Notification of a Proposal to issue a Certification Memorandum

Turbine Engines – High Pressure Turbine Shaft Loss of Load and Rotor Integrity

EASA CM No.: Proposed CM–PIFS-017 Issue 01 issued 31 July 2020

Regulatory requirement(s): See table in Paragraph 1.2

In accordance with the EASA Certification Memorandum procedural guideline, the European Union Aviation Safety Agency proposes to issue an EASA Certification Memorandum (CM) on the subject identified above. All interested persons may send their comments, referencing the EASA Proposed CM Number above, to the e-mail address specified in the "Remarks" section, prior to the indicated closing date for consultation.

EASA Certification Memoranda clarify the European Aviation Safety Agency's general course of action on specific certification items. They are intended to provide guidance on a particular subject and, as non-binding material, may provide complementary information and guidance for compliance demonstration with current standards. Certification Memoranda are provided for information purposes only and must not be misconstrued as formally adopted Acceptable Means of Compliance (AMC) or as Guidance Material (GM). Certification Memoranda are not intended to introduce new certification requirements or to modify existing certification requirements and do not constitute any legal obligation.

EASA Certification Memoranda are living documents into which either additional criteria or additional issues can be incorporated as soon as a need is identified by EASA.

Log of issues

Issue	Issue date	Change description
01	31.07.2020	First issue.

Table of Content

1. Introduction

1.1. Purpose and scope

The purpose of this Certification Memorandum is to provide additional guidance to the Applicant when complying with CS-E 840 (c) and CS-E 850 (a)(3) & (b)(2) for a High Pressure Turbine (HPT) shaft. In particular the criteria defined by CS-E 850 (b)(2)(i) thru (v) are further clarified, and additional guidance is provided to demonstrate that the failure of certain elements of the HPT shaft are predicted to occur at a rate not in excess of Extremely Remote.

1.2. References

It is intended that the following reference materials be used in conjunction with this Certification Memorandum:

Reference	Title	Code	Issue	Date of entry into force
CS-E 25	Instructions for Continued Airworthiness	CS-E	6	24 June 2020
CS-E 510	Safety Analysis	CS-E	6	24 June 2020
CS-E 515	Engine Critical Parts	CS-E	6	24 June 2020
CS-E 520	Strength	CS-E	6	24 June 2020
CS-E 650	Vibration Surveys	CS-E	6	24 June 2020
CS-E 840	Rotor Integrity	CS-E	6	24 June 2020
CS-E 850	Compressor, Fan and Turbine Shafts	CS-E	6	24 June 2020

1.3. Abbreviations

ALS	Airworthiness Limitation Section
CM	Certification Memorandum
ESF	Equivalent Safety Finding
FMECA	Failure Modes, Effects and Criticality Analysis
HPT	High Pressure Turbine
ICA	Instructions for Continued Airworthiness
TC	Type Certificate

1.4. Definitions

Shaft System	See applicable item of Table 1 in paragraph 3.1 of this CM

2. Background

2.1. CS-E 840 and CS-E 850 Specifications

When determining the operating conditions applicable for rotor overspeed, CS-E 840 Rotor Integrity requires to evaluate the loss of load of the turbine rotor(s):

> *(c) The highest over-speed which will result from a complete loss of load on a turbine rotor, unless it can be shown to be Extremely Remote under the provisions of CS-E 850, must be included in the over-speeds considered under each of CS-E 840(b)(3)(i), (ii) and (b)(4), irrespective of whether it is the result of a Failure within the Engine or external to the Engine.*

As seen above, CS-E 840 (c) allows to exclude this evaluation when the loss of load can be shown to be Extremely Remote. The relevant provisions of CS-E 850 Compressor, Fan and Turbine Shafts are extracted below:

> *(a) Objectives.*
>
> > *(1) It must be demonstrated that Failures of the shaft systems will not result in Hazardous Engine Effects, except as provided in CS-E 850(a)(3).*
> >
> > *…*
> >
> > *(3) If compliance with the objective of CS-E 850(a)(1) is not achieved for certain elements of a shaft, it must be shown that Failures of these elements are predicted to occur at a rate not in excess of that defined as Extremely Remote.*
>
> *(b) Compliance.*
>
> > *…*
> >
> > *(2) Hazardous Shaft Failures. In complying with CS-E 850(a)(3), the Failure rate of certain elements of shaft systems will be accepted as Extremely Remote if: -*
> >
> > – *Paragraphs (i) through (v)*

2.2. EASA ESF E-07 on CS-E 840 and CS-E 850

In December 2012, EASA published for public consultation a Proposed Equivalent Safety Finding (ESF) on CS-E 840/850 – Rotor Integrity/Shafts in order to accept, if sufficiently substantiated, exclusion of the whole or part of the High Pressure Turbine (HPT) shaft from failure considerations when determining the terminal high pressure turbine rotor speed in the event of a complete loss of load event. Following the publication of the Comment Response Document (CRD), the ESF was adopted[1].

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[1] ESF on CS-E 840/850 – Rotor Integrity/Shafts, published in December 2012. For record purposes, this ESF is considered to be Issue 1 of EASA ESF E-07.
Note: The CRD did not modify the Proposed ESF, which is considered Final.

ESF CS-E 840-850 Dec2012   CRD ESF CS-E 840-850

Proposed ESF : https://www.easa.europa.eu/sites/default/files/dfu/certification-docs-esf-ESF-on-CS-E-840-%26-850.pdf
CRD : https://www.easa.europa.eu/sites/default/files/dfu/certification-docs-esf-CRD-to-ESF-on-CS-E-840_850.pdf

Since EASA published this ESF, other authorities took similar approaches for accepting such exclusions of HPT shaft elements from the failure considerations described above. However some specific or additional provisions were introduced by these authorities within their regulatory framework, which in some cases were not fully harmonised with the EASA ESF.

2.3. The Propulsion Industry/Authority Working Group (AIA Advisory Group)

In the past years applicants have improved their understanding of the behaviour of turbine engines following shaft failure, notably using modern simulation tools validated through engine testing and/or actual events.

A propulsion industry/authority working group has reviewed the provisions contained in both CS-E and CFR Part 33 on this topic, considered the various publications described above, and recommended improvements to clarify and harmonise the way compliance should be shown with the applicable certification specifications.

On 13 May 2019, the working group issued a report entitled "Guidance on exclusion of a High Pressure Turbine (HPT) shaft element, section, or system from failure consideration in determining the terminal High Pressure Turbine rotor speed in the event of a complete loss of load event". This report is included in Annex 1 of this CM.

3. EASA Certification Policy

3.1. Guidance on exclusion of a High Pressure Turbine (HPT) shaft element from failure consideration in determining the terminal High Pressure Turbine rotor speed in the event of a complete loss of load

In view of the above, EASA considers that the guidance material released by the industry/authority working group, as included in Annex 1 of this CM, is appropriate.

This guidance should be used by applicants when showing compliance with CS-E 840 (c), CS-E 850 (a)(3) & (b)(2), or when proposing an Equivalent Safety Finding such as ESF E-07 (referred in paragraph 2.2 of this CM) for an HPT shaft, in complement to AMC E 840 and AMC E 850, when excluding HPT shaft element from failure consideration in determining the terminal HPT rotor speed in the event of a complete loss of load event.

Table 1 lists the items that should be assessed for the excluded shaft elements, the corresponding paragraph and page number in the report in Annex 1 of this CM, and additional comments or clarifications where necessary.

Table 1

Items to be assessed when excluding HPT shaft element from failure consideration in determining the terminal HPT rotor speed in the event of a complete loss of load event

Item / Paragraph of the Report in Annex 1 of this CM	**Report Page #**	**Comments**
Definition of a Shaft System	3 & Appx 5	Provides definition of a shaft system and examples for different rotor architectures
Assessments as part of the Engineering Plan		
Fatigue and Damage Tolerance	7-9	Complementary guidance to CS-E 515 and AMC E 515 for lifing process and life debit for the excluded shaft elements
Additional Guidance on Fatigue and Damage Tolerance Assessments	9-11	Assessment of loadpath components and crack propagation analysis to select or exempt locations from enhanced fatigue and damage tolerance assessment
Low Pressure or High Pressure spool imbalance	11-12	Complementary guidance to CS-E 650 for the excluded shaft elements
Rub/contact with adjacent components	12-13	Considerations of shaft areas subject to contact or rubs with adjacent parts
Shaft overload conditions – Torsional, Axial, and Bending	13	Complementary guidance to CS-E 520 for imbalance and ultimate loads
Bearing failures	13-14	Considerations of mechanisms, rates and consequences of bearing failures
Over-temperature (Overheating)	14	Considerations of failure scenarios leading to over-temperature of the shaft
Internal oil leaks and fires	14-15	Assessment of risks of internal fires from combustible fluids in the shaft FMECA (ref. CS-E 510)
Failure of Combustion Systems	15	Assessment of combustion system failure in the shaft FMECA (ref. CS-E 510)
Oscillatory loading from fuel flow instability or other aero-mechanical and vibratory resonant interactions	16	Consideration of vibratory resonances of shaft systems due to resonances with fuel system control natural frequencies or instabilities (ref. CS-E 650)
Loss of spline lubrication	16	Assessment of loss of lubrication of spline or other mechanical torque coupling feature in the shaft FMECA (ref. CS-E 510)
Assessments as part of the Manufacturing Plan		
Improper assembly of the shaft system or damage to the shaft from the assembly process	16	Complementary guidances to the Manufacturing Plan of the shaft for the excluded elements (ref. CS-E 515 and AMC E 515)
Manufacturing tolerances	16-17	
Assessments as part of the Service Management Plan		
In service and environmental assessments	17	Complementary guidance to the Service Management Plan of the shaft for the excluded elements (ref. CS-E 515 and AMC E 515)

3.2. Instructions for Continued Airworthiness

Any life limitation or maintenance action established following the assessment performed in paragraph 3.1 of this CM should be reviewed and, where applicable, recorded in the Airworthiness Limitations Section (ALS) of the Instructions for Continued Airworthiness (ICA) in accordance with CS-E 25.

3.3. Who this Certification Memorandum affects

This Certification Memorandum affects applicants for new turbine engine Type Certification (TC) when showing compliance with CS-E 840 (c) and CS-E 850 (a)(3) and (b)(2), as well as significant major changes to TCs (per point 21.A.101 of Part-21) of turbine engines where the affected areas include HPT shaft elements sought for exclusion from loss of load considerations.

4. Remarks

1. This EASA Proposed Certification Memorandum will be closed for public consultation on the 11th of September 2020. Comments received after the indicated closing date for consultation might not be taken into account.
2. Suggestions for amendment(s) to this EASA Certification Memorandum should be referred to the Certification Policy and Planning Department, Certification Directorate, EASA. E-mail CM@easa.europa.eu.
3. For any question concerning the technical content of this EASA Certification Memorandum, please contact:
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Annex 1 to Proposed CM-PIFS-017 Issue 01

Guidance on exclusion of a High Pressure Turbine shaft element, section, or system from failure consideration in determining the terminal High Pressure Turbine rotor speed in the event of a complete loss of load event

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AIA CARS Committee *(*)*
Propulsion Subcommittee
Advisory Working Group
Loss of Load and Overspeed (14 CFR §33.27)

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Issued on 13 May 2019

Annex 1a AIA HPT Shaft Loss of Load May2019

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Annex 1b Appendix 5 in AIA Report

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(*) Aerospace Industries Association – Civil Aviation Regulatory and Safety Committee

(**) In reference to the "Confidential" note on cover page of the document included in this Annex, EASA received on 22 July 2020 the clearance from AIA CARS to include the report in an EASA public CM.

(***) Note for Appendices of the AIA report :

- *Appendix 4 "Data Collection Summary" is not deemed necessary to be included for the purpose of this CM*
- *Appendix 5 "Shaft Definition" is provided herein*