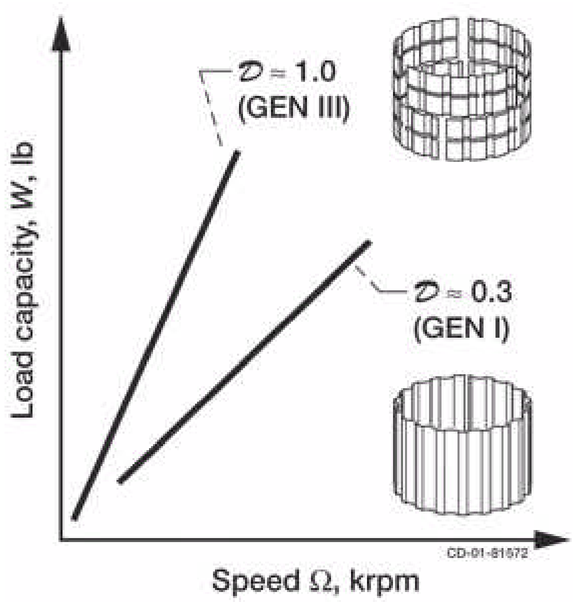
Mystery of Foil Air Bearings for Oil-Free Turbomachinery Unlocked: Load Capacity Rule-of-Thumb Allows Simple Estimation of Performance



Foil bearing load capacity is enhanced by higher complexity in the elastic support (springs) structure. $W = \mathcal{D}(L \times D)(D \times \Omega)$, where W is the maximum steady-state load that can be supported (N, lb), $\mathcal{D}$ is the bearing load capacity coefficient (N/mm^3-krpm, lb/in.^{3}-krpm), L is the bearing axial length (mm, in.), D is the shaft diameter (mm, in.), and Ω is the shaft speed in 1000 rpm (krpm).

Long description: This figure graphically shows that a linear relationship exists between the foil bearing load capacity and the bearing speed and that the slope (load capacity performance) increases with the level of the design complexity of the foil elastic support (spring) structure.

The Oil-Free Turbomachinery team at the NASA Glenn Research Center has unlocked one of the mysteries surrounding foil air bearing performance. Foil air bearings are self-acting hydrodynamic bearings that use ambient air, or any fluid, as their lubricant. In operation, the motion of the shaft's surface drags fluid into the bearing by viscous action, creating a pressurized lubricant film. This lubricating film separates the stationary foil bearing surface from the moving shaft and supports load. Foil bearings have been around for decades and are widely employed in the air cycle machines used for cabin pressurization and cooling aboard commercial jetliners. The Oil-Free Turbomachinery team is fostering the maturation of this technology for integration into advanced Oil-Free aircraft engines. Elimination of the engine oil system can significantly reduce weight and cost and could enable revolutionary new engine designs. Foil bearings, however, have complex elastic support structures (spring packs) that make the prediction of bearing performance, such as load capacity, difficult if not impossible.

Researchers at Glenn recently found a link between foil bearing design and load capacity performance. The results have led to a simple rule-of-thumb that relates a bearing's size, speed, and design to its load capacity. Early simple designs (Generation I) had simple elastic (spring) support elements, and performance was limited. More advanced bearings (Generation III) with elastic supports, in which the stiffness is varied locally to optimize gas film pressures, exhibit load capacities that are more than double those of the best previous designs. This is shown graphically in the figure. These more advanced bearings have enabled industry to introduce commercial Oil-Free gas-turbine-based electrical generators and are allowing the aeropropulsion industry to incorporate the technology into aircraft engines. The rule-of-thumb enables engine and bearing designers to easily size and select bearing technology for a new application and determine the level of complexity required in the bearings. This new understanding enables industry to assess the feasibility of new engine designs and provides critical guidance toward the future development of Oil-Free turbomachinery propulsion systems.

Find out more about this research http://www.grc.nasa.gov/WWW/Oilfree/.

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