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Hybrid bearings

Proposed CM-RTS-003 issue 1

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Contents

1. Introduction
2. LoI and change classification
3. Design
4. Strength evaluations, materials and fabrication methods
5. In service monitoring and instructions for continued airworthiness
5. Building block tests approach
6. Conclusions

Note: The text referring to the Proposed CM-RTS-003 Issue 01 is modified/simplified in this presentation for readability purposes.

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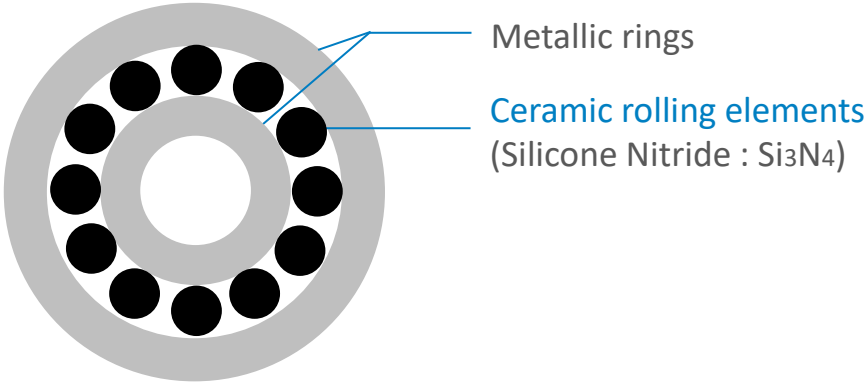
1. Introduction

1. Introduction (1/2)

What is an hybrid bearing ?



How ceramic rolling elements are produced ?

STEP 1
Powder fabrication

STEP 2
Consolidation (sintering)

STEP 3
Finishing (Grinding)

1. Introduction (2/2)

Context for creating the proposed CM-RTS-003 issue 1:

NEW - Currently limited applications using this technology and no specific guidance for certification.

- Service events involving this technology on rotor drive systems / rotor controls.

- Interest of industry to extend this technology to new applications.

Objective of the CM-RTS-003 issue 1:

To provide guidance for the certification of hybrid bearings on rotor drive systems and rotor control mechanisms of CS-27/29 rotorcrafts.

2. LoI and changes classifications

2.1 Level of involvement


Novelty

- Novel, except if the applicant can justify appropriate experience using this technology by similarity to previous certifications.


Complexity

- Usually complex due to the complex behavior and failure modes to be assessed, especially when used in complex systems like gearboxes.


Criticality

- May be critical depending of the application

2.2 Change classification

Major

→ Changes affecting hybrid bearings identified as:

- critical parts (for critical characteristics) and/or
- PSEs and/or
- having hazardous or catastrophic failure consequences as per design assessments (when applicable)

→ Changes affecting rotor drive system and control mechanism endurance tests

Minor

→ All other cases not classified as Major

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3. Design

3.1. Failure modes (1/2)

Applicable requirements: CS 27.601(b), .602, .927(a) ; CS 29.547(b), .601(b), .602, .917(b), .927(a)

Background: Complete and quick failures of silicon nitride rolling elements of hybrid bearings have been observed. in two main categories:

1. When the rolling elements are subjected to excessive tensile and/or shear stress. (see examples)
2. When the hybrid bearings are running in gearboxes in loss of lubrication conditions with power

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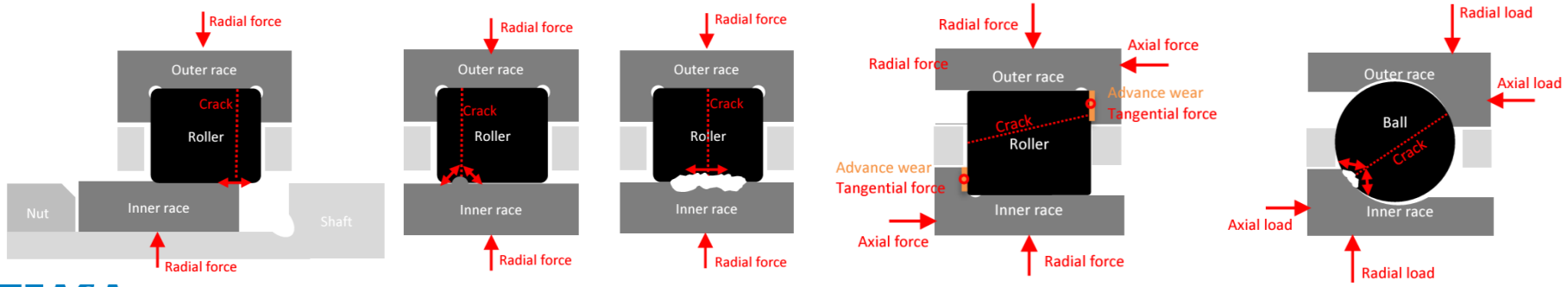
Examples: Some cases where excessive tensile and/or shear stress on rolling elements could be reached:



3.1. Failure modes (2/2)

Guidance for certification:

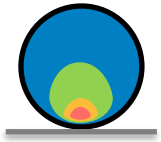
A proper understanding of all potential failure modes of hybrid bearings is needed to determine the failure consequences in the frame of:

- design assessments and/or
- parts classifications (e.g. identification of critical parts and/or principle structural elements).

Sufficient testing should be carried out to fully characterize the failure modes, accounting for potential scatter.

For design assessments, the applicant should pay particular attention to the definition of compensating provisions associated to quick and complete failures of hybrid bearings.

3.2. Contact pressures



Applicable requirements: CS 27.601(b), .927(a) ; CS 29.601(b), .927(a)

Guidance for certification:

When contact pressures are higher than the ones usually seen on conventional steel bearings, the hybrid bearing design might be questionable.

Such cases should require additional tests to demonstrate the suitability and compliance of the design.

3.3. Temperature effects

Applicable requirements: CS 27.571, .601(b), .927(a) ; CS 29.571, .601(b), .927(a)

Background:

Different thermal expansion coefficients of steel VS ceramic.

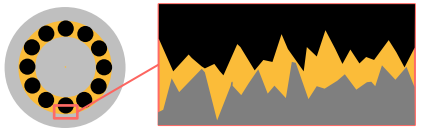
Low thermal conductivity of ceramic

Guidance for certification:

The applicant should determine that the bearing function is not impaired as a result of the change of internal clearances of hybrid bearings as a function of operating temperatures.

This may require tests to assess the bearing behaviour under minimum and maximum clearances and/or preloads accounting for drawings allowable and operating conditions.

3.4. Mixed lubrication



Applicable requirements: CS 27.601(b), .927(a) ; CS 29.601(b), .927(a)

Guidance for certification:

In case it is identified that hybrid bearings may run in mixed lubrication mode with lower lambda ratio than usual, additional tests may be needed to assess the bearing's reliability.

Note: The surface roughness should be well chosen to avoid mixed lubrication conditions as this may result in early degradations of the bearings.

3.5. Loss of lubrication

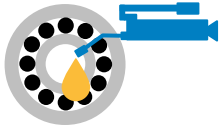
Applicable requirements: CS 27.927(c) ; CS 29.927(c)

Guidance for certification:

Applications for which loss of lubrication conditions with power needs to be addressed will require deep investigations and research to understand the failure modes to propose appropriate designs.

The use of reduction factors to determine the maximum period of operation following loss of lubrication based on test results, proposed in AMC1 29.927(c),(f)(2), is not demonstrated to be appropriate for hybrid bearings. Therefore, the applicant should determine appropriate reduction factors when using hybrid bearings.

3.6. Greased bearings



Applicable requirements: CS 27.927(a), .1529 ; CS 29.927(a), .1529

Guidance for certification:

Due to the particular sensitivity of hybrid bearings to temperature (affecting clearances/preload), the applicant should pay particular attention to the impact of grease quantity on bearing's behaviour.

This may require additional tests and should account for minimum and maximum grease quantity allowed (from production and from regreasing when applicable).

The evaluation of grease life and bearing performance demonstration may require additional tests, potentially with

- pre-degraded/aged grease, and
- contaminated grease with ceramic particles.

The results of these evaluations should support the definition of the ICAs.

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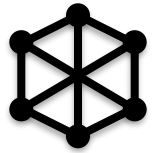
4. Strength evaluations, materials and fabrication methods

4.1. Rolling contact fatigue

Applicable requirements: CS 27.571 ; CS 29.571

Guidance for certification: Rolling contact fatigue should be considered as part of the fatigue evaluation also for hybrid bearings in line with AMC1 27.571 or AMC1 29.571, as applicable.

4.2. Material class and geometrical grades



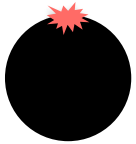
Applicable requirements: CS 27.571, .601(b), .602, 603, .605, .927(a) ; CS 29.571, .601(b), .602, 603, .605, .927(a)

Guidance for certification:

The selection of material class and geometrical grades (See Note hereafter) for bearing rolling elements should be carefully evaluated to demonstrate that the design is suitable for the application.

Note: For critical bearings, common design practices include the use of material class 1 and grades 10 to 16 (or better) for rolling elements (as per ASTM F2094 / ASTM F2730). In addition, for critical bearings running in challenging conditions (e.g., high contact pressures, low oil film thickness…), the need to use better grades than 10 to 16 should also be evaluated as this may be needed to ensure an adequate bearing performance.

4.3. Surface defects



Applicable requirements: CS 27.571, .602, .603, .605 ; CS 29.571, .602, .603, .605

Guidance for certification:

Production/quality processes and controls applied to rolling elements should be appropriately defined and justified, to ensure appropriate material characteristics and surface properties.

Particular attention should be paid by applicants to the sintering, handling and finishing processes used on ceramic rolling elements to avoid finishing marks and cracks.

Visual inspections, fluorescent penetrant inspection or other NDI techniques could be used to detect surface defects.

When visual inspections are retained as a means of defect detection, the applicant should consider human factor errors and implement appropriate mitigation measures (e.g. double visual inspections, NDI techniques).

Fatigue evaluation should account for acceptable flaws and non-detectable flaws.

4.4. Sub-surface defects

Applicable requirements: CS 27.571, .602, .603, .605, .927(a) ; CS 29.571, .602, .603, .605, .927(a)

Guidance for certification:

Production/quality processes (e.g. ceramic powder screening, batch sampling destructive tests according to ASTM 2094 and 2730) and controls (e.g. X-ray, radiography), should be appropriately defined and justified to ensure appropriate material characteristics and sub-surface properties.

Fatigue evaluation should account for acceptable flaws and non-detectable flaws.

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5. In service monitoring and ICAs

5.1. Monitoring systems (1/2)

Applicable requirements: CS 27.1337(e), .1529 ; CS 29.547(b), .917(b), .1337(e), .1465, .1529

Background:

The spalling generated from a ceramic rolling element may not systematically transfer to a spalling on the metallic races.

In addition, fatigue evaluations tests and rotor drive system and rotor control mechanism tests do not typically involve the demonstration that these systems can operate with advanced degraded bearings (e.g. with advance spalling or advanced wear).

5.1. Monitoring systems (2/2)

Guidance for certification:

Monitoring means are expected to be implemented and should be demonstrated to be effective, accounting for the different failure modes to be envisaged and associated failure consequences.

The applicant should demonstrate the effectiveness of the monitoring means to avoid bearings running in advanced degraded conditions.

For magnetic chip detection systems, the AMC2 27./29.1337(e) may not be adequate for applications using hybrid bearings. In particular, the amount of ferromagnetic particles to be used to demonstrate the performance of the chip detection system by test needs to be evaluated and defined in accordance with the specific characteristics of the bearing and its operating conditions.

5.2. ICAs

ALS

Applicable requirements: CS 27.1529 ; CS 29.1529

Guidance for certification:

Instruction for continued airworthiness (ICAs) of the bearing identified a critical aspect of ensuring the appropriate levels of safety and reliability, should be recorded within the Airworthiness Limitation Section (Chapter 4) of the rotorcraft maintenance manual.

This may include:

→ retirement times of bearings and/or

→ maintenance intervals (e.g. regreasing intervals) and/or

→ inspection intervals (e.g. sensitivity check intervals),

5.3. CIVP

Applicable requirements: CS 27.602 ; CS 29.602

Guidance for certification: A CIVP should be considered to ensure the continued validity of assumptions made during certification of hybrid bearings as per applicable EASA policy on CIVP.

6. Building block tests approach

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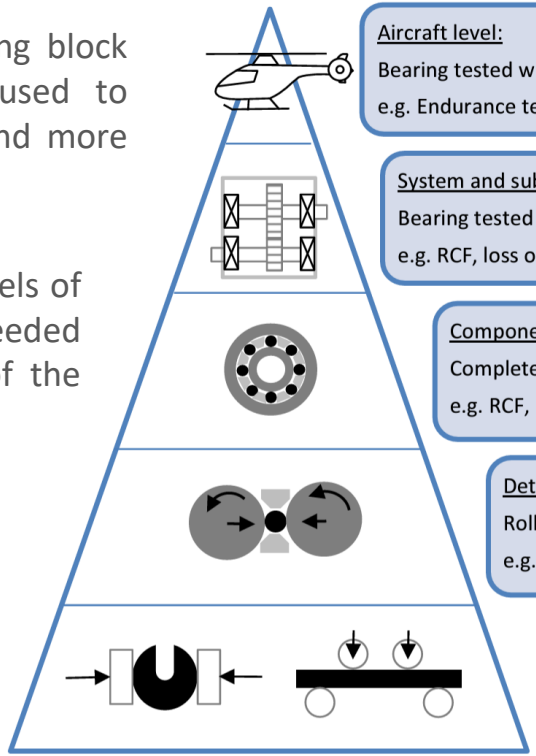
A building block tests approach could be used as a mean to evaluate the performance and failure modes of bearings:

The higher-level tests of a building block approach are expected to be used to perform evaluations in a more and more representative environment.

Correlations between different levels of building block approach may be needed to demonstrate the robustness of the building block approach.

The lower-level tests of a building block approach are expected to be used to provide statistical basis, sensitivity, and variability.



Aircraft level:
Bearing tested within the aircraft of application.
e.g. Endurance tests on tie-down helicopter, thermal survey in flight

System and subsystem level:
Bearing tested within the system or subsystem of application.
e.g. RCF, loss of lubrication, long endurance tests on gearboxes

Component level:
Complete bearing tested in simplified environment.
e.g. RCF, loss of lubrication tests on bearings

Details level:
Rolling elements tested with representative races and/or cage
e.g. RCF, lubricant performance on “simplified bearings”

Coupon and elements level:
Tests using raw material
e.g. Tests on notched rolling elements for strength properties

7. Conclusions

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Although **EASA did not identify the need for new requirements** for the certification of hybrid bearings within rotor control mechanisms and rotor drive systems, the certification of these items **may be challenging and request additional effort** compared to conventional bearings, in particular for the following topics:

- Evaluating the failure modes, including complete and quick failures of silicon nitride rolling elements
- Evaluating the performance in loss of lubrication (for bearings of pressurized gearboxes)
- Evaluating the effects of temperature variations
- Quality controls in production, as the potential good performance of hybrid bearings is highly dependent on almost defect free ceramic rolling elements
- Monitoring in service (for bearings inside gearboxes, as chip detection alone may not be sufficient)

The **certification effort** also depends on:

- the "criticality" of the bearing (e.g. PSE, critical part)
- the existing knowledge and experience of the applicant using this technology
- the type of hybrid bearing used (e.g. balls, duplex balls, rollers, tapered roller bearing)
- the locations of the bearing (e.g. inside gearboxes)
- the means for lubrication of the bearing (e.g. oil lubricated, greased lubricated)

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