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Towards health monitoring of hybrid ceramic bearings in aircraft starter/generators

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Abstract

On-board electrical power demands in modern aircraft are substantially increasing. Scaling-up the size of the current starter/generators to provide the additional power requirements inevitably increases their mass. Instead, aircraft electrical designers are considering to increase the rotational speed of these machines. This imposes severe loading demands in the current starter/generator bearings. Hybrid bearings offer the most potential to deal with these demands. However, not much is known about their wear behavior in this new application.

Our research is assessing the degradation of hybrid ceramic bearings in the newest generation of starter/generators for condition monitoring and health management. This paper discusses bearing degradation as foundation for the definition of relevant health condition assessment and decision making approach, and the integration of a monitoring system into a prototype test bearing to be used for data generation and algorithm validation. Initial results indicate this approach can effectively diagnose bearings faults. Validation was conducted by using repository data.

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Keywords: healh management; data-fusion; hybrid bearings; starters; generators; diagnosis

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1. Introduction

Driven by higher availability demands and optimization of maintenance tasks, aircraft manufacturers have been gradually adopting health monitoring systems for an increasing number of sub-systems and components. Starter/generators are an important component of aircraft engines; they initiate the engine operation and provide power to other aircraft systems too. Starter/generator bearings are generally replaced at scheduled preventive maintenance intervals. Their health monitoring will help reducing unnecessary maintenance tasks, and optimize maintenance schedules.

Modern aircraft require more on-board electrical power than ever before. Increasing the size of starter/generators to provide these additional requirements inevitably increases their mass. Instead, starter/generators manufacturers are considering increasing their operational speed. The rotational speeds of the newer generation of starter/generators are expected to approach 30,000 rpm. This will impose severe loading demands on the currently employed bearings; which can lead to earlier degradation due to harsher rolling contact fatigue (RCF). Additionally, bearings in starter/generators experience severe operational conditions, e.g., extreme temperature, vibration and electrical interference. In response to these new requirements, bearing designers are turning to hybrid bearings for the newest generation of starter/generators. However, not much is known about hybrid bearings wear behavior in this application.

Hybrid bearings are typically constructed using rolling elements made of a ceramic material such as silicon nitride, running over fatigue resistant steel raceways. Critically, ceramic materials' mass can be up to 60 % lower than that of conventional ball bearings, resulting in lower centrifugal loading and skidding [1]. Some of the most recognized performance benefits of hybrid bearings include [2]: higher rotational speed, longer life, lower heat generation and superior starvation tolerance.

1.1. Research program objectives

The overall objectives of our research are:

1. Identification of relevant condition indicators for health monitoring of hybrid bearings in starter/generators;
2. Assessment of an integrated bearing/monitoring test prototype;
3. Development of algorithms for health assessment and remaining life decisions;
4. Run experimental fatigue life tests for data generation and system validation;
5. Validation of a concept prototype for instrumented starter/generator bearings.

To effectively achieve these objectives, the work is being conducted as part of a European industrial/academic collaboration. Thales AES has initially provided a relevant bearing specification for starter/generators newest generation as a project foundation. Cranfield University is investigating health assessment and decision making algorithms. Active Space Technologies is developing and integrating the bearing test prototype; whereas bearing specialist Barden has specified and supplied the appropriate bearing design for this application. Laboratory fatigue tests and their post-examination will be conducted at Schaeffler's state of the art facilities.

By achieving these objectives, the greater following benefits will be achieved:

- Increased confidence in starter/generator availability;
- Optimised maintenance planning and cost effectiveness;
- Lower mass, leading to lower fuel consumption.

In the present paper, we present the initial developments of the on-going collaborative i-BEARING CleanSky project, funded by the European Commission. The paper structure comprises of a concise literature review covering relevant degradation mechanisms, and approaches to health management. Both, failure mode and effect (FMEA) and performance failure analyses were conducted to substantiate sensor selection and development of health management algorithms. We also present initial diagnosis algorithm validation results.