



Comment-Response Document 2014-03

Engine Vibration Surveys

CRD TO NPA 2014-03 — RMT.0176 (E.004) — 12.3.2015

Related Decision 2015/009/R

EXECUTIVE SUMMARY

The aim of rulemaking task RMT.0176 is to address a clarity-of-rules/economic issue related to compliance with CS-E 650 Vibration Surveys.

This update was mainly triggered by the practical difficulties related to compliance with CS-E 650. CS-E 650 and AMC E 650 have been updated in order to both clarify and reflect the current certification practice. Certain prescriptive requirements in the rule have been moved to the AMC, but the scope and intent of the rule has not been changed. The AMC has been reorganised and expanded. Links with the other requirements have been updated.

These changes are expected to maintain safety, reduce regulatory burden and increase cost-effectiveness.

This Comment-Response Document (CRD) contains the comments received on NPA 2014-03 (published on 5 February 2014) and the responses provided by the Agency.

AMC E 650 has been updated based on the comments received. These updates consist of clarifications, corrections or addition of Guidance Material (GM), while the main principles and substance of the AMC have been maintained. A summary of the main comments, responses, and AMC changes is provided in Chapter 2 of this CRD.

Decision 2015/009/R has been developed taking into account the comments and responses in this CRD.

Applicability		Process map	
Affected regulations and decisions:	ED Decision 2003/009/RM; CS-E 650.	Concept Paper:	No
Affected stakeholders:	Turbine Engine manufacturers.	Rulemaking group:	No
Driver/origin:	Legal obligation (clarity of rules); cost effectiveness;	RIA type:	Light
Reference:	Non applicable.	Technical consultation during NPA drafting:	Yes
		Publication date of the NPA:	5.2.2014
		Duration of NPA consultation:	3,5 months
		Review group:	No
		Focussed consultation:	No
		Publication date of the Opinion:	N/A
		Publication date of the Decision:	2015/Q1

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1. Procedural information

1.1. *The rule development procedure*

The European Aviation Safety Agency (hereinafter referred to as the 'Agency') developed this Comment-Response Document (CRD) in line with Regulation (EC) No 216/2008¹ (hereinafter referred to as the 'Basic Regulation') and the Rulemaking Procedure².

This rulemaking activity is included in the [Agency's Rulemaking Programme](#), under RMT.0176 (E.004). The scope and timescale of the task were defined in the related Terms of Reference (see process map on the title page).

The draft CS/AMC changes have been developed by the Agency with the support of the stakeholders-led drafting group for RMT.0176 (E.004).

All interested parties were consulted through NPA 2014-03³, which was published on 5 February 2014. 35 comments were received from interested parties, including industry and National Aviation Authorities (NAAs).

The process map on the title page contains the major milestones of this rulemaking activity.

1.2. *The structure of this CRD and related documents*

This CRD provides a summary and the full set of individual comments received on NPA 2014-03 and responses thereto. The resulting text is provided with the ED Decision amending CS-E.

¹ Regulation (EC) No 216/2008 of the European Parliament and of the Council of 20 February 2008 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC (OJ L 79, 19.3.2008, p. 1).

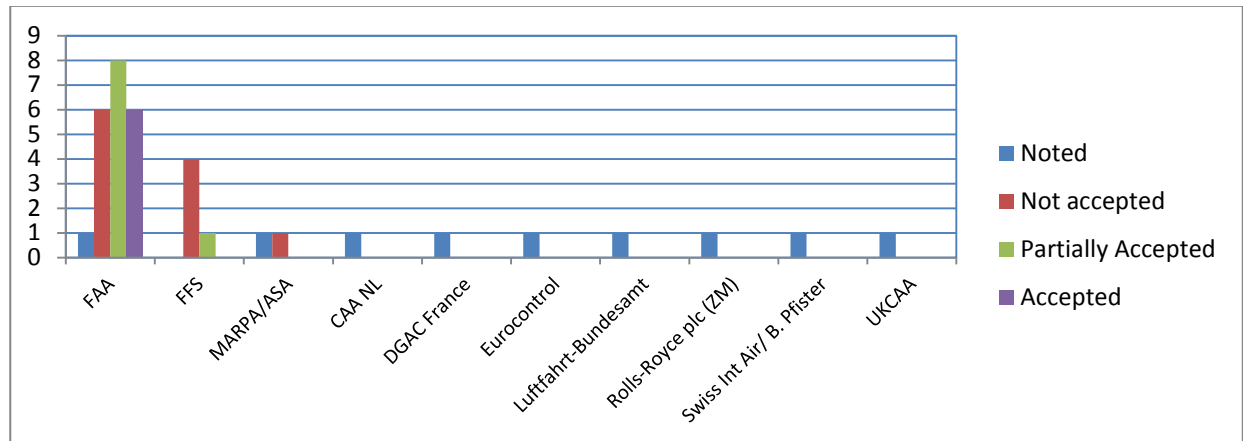
² The Agency is bound to follow a structured rulemaking process as required by Article 52(1) of the Basic Regulation. Such process has been adopted by the Agency's Management Board and is referred to as the 'Rulemaking Procedure'. See Management Board Decision concerning the procedure to be applied by the Agency for the issuing of Opinions, Certification Specifications and Guidance Material (Rulemaking Procedure), EASA MB Decision No 01-2012 of 13 March 2012.

³ <http://www.easa.eu.int/rulemaking/r-archives.php#npa>



2. Summary of comments and responses

There were 35 comments received from 10 commenters. The distribution of the comments and the Agency's overall disposition status are reflected in the table below:



The majority of the comments have been submitted by the FAA. Some of the comments are interconnected; therefore, the responses provided may include references to responses provided to other comments.

The comments below do not constitute an exhaustive list of the topics addressed. The full list of comments and responses is provided in Chapter 3.

FAA Comment No. 15 has led to additional clarification of the concept of similarity. See the text added to the AMC E 650 paragraph (14)(a) 'Baseline test' and paragraph (14)(b)(ii) 'Use of validated analysis'.

As a result of the FAA Comment Nos. 15 and 21 on the boundaries for the application of the validated analysis as a means to supplement testing, the proposed text has been changed to better establish these bounds. Therefore, AMC E 650 paragraph (14)(b)(i) 'Development of the validated analysis' defines better typical design characteristics and operating conditions which may constitute the domain of applicability of the validated analysis. More specifically, the following were added:

- Engine architecture: The number, location and type of bearings were supplemented by the concept of installation and associated support structures.
- Details on the structural dynamic characteristics, aeroelastic characteristics and sources of vibratory excitations and forcing strength.
- Clarifications on 'Operating conditions'.

As a result of the FAA Comment No. 28 on the presence of flutter, AMC E 650 paragraph (8)(a) 'Flutter' has been amended to add that 'the resulting vibration stresses must always satisfy the requirements of CS-E 650 (f)'.

FAA Comment No. 29 required clarification that the engine model for which the validated analysis was shown, to be sufficiently similar to those of the engine model being certified, and that the demonstrated domain of applicability for the validated analysis should be inclusive of the engine being certified. Text has been added to AMC E 650 paragraph (14)(a) to clarify these two issues.



In the definitions section of the AMC E 650, the 'Module' definition has been clarified and improved. (See Comment No. 1 from Francis Fagegaltier Services).

Various other comments have been accepted or partially accepted to improve the text.

A summary of the changes made compared to the text proposed in the NPA 2014-03 is provided in the 'Engine Vibration Survey' Section of the Explanatory Note of the Decision [2015/XXX/R](#) on 'CS-E Amendment 4.



3. Individual comments (and responses)

In responding to comments, a standard terminology has been applied to attest the Agency's position. This terminology is as follows:

- (a) **Accepted** — The Agency agrees with the comment and any proposed amendment is wholly transferred to the revised text.
- (b) **Partially accepted** — The Agency either agrees partially with the comment, or agrees with it but the proposed amendment is only partially transferred to the revised text.
- (c) **Noted** — The Agency acknowledges the comment but no change to the existing text is considered necessary.
- (d) **Not accepted** — The comment or proposed amendment is not shared by the Agency.

(General Comments)	-
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comment	7	<p>We have no comment to this NPA, however we regret that the FAA will not make the same change and stays harmonised. We agree with the conclusion that when this is already current practice it will not bring any practical disadvantage.</p>	comment by: <i>CAA-NL</i>
response	Noted		
comment	8	<p>The EUROCONTROL Agency does not have any comment on NPA 2014 - 03.</p>	comment by: <i>EUROCONTROL</i>
response	Noted		
comment	9	<p>The LBA has no comments on NPA 2014-03.</p>	comment by: <i>Luftfahrt-Bundesamt</i>
response	Noted		
comment	10	<p>Please be advised that the UK CAA do not have any comments on NPA 2014-03, Engine Vibration Surveys.</p>	comment by: <i>UK CAA</i>
response	Noted		
comment	11	<p>Rolls-Royce plc thank EASA for the opportunity to be involved in the industry working group activity developing this NPA and fully support the changes proposed to CS-E 650 and AMC E 650.</p>	comment by: <i>Rolls-Royce plc (ZM)</i>



response	Noted
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General comments	p. 1-2
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comment	6	comment by: <i>DGAC France</i>
	DGAC France supports the general objectives if this NPA.	

response	Noted
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comment	12	comment by: <i>Swiss International Airlines / Bruno Pfister</i>
	Swiss Intl Air Lines take note of the NPA 2014-03 as being relevant to OEMs.	

response	Noted
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2. Explanatory Note	p. 4-7
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comment	13	comment by: <i>Francis Fagegaltier Services</i>
	<p>The statement found in §2.1 of explanatory note is quite surprising. The wording "vibration surveys" had been specifically used to avoid mandating an engine test ! Simply based on the definition of the English word "survey", it had been thought that the intent was clear enough.</p> <p>This was reminded in the current AMC E 650 §(2)</p> <p><i>"Analyses should be conducted to identify the Engine components whose vibration characteristics require verification by Engine test or by other means shown to be equivalent or more appropriate."</i></p>	

response	Not accepted
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	<p>The term 'Vibration Survey' was found to have been interpreted in different ways in the past. AMC E 650 (1) 'Definitions' now clearly defines the term 'Vibration Survey' for the purpose of CS-E 650.</p>	
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comment	14	comment by: <i>FAA</i>
	<p>Paragraph 2.4.21 EASA-FAA harmonization</p> <p>The engine vibration requirements of § 33.83 and CS-E 650 were harmonized in 1996. The proposed CS-E 650 and AMC E 650 will result in de-harmonization with corresponding § 33.83 and AC33-83A. As prescribed by the proposed rule and AMC, the concept of validated analysis differs relative to how the FAA regulation has been interpreted and applied since harmonization. The differences associated with introduction of analysis are significant.</p>	

response	Noted
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The Agency considers that the scope and intent of the FAA AC 33-83A 'Turbine Engine Vibration Test' and of the amended AMC E 650 remain the same. Sections 2.4.17 to 2.4.20 of the NPA support the Agency's statement in Section 2.4.21 which concludes that loss of harmonisation is minimal.

comment

15

comment by: FAA

Paragraph 2.4 Overview of the proposed amendments

The Preamble covers historical perspective, confirms that CS-E 650 is an engine test based rule, identifies shortcomings with trying to meet the rule as written, introduces validated analysis as a means to supplement engine testing, raises concerns with setting bounds on application of validated analysis, and acknowledges the need for regulatory judgment in maintaining realistic bounds for the analysis. Where it falls short is:

- Explaining that analysis must be tied to engine and/or module level tests having hardware and operating conditions sufficiently similar to the certification engine
- Explaining the critical requirements and limitations in the "domain of applicability" for analysis

While the intent is to make the revised rule less prescriptive and provide guidance to the applicant on prescriptive requirements in the AMC, the revisions to the AMC do not fully close key gaps opened by generalizing the rule.

response

Partially accepted

1st bullet — The concept of validated analysis is explained in Section 2.4.17. The amended AMC E 650(14) defines the baseline test(s) and the development and use of the validated analysis. The domain of applicability, fully part of the validated analysis, ensures that hardware design and operating conditions of the product to be certified are sufficiently similar to previously tested and certified designs. Additional clarification on similarity has been added in the amended AMC E 650(14)(a) and (b)(ii) in response to this comment.

2nd bullet and last paragraph — The domain of applicability of the validated analysis includes specifically design characteristics and operating conditions which are listed in the amended AMC E 650(14)(b)(i). This paragraph has been expanded to better address flutter in response to this comment and Comments 21, 22 and 23. The domain of applicability constitutes the basis of these 'critical requirements and limitations' which close the gaps with the baseline test(s). Adding further and more specific prescriptive requirements is not deemed to bring additional benefits.

comment

16

comment by: FAA

Paragraph 2.4 Overview of the proposed amendments

The NPA notes that CS-E 650 is intended to be an engine test that demonstrates the acceptability of the hardware being certified and states that it is not always feasible to meet the required test parameters at sea level test stand conditions, even after making significant modifications to the type design configuration. To address this, the NPA introduces validated



	<p>analysis as a means to allow testing of a type design engine (or as near type design as possible) and filling gaps by a combination of analysis and alternate tests (rig and module). Care must be taken in revising the rule and guidance to ensure that broadening the means of compliance retains the intended rigor. For example, if the baseline testing is not grounded to an engine test using similar hardware, it will be difficult for the applicant to make the significant response and dwell acceptability determinations laid out in the proposed AMC section (10), Dwell Testing (current AMC section (7), Resonance Dwell).</p>
response	<p>Not accepted</p> <p>The capability to perform the dwell acceptability determinations laid out in the amended AMC E 650(10) should not be affected by using a validated analysis within its demonstrated domain of applicability. See also response to Comment 15.</p>
comment	<p>17 comment by: FAA</p> <p>Paragraphs 2.4.6 and 2.4.7 Safety recommendation from AAIB</p> <p>The preamble discusses the Air Accidents Investigation Branch (AAIB) safety recommendation 4.16 resulting from investigation of the fatal B737-400/CFM56-3 accident near Kegworth, UK, on January 8, 1989. The safety recommendation's objective was to preclude the potential for engine flutter in the declared operating envelope by recommending amendment of the turbine engine requirements to include "instrumented flight tests". In paragraph 2.4.7 the preamble states that "it would not have been appropriate to introduce a flight test requirement into the engine rules. The intent was to prescribe an engine test that could be conducted at sea level." and concludes that the recommendation was implemented in CS E-650 by adding the corrected speeds requirement. We do not entirely agree with the interpretation above. We agree that corrected speeds were added to address the shortcomings of sea level tests, but a sea level test was not envisioned as the only option. FAA understands the intent was to assure that altitude conditions are represented, but the rule revision did not preclude an applicant from performing altitude tests if that was deemed to be the most appropriate approach. The FAA interpretation of the phrase "instrumented flight test" has been implemented in engine certification by allowing the applicant to select from running a sea level test in a test cell, or an altitude test in a test cell, or an altitude test on an airplane. This intent is captured in the current FAA and EASA guidance for evaluation of altitude effects.</p>
response	<p>Partially accepted</p> <p>It is recognised that sea level test was not intended to be the only option. The final sentence of paragraph 2.4.7 has been modified to read: 'The intent was to prescribe the corrected speed requirements in case an Engine test conducted at sea level was selected'.</p> <p>The amended rule wording and guidance in no way precludes the applicant from simulating altitude effects in a test cell or by using a dedicated flight test. See also the amended AMC E 650(5) Altitude and Temperature Effects.</p>



comment	<p data-bbox="359 235 391 280">18</p> <p data-bbox="1268 235 1484 280" style="text-align: right;">comment by: FAA</p> <p data-bbox="359 302 1173 336">Paragraphs 2.4.5 through 2.4.8 Safety recommendation from AAIB</p> <p data-bbox="359 347 1484 459">Preamble section 2.4.6, discusses the Air Accidents Investigation Branch (AAIB) safety recommendation 4.16 resulting from investigation of the fatal B737-400/CFM56-3 accident near Kegworth, UK, on January 8, 1989.</p> <p data-bbox="359 470 1484 907">The proposed introduction of validated analysis to assess flutter comes many years after the rule was changed to address the AAIB recommendations and since that change, there have been a number of new engine certifications. It would have been beneficial for the preamble to have reviewed the service history of these engines and compare them against earlier engines to determine whether the current requirements have produced the desired reduction in flutter risk. Where flutter problems have continued to occur, the preamble should assess whether the means by which the test was conducted was an issue and whether analysis or other types of testing may have helped prevent the shortfall. Such an assessment should help support the case for use of validated analysis, or other means of testing, and point to where bounds need to be established for application of analysis and similarity. We recommend including this assessment in the final rule preamble.</p>
response	<p data-bbox="359 929 526 963">Not accepted</p> <p data-bbox="359 996 1484 1108">It is deemed that the low number of in-service cases does not provide a sufficient statistical basis to allow such a comprehensive review and analysis to be undertaken, particularly in enough detail to allow limitations of analysis to be derived.</p> <p data-bbox="359 1108 1484 1310">Boundaries of the validated analysis are addressed in the amended AMC E 650(14)(b)(i), which has been expanded to better address flutter in response to Comments 21, 22 and 23. The domain of applicability establishes these bounds for developing and using the validated analysis. In addition, the concept of similarity has been further clarified in the amended AMC E 650(14)(a) and (b)(ii) in response to Comment 15.</p>
comment	<p data-bbox="359 1366 391 1400">35</p> <p data-bbox="1268 1366 1484 1400" style="text-align: right;">comment by: ASA</p> <p data-bbox="359 1433 1484 1780">The Modification and Replacement Parts Association applauds efforts to clarify rules and improve safety. Paragraph 2.4.21 of the NPA declares that any loss of harmonization with FAA rule 33.83 is expected to be minimal. MARPA encourages best efforts be made to retain harmonization to the greatest extent possible to better enhance uniformity of understanding across the aviation industry. Uniform understanding enhances safety by ensuring manufacturers and operators working under both regulatory regimes accurately and consistently comply with safety requirements. To the extent that the EASA and FAA rules become disharmonized, MARPA suggests revising the NPA in an effort to retain existing harmonization.</p>
response	<p data-bbox="359 1814 526 1848">Not accepted</p> <p data-bbox="359 1881 726 1915">See response to Comment 14.</p> <p data-bbox="359 1926 1484 1993">Please also note that means of compliance accepted in accordance with the current rules and guidance would continue to be acceptable with the amended CS-E 650 and AMC E 650.</p>



3. Proposed amendments — 3.1. Draft Certification Specifications (Draft EASA Decision) — Certification Specifications for Engines (CS-E), Book 1 — Airworthiness Code, SUBPART E — p. 8-10 TURBINE ENGINES TYPE SUBSTANTIATION — CS-E 650 Vibration Surveys (See AMC E 650)

comment	<p>1 comment by: <i>Francis Fagegaltier Services</i></p> <p>Proposed CS-E 650 (b). There is reference to "each rotor module" when in current text it is "each rotor system". The intent of the current wording was to cover designs incorporating a gear box. The proposed definition of "module" in the proposed AMC E 650 clearly does not cover gear boxes.</p> <p>Gear boxes should not be eliminated from the vibration surveys/ analysis, especially when there are designs where very large gears (sometimes called "bull gear") could fail in high cycle fatigue, potentially uncontained, likely to make them engine critical parts unable to comply with CS-E 515 (a) (lives can be calculated for low cycle fatigue not for HCF).</p> <p>It is suggested keeping the current word "system", eliminating the concept of "module" : this would also be consistent with the proposed wording of CS-E 650 (d).</p>
response	<p>Partially accepted</p> <p>The concept of module is deemed to be widely used and understood. However, to address this comment, the definition of 'Module' in the amended AMC E 650(1) has been expanded to include gear boxes.</p>
comment	<p>2 comment by: <i>Francis Fagegaltier Services</i></p> <p>Proposed CS-E 650 (a). If this proposal is maintained, the singular "test" could be confusing : a unique test is not the requirement ! To be consistent with the intent, it would be better to write "tests" (plural) ("tests or a combination of tests ...")</p> <p>But it would be much better to revert to the current wording "vibration surveys" as explained in other comments.</p>
response	<p>Not accepted</p> <p>'Test' is a procedure to establish quality, performance, reliability and behaviour. In the context of CS-E 650 it is not singular, and describes a series of experiments.</p>
comment	<p>4 comment by: <i>Francis Fagegaltier Services</i></p> <p>The rationale for eliminating reference to "surveys" in CS-E 650 (a) is noted. However, to understand the logic of the whole proposal is more difficult. Indeed, CS-E 650 (b) still refers to the "vibration surveys" of the former E 650 (a) which are now proposed to be deleted !</p> <p>Similarly, it is noted that paragraph (3) of the AMC states this : "CS-E 650 (a) requires that the survey ..." : this does not seem consistent with the proposed text of CS-E 650 !</p> <p>Instead of cleaning up all of CS-E 650 and associated AMC, it is suggested modifying the definition of "vibration survey" to read as follows (based on Oxford dictionary definition) :</p>



a vibration survey is an investigation to establish the vibratory characteristics of engine components, based on tests and analyses.

This was the intended definition of "vibration surveys" when the current text of CS-E 650 was developed.

response Not accepted

See response to Comment 13.

comment 19

comment by: FAA

Paragraph 3.1 Draft Certification Specifications - CS-E 650(a)

In replacing the phrase *"each engine must undergo vibration surveys"* with *"it must be established by test or combination of test and validated analysis"*, the proposed rule does not preserve the intent for proof of design by a representative engine test. The preamble paragraph 2.1 states that *"...‘survey’ has generally been interpreted to mean a full engine test..."*. Therefore, to maintain the understood intent and past practices, the revision to CS-E 650 should be grounded in a representative engine test and the validated analysis should be tied to a representative engine test.

We recommend revising the phrase *"It must be established by test or a combination of test and validated analysis..."* to read:

"It must be established by engine test of the type for which certification is requested or a combination of test(s) and analysis based on, and equal in accuracy to the results of an engine test ..."

This recommendation retains the engine test requirement for the baseline engine and provides expectations for the validated analysis. We understand EASA's desire to avoid prescriptive language, but we believe the proposed language offers sufficient flexibility by allowing the use of validated analysis while retaining the original rule intent for an engine test. We believe this language also provides the regulatory balance between "prescriptive" and "significant content" as explained in preamble paragraph 2.4.3. This suggested language is comparable to that of airplane regulation CS 25.21(a)(1), addressing similar concerns over use of analysis.

The engine vibration rule is concerned with engine level aerodynamic and aeromechanical effects resulting in complex synchronous, nonsynchronous, transient, and unsteady responses that are difficult to predict and sensitive to engine specific design details and test conditions. The available analytical models are known to have limitations; therefore, it is essential that the regulation remains grounded in an engine test and any proposed analytical tools be validated against representative tests of hardware sufficiently similar to that being considered for certification.

response Not accepted

The reference to **'Engine test of the type for which certification is requested'** may not necessarily imply a certain level of similarity with that engine. For commercial reasons applicants have used the concepts of 'new types' or 'new models/variants/derivatives to an



existing type' in very different ways, which to EASA view cannot be tied to a level of similarity.

EASA believes that grounding the regulation to an **engine test** does not reflect currently accepted Means of Compliance reflected in current EASA AMC E 650 and FAA AC 33-83A which both allow e.g. Rig testing under the condition that hardware and operating conditions are representative of a full engine test. The amended AMC E 650 achieves the same intent as sufficient similarity with a full engine test is achieved by the combination of baseline test(s), validated analysis and domain of applicability.

Boundaries of the validated analysis are addressed in the amended AMC E 650(14)(b)(i), which has been expanded to better address flutter in response to Comments 21, 22 and 23. The domain of applicability establishes these bounds for developing and using the validated analysis. In addition, the concept of similarity has been further clarified in the amended AMC E 650(14)(a) and (b)(ii) in response to Comment 15.

comment

20

comment by: FAA

Paragraph 3.1 Draft certification specifications - CS-E 650(f) - Stress margins

Paragraph (9)(b) of the AMC states that "Section CS-E 650(f) requires suitable stress margins ...", but the rule does not clearly set this requirement. A clarification should be added to CS-E 650(f) as follows:

"... when combined with the appropriate steady stresses, must *provide suitable margin to the endurance limit of each component ...*"

The above clarification provides context for the next to the last sentence in paragraph (f) and provides the link that is referred to by the AMC.

response

Accepted

The proposed wording has been included in the amended CS-E 650(f).

comment

21

comment by: FAA

Flutter under CS-E 650(d) and the AMC paragraph 14(b)

The complexity and operational sensitivities of flutter that an applicant needs to address in a certification program are objectively identified in the revised CS-E 650. The change introduced by the revised rule is the option to use analysis to extend the applicability of existing results from a baseline test (NPA section 2.4.17). To ensure that the critical environmental and operational issues are addressed, the proposed rule and AMC should set or provide guidance for setting boundaries on when analysis might be used in lieu of an engine test for compliance with the flutter requirements of CS-E 650.

Flutter is a complex phenomenon that is difficult to predict, which is why the current rule and guidance specify requirements for testing across the operating envelope and just outside if significant responses are discovered near the edge. Allowing analytical extrapolation of results from a baseline test introduces significant risk (preamble section 2.4.17) that must be mitigated by appropriate validation of the extrapolation procedure. To retain the intent and level of safety associated with the current rule, the limitations associated with a validated



	analysis should be identified by the regulation and/or guidance.
response	<p>Partially accepted</p> <p>Boundaries of the domain of applicability are addressed in the amended AMC E 650(14)(b)(i), which has been expanded to better address flutter in response to Comments 21, 22 and 23. The domain of applicability establishes these bounds for developing and using the validated analysis. In addition, the concept of similarity has been further clarified in the amended AMC E 650(14)(a) and (b)(ii) in response to Comment 15.</p>
comment	<p>22 comment by: FAA</p> <p>CS-E 650 and AMC paragraph 14(b)</p> <p>The AMC paragraph 14(b)(i) prescribes the basis for creating a validated analysis in terms of well understood structural, mechanical, and high level system design details. The details listed are typically associated with defining important modal response characteristics and dynamic excitation sources. However, this paragraph does not sufficiently identify, or direct the applicant to identify and quantify, those key characteristics affecting flutter that must be understood in order to make accurate analytical flutter predictions. The AMC paragraph 14(b)(ii) states that to use validated analysis, the engine must be “sufficiently similar”, but no guidance is provided to establish flutter related similarity criteria between the certification engine and the baseline engine(s).</p> <p>We recommend running an engine test for new type designs and for modifications to a type design that have been shown to have an effect on flutter. If the differences that affect flutter are shown to be minor, recommend allowing use of analysis that is validated based on engine test data from the similar baseline engine and partial engine test data from the engine being certified. Partial test data from the engine being certified could be data collected from running of specific CS-E 650 conditions or relevant data collected during other certification tests.</p>
response	<p>Partially accepted</p> <p>See response to Comment 21.</p>
comment	<p>23 comment by: FAA</p> <p>CS-E 650 and AMC paragraph 14(b)</p> <p>AMC paragraph 14(b)(ii) states that validated analysis may be used “to cover the speed ranges not achieved during testing” and section (8)(d) states that, when testing is conducted at sea level only, “the applicant may propose a procedure acceptable to the Agency to account for altitude effects”. An applicant may agree to evaluate flutter and the altitude effects required in CS-E 650 by an engine test, or by a combination of test and validated analysis. If the agreed method of compliance is an engine test (applicant does not propose to supplement with analysis), the above statements may be interpreted that validated analysis may be used to fill-in the speed range shortfalls that occurred during testing. The risk is that</p>



critical flutter conditions may be missed if the test does not cover the entire speed ranges and the applicant does not have an approved approach for validating and applying analysis. As a result, we do not agree that analysis may be used in lieu of an engine test when an engine test was established as the CS-E 650 method of compliance.

When the engine cannot be tested at sea level to address the full range of operating conditions, we recommend that the applicant modify the engine so it can reach the envelope conditions (includes reconciliation of proposed modifications), or test the engine in an altitude chamber, or perform altitude tests on an airplane for compliance with CS-E 650(d). This recommendation is in agreement with the AMC paragraph (5) and the previously discussed AAIB safety recommendation.

response Partially accepted

See responses to Comments 17, 18 and 21.

comment

36

comment by: ASA

CS-E 650 paragraph (a) states that "vibration characteristics of all components that may be subject" to vibratory responses be acceptable as determined by test or by combination test and validated analysis. MARPA understands this provision (and all others falling under this section) to apply to full turbine engine type substantiation, but that the regulatory requirements with respect to development of replacement parts (known under the FAA approval regime as PMA parts) remain unchanged by this NPA. In many cases, it is not necessary for full engine testing to be performed to verify the characteristics of a replacement part; safety can be assured by making a showing of equivalency via test and computation analysis methods. MARPA seeks clarification to ensure that FAA-approved PMA parts should remain acceptable under the terms of the Bilateral Aviation Safety Agreement between the European Union and the United States, as parts approved by the regulatory agency of one of the signatories.

response Noted

It is not the intent of this rulemaking task to change the acceptability of the FAA-approved PMA parts into the EASA system.

3. Proposed amendments — 3.1. Draft Certification Specifications (Draft EASA Decision) — Certification Specifications for Engines (CS-E), Book 2 — Acceptable Means of Compliance (AMC), p. 10-23 SUBPART E — TURBINE ENGINES TYPE SUBSTANTIATION — AMC E 650 Vibration Surveys

comment

3

comment by: Francis Fagegaltier Services

In the proposed AMC E 650, in various places we find reference to the Agency. For example, in definition of "significant response" : "that has been previously agreed by the Agency". Or in paragraph 4 (b) : "the Agency may accept" (in 3 places) or "with Agency agreement" (in 2 places).



This is no longer consistent with Part 21.A.263 (b) where it is imposed to the Agency to accept without verification elements of the demonstration of compliance. Under the current Part 21, demonstration of compliance with CS-E may not be subjected to agreement by the Agency. All texts of CS-E should be understandable by any applicant without referring to EASA.

It is suggested cleaning up the whole text to eliminate references to the Agency.

response

Not accepted

While Part 21.A.263(b) defines the acceptability of the compliance documents by the Agency without further verification, as a privilege for a design organisation, this is to be considered along with Part 21.A.257(b) where the Agency is allowed to review any report to check the validity of the compliance statements. Additionally, Part 21.A.33(d) allows the Agency to review any report and to check the validity of the declaration of compliance. Future rulemaking on EASA Level of Involvement (LOI) may provide further clarifications on this issue.

3. Proposed amendments — 3.1. Draft Certification Specifications (Draft EASA Decision) — Certification Specifications for Engines (CS-E), Book 2 — Acceptable Means of Compliance (AMC), SUBPART E — TURBINE ENGINES TYPE SUBSTANTIATION — AMC E 740(g)(1) Endurance Tests — Incremental Periods

p. 23

comment

24

comment by: FAA

AMC E 650 - General comments

In revising CS-E650 to allow use of validated analysis, EASA is trying to balance between writing an objective rule that only lays out safety objectives and creating a prescriptive rule that defines what an applicant must do. EASA recognizes the potential risks and in preamble section 2.4.3, states that “departing too far from prescriptive requirements leaves the rule with no significant content.” . The revision to CS-E 650 follows the objective approach but still includes limited prescriptive elements, while the guidance in AMC E 650 tries to explain intent and provide any necessary prescriptive elements. However, in trying to avoid being overly prescriptive, EASA has lost elements in the AMC that would have provided sufficient guidance to preserve rule intent against unintended misinterpretations.

In the comments below, we make recommendations to modify the AMC with the goal to clarify the baseline test, the development of the validated analysis, and develop appropriate bounds for when a validated analysis might be used.

response

Not accepted

See responses to Comments 25 through 34.

comment

25

comment by: FAA

AMC-E 650 paragraph (1) - Definitions, Baseline Test



The “baseline test” definition provided in this section is not in harmony with what FAA accepts for a baseline test (see FAA Policy ANE-2006-33.94-2), and is not consistent with the guidance in the proposed AMC paragraph (14)(a).

The FAA considers a baseline test as the engine test performed on the parent engine that is then used as the reference for developing similarity or validated analyses for use in certifying a derivative engine. The EASA definition of “baseline test” is more general and appears to include any test that might be used to validate an analytical method. For example, the proposed definition appears to accept that an applicant might develop a flutter model based on extensive testing of an engine they have available for R&D work, then use this model in certification of new engines that may differ significantly from the R&D engine. Under the EASA wording, this model could be considered validated for application to an entirely different engine model. But under FAA Policy, the model would require further validation to demonstrate that its range of applicability includes the new engine design. For clarity, we recommend two definitions:

- Baseline test: define as the parent engine from which there would be direct similarity connections for assessing a derivative and validating the applicability of an analytical model.
- Development test: could be any engine, module, or other test used to develop and calibrate an analysis method.

By making this distinction, EASA could then accept a calibrated modeling method developed on “other” hardware, and then direct the applicant to show that based on validation against the baseline test, the range of applicability for this model includes the hardware proposed for certification, before approving use of the model in the certification program.

response

Not accepted

First paragraph — The intent of the amended AMC E 650 is considered identical to the intent of the FAA Policy ANE-2006-33.94-2.

Other paragraphs — See responses to Comments 15, 18, 19, 20 and 21 related to similarity, Baseline Test, Validated Analysis and domain of applicability.

comment

26

comment by: FAA

AMC-E 650 paragraph (1) - Definitions, Module

To prevent possible confusion, a clarification should be added:

“A single stage or subset of stages isolated from a multi-stage compressor or turbine does not constitute a module.”

response

Accepted

The proposed wording is included in the amended AMC E 650(1) Module.

comment

27

comment by: FAA

AMC-E 650 paragraph (4)(a) - Test Conditions, Rig Testing

(a) The next to the last sentence opens the possible interpretation that testing a single blade or vane might be acceptable. To prevent potential confusion, reword this sentence as



follows:
 "...Rig tests generally consist of testing full or part of engine modules. ...
 This revision maintains the understood intent, but since the sentence starts with "... generally ...", it still allows the regulator to make an exception for use of a subset of hardware if a valid situation is presented.
 (b) To minimize potential confusion in the last sentence, change the phrase "... closely model actual ..." to "... closely replicate actual ..."
 As written, this phrase could be misinterpreted as being another use of analysis. By making the suggested word change, this potential confusion is eliminated.

response Partially accepted

(a) The first comment is not understood. The proposed rewording appears to be the same as the current text.
 (b) The proposed wording is included in the amended AMC E 650(4)(a).

comment

28

comment by: FAA

AMC-E 650 paragraph (8)(a) – Flutter

This paragraph states: "The presence of flutter may be acceptable in some circumstances, for example in a speed range encountered only briefly or infrequently, or where the flutter amplitude is limited to a safe level."

The flutter amplitude "safe level" in this statement should be linked to the regulation to clarify that the associated vibration stresses must satisfy the requirements of CS-E 650(f). Otherwise, as written this phrase suggests that flutter encountered briefly or infrequently may be permissible even if resulting stresses are not compliant with CS-E 650(f) because they exceed endurance limits.

We recommend adding at the end of the above phrase: "However, the resulting vibration stresses must always satisfy the requirements of CS-E 650(f)."

response Accepted

The proposed wording is included in the amended AMC E 650(8)(a).

comment

29

comment by: FAA

AMC-E 650 paragraph (14)(a) - Modelling and Analysis, Baseline Test

Paragraph 14(a)(i) states that a validated analysis based on the first model of a type certificate (TC) may be used on derivative engines within the same TC. This statement suggests that analysis may be used regardless the differences between the first model on the TC and the derivative model and regardless of the domain of applicability for the validated analysis. This paragraph appears to contradict section 14(b) guidance.

Recommend adding the clarification that the engine model for which validated analysis was shown and the engine model being certified should be sufficiently similar and that the demonstrated domain of applicability for the validated analysis should be inclusive of the engine being certified.



response Accepted

The proposed recommended clarification has been included in the amended AMC E 650(14)(a), as applicable to sub-paragraphs (i),(ii) and (iii).

comment 30 comment by: FAA

AMC-E 650 paragraph (14)(a) - Modelling and Analysis, Baseline Test

Paragraph 14(a)(ii) states that a validated analysis developed on the basis of a test from a different TC may be used for “engines whose design characteristics and operating conditions are shown to be sufficiently similar to those of the engine in the baseline test”. However, the domain of applicability for the validated analysis is not discussed. This paragraph appears to contradict section 14(b) guidance.

Recommend adding the clarification that the domain of applicability for the validated analysis should be inclusive of the engine being certified.

response Accepted

See response to Comment 29.

comment 31 comment by: FAA

AMC-E 650 paragraph (14)(a) - Modelling and Analysis, Baseline Test

Paragraph 14(a)(iii) appears to allow a model to be developed in isolation from the engine type design hardware configuration and operating conditions, and then assumed to be applicable to the type design of the engine to be certified. The intent needs to be clarified to ensure that the scope of applicability is preserved. Suggest adding the clarification sentence (italic):

“(iii) An Engine or rig test specifically run to support the creation of the validated analysis. *The hardware and conditions run in this test must be shown to be sufficiently similar and inclusive of the domain of applicability for the engine being certified.*”

response Accepted

See response to Comment 29.

comment 32 comment by: FAA

AMC-E 650 paragraph (14)(b) - Validated Analysis, Baseline Test

Paragraph 14(b)(i) provides guidance for the development of the validated analysis and its domain of applicability. The engine design characteristics and the operating conditions are identified as criteria for the domain of applicability. However, these criteria are broad and do not account for the complexity, variability, and uncertainty related to engine vibration. We find that the concept of a “domain of applicability” is insufficiently defined to capture the numerous variables affecting engine vibratory response.

We recommend characterizing the use of validated analysis and criteria for similarity as is



	<p>done in FAA policy ANE-2006-33.94-2, “Use of Structural Dynamic Analysis Methods for Blade Containment and Rotor Unbalance Tests”. An analytical model for predicting engine vibration, flutter, and the effects of CS-E 650(e), is similar in complexity with that for the blade-out test. Alternatively, adopt appropriate methods for predicting dynamic and unsteady phenomena from other certification products, such as airplanes (CS-25 and AMC-25).</p>
response	<p>Not accepted</p> <p>Guidance was deliberately kept to the level proposed in the draft AMC to avoid providing a ‘step-by-step’ manual.</p> <p>See also responses to Comments 15 and 25.</p>
comment	<p>33 comment by: FAA</p> <p>Paragraph (14)(b)(i) Development of the validated analysis</p> <p>(1) First “dash” bullet, third “dot” sub-bullet (bearings) - Engine Architecture (bearings): Suggest replacing “number, location and type of bearings” with “number, location, installation (inner/outer race grounded, intershaft, damped, etc) and type of bearings ”</p> <p>(2) Fourth “dash” bullet, second “dot” sub-bullet - Structural Dynamics characteristics (restraints): Suggest replacing “restraints, for example blade or vane attachment design, snubbers or dampers;” with “restraints, for example blade or vane attachment design, snubbers or dampers, bladed disk or blisk; ”</p> <p>(3) Fifth “dash” bullet, first “dot” sub-bullet - Sources of vibratory excitations Suggest adding the word “struts” to read “upstream or downstream stators <i>or struts</i>; ”</p> <p>(4) Fifth “dash” bullet, second “dot” sub-bullet - Sources of vibratory excitations Suggest adding the words after “flow characteristics” to read: “flow characteristics, <i>inlet or flow path asymmetry</i>; ”</p>
response	<p>Partially accepted</p> <p>Comment (1) — Accepted. AMC E 650(14)(b)(i) has been amended as proposed.</p> <p>Comment (2) — Not accepted. ‘Bladed disk or blisk’ is a design style rather than a restraint.</p> <p>Comment (3) — Accepted. AMC E 650(14)(b)(i) has been amended as proposed.</p> <p>Comment (4) — Accepted. AMC E 650(14)(b)(i) has been amended as proposed.</p>
comment	<p>34 comment by: FAA</p> <p>Paragraph 14(b)(ii) - Use of validated analysis</p> <p>It is not clear in the proposed rule and guidance, whether the “baseline tests” have to bear any significant similarity to the hardware being certified. Discussions with EASA indicate that “baseline tests” are expected to provide an appropriate degree of similarity so that the domain of applicability can be established. However, the revised rule and AMC do not clearly address this expectation. Examples include:</p>



- The proposed AMC does not specify that the baseline test is expected to be performed on hardware similar to what is proposed for certification.

- The proposed AMC does not require the baseline test to cover the range of conditions for which the validated analysis will be applied. For example, if the baseline test does not reach the required speeds or other conditions, the current wording implies the applicant could extrapolate from the baseline test to the certification analysis condition without validating the accuracy or applicability of the extrapolation. To be properly validated, the validated analysis must be shown to be valid for the range of conditions necessary for showing certification by analysis.

response

Partially accepted

See response to Comment 15. Additional clarification on similarity has been added in the amended AMC E 650(14)(a) and (b)(ii). The domain of applicability of the validated analysis constitutes the basis of the ‘critical requirements and limitations’ which close the gaps with the baseline test(s).

Considering the example, ‘rotational speeds’ is specifically listed as operating conditions to be included in the domain of applicability of the validated analysis.



4. Appendix A — Attachments

None.

