A bearing test stand to represent E-VTOL air-screw loads in vertical and forwards flight.

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Abstract: The aerospace sector is currently seeing a rapid growth of interest in electrically propelled light aircraft for use as air-taxis, public service vehicles or private craft [1]. Many of these vehicles fall into either the Electric Vertical Take-Off and Landing (E-VTOL) or tilt-rotor categories. These types of multi-rotor craft can impose very severe loading cases on their propulsion machinery. Many present designs mitigate the direct mechanical loading of electrical machine components by inclusion of a gearbox, but this adds both mass and complexity.

The difficulty arises from the use of fixed-pitch fans for small distributed propulsion craft. These induce a cyclical combined axial, radial and bending moment about the shaft end at the blade pass frequency when vertically oriented in forwards flight. This phenomenon is known as blade 'flapping' and the advancing blade can generate up to 80% of the lift [2]. When compared to a conventional rotorcraft, the fan speeds for distributed propulsion craft are significantly higher, and typically no feathering mechanism is fitted to control blade 'flapping'. Most bearing designs are arranged to support high loading in either axial or radial directions and solutions for combined loading tend to add either mass or friction. As a result, the majority of bearing test machines focus on loading in a single direction [3] although solutions for combined axial and radial loads [4] and moment loading exist [5].

To fully reproduce the loading experienced by the drive end bearings of an E-VTOL propulsion machine with a directly coupled fixed-pitch propellor would require a loading system with five degrees of freedom, the sixth being shaft rotation. Additionally the bandwidth of actuation would need to be able to accommodate the blade pass frequency in order to replicate cyclical loading. In this study, we present a viable simplification that allows a combined radial and thrust bearing set to be loaded cyclically with combined forcing. The mechanical layout and actuation strategies of such a test-stand, illustrated in Figures 1 and 2, will be discussed, including the possibility of using novel actuation techniques to increase bandwidth [6]. An overview will also be given of the development of an instrumentation system capable of generating training data for prognostics.

Keywords: Wear and friction, Contact mechanics, Test methodologies and measurement technologies, Rotorcraft, Rolling Element Bearings.

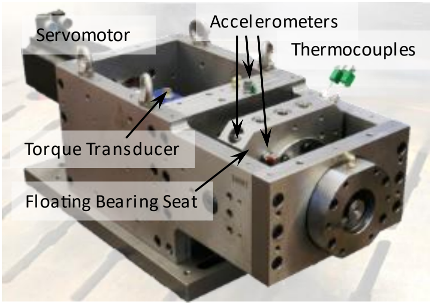

Figure 1: Main chassis of bearing test stand.

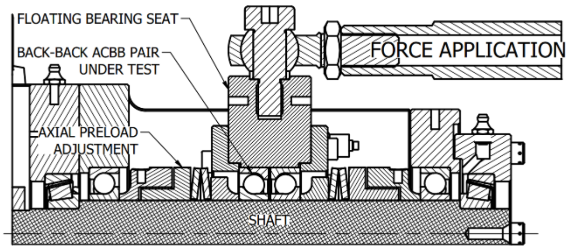

Figure 2: Sectional schematic of bearing loading system.

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