	Consultation paper **Equivalent Safety Finding**	Doc. No. : ESF-B25.251-01 Issue : 1 Date : 10 August 2023 Proposed ☒ Final ☐ Deadline for comments: 31 AUG 2023

SUBJECT	**:**	Vibration and Buffeting
REQUIREMENTS incl. Amdt.	**:**	CS 25.251(b) and (d) at Amdt. 27[1]
ASSOCIATED IM/MoC	**:**	Yes☒ / No ☐
ADVISORY MATERIAL	**:**	

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[1] This ESF may be applied to the listed certification specifications at the amendment or JAR 25 change used for the original type certification basis of the basic aircraft as defined in the relevant EASA TCDS.

INTRODUCTORY NOTE:

The following Equivalent Safety Finding (ESF) has been classified as important and as such shall be subject to public consultation in accordance with EASA Management Board decision 12/2007 dated 11 September 2007, Article 3 (2.) which states:

"*2. Deviations from the applicable airworthiness codes, environmental protection certification specifications and/or acceptable means of compliance with Part 21, as well as important special conditions and equivalent safety findings, shall be submitted to the panel of experts and be subject to a public consultation of at least 3 weeks, except if they have been previously agreed and published in the Official Publication of the Agency. The final decision shall be published in the Official Publication of the Agency.*"

ABBREVIATIONS:

M_{DF}	demonstrated flight diving Mach number
M_{MO}	maximum operating limit Mach number
V_{DF}	demonstrated flight diving speed
V_{MO}	maximum operating limit speed

IDENTIFICATION OF ISSUE:

Large aeroplane design changes that include the installation on the fuselage of a large[2] radome or antenna covered by an aerodynamic fairing must comply with CS 25.251(b), which states that each part of the aeroplane must be demonstrated in flight to be free from excessive vibration under any appropriate speed and power conditions up to V_{DF}/M_{DF}.
Such design changes must also comply with CS 25.251(d), which states that there may be no perceptible buffeting condition in the cruise configuration in straight flight at any speed up to V_{MO}/M_{MO}, except that the stall warning buffeting is allowable.

The extent of the aeroplane modifications, particularly the size and location with respect to the unmodified aeroplane, may cause significant changes in the aerodynamic flow field around the aeroplane at high speed, which may lead to excessive vibration. Potential vibration sources include unsteady flow conditions on the new or modified fuselage, tail assembly, or control surfaces arising from shocks, flow separation or other unsteadiness in the flow.

Because of these potential effects, the original demonstration of compliance with CS 25.251(b) and (d) may not be valid for the modified aeroplanes. Normally, the demonstration of compliance must be based on flight tests only.

[2] A definition of what constitutes a "large antenna installation" is provided in chapter 2 of Certification Memorandum ref. CM-S-013 at Issue 1 published by EASA on 15 November 2019.

Neverthless, an applicant may propose an Equivalent Safety Finding (ESF) based on an acceptable method (such as a similarity analysis to other EASA approved designs, computational fluid dynamics tools, vibrations analysis, partial flight tests) to substantiate that the original demonstration of compliance with CS 25.251(b), or CS 25.251(b) and (d), at time of TC remains valid with the design change applied. This ESF provides compensating factors allowing to reach an equivalent level of safety per point 21.B.80(a)2 of Part-21 (Annex I to Regulation (EU) No 748/2012).

EASA already published an ESF on this subject in April 2016 that can be found under the following link on the EASA website:

https://www.easa.europa.eu/en/document-library/product-certification-consultations/equivalent-safety-finding-cs-25251b-vibration

The present ESF aims at extending the scope of the formerly published ESF, which was limited to CS 25.251(b), to include CS 25.251(d). All changes introduced compared to the previously published ESF are tracked for traceability reasons.

Considering all the above, the following Equivalent Safety Finding to CS 25.251(b), or CS 25.251(b) and (d), at Amdt 27 is proposed.

ESF-B25.251-01

Equivalent Safety Finding

Vibration and Buffeting

1. APPLICABILITY

This ESF is applicable to CS-25 Large Aeroplanes fitted with large radome or antenna fairing on the fuselage.

1.1 AFFECTED CS

CS 25.251(b) and (d) at Amendment 27

2. SCOPE

In lieu of showing direct compliance for the modified large aeroplane with CS 25.251(b), or CS 25.251(b) and (d), by using flight test only, and provided that the below compensating factors are complied with, large radomes or antenna fairings might be installed on the fuselage of a large aeroplane without demonstrating in flight that:

- there is no perceptible buffeting condition in the cruise configuration in straight flight at any speed up to V_{MO}/M_{MO}, except that the stall warning buffeting is allowable and/or that
- the aeroplane is free from excessive vibration under any appropriate speed and power conditions up to V_{DF}/M_{DF}.

3. COMPENSATING FACTORS

The applicant must demonstrate, by using proposed method (taking into account the attached Interpretative Material), that the design change does not invalidate the original demonstration of compliance with CS 25.251(b), or CS 25.251(b) and (d).

To evaluate whether the design change could affect the original compliance finding, the applicant may propose to use any suitable combination of the following factors 1-4 to address CS 25.251(b) or factors 1-3 to address CS 25.251(b) and (d) :

1. Similarity to other EASA approved designs. (Consider the size, shape, and location of the respective fuselage modifications, the aeroplanes they are installed on, the respective V_{DF}/M_{DF} speeds, and the means of compliance used for the approved designs.)

2. Flowfield analysis using an acceptable computational fluid dynamics tool. The applicant must show that the tool is valid for its intended use. For example, the tool must be capable of accurately assessing whether a shock is present, including its strength and location, and the area of separated flow. Generally, a full Navier-Stokes code with robust turbulence modeling is needed for such an analysis. Validation using flight test data is preferred, but suitable wind tunnel data may be acceptable. The applicant should also address other known limitations and characteristics of the code to be used, such as:

   a. Grid sizes and spacing.

b. Geometric fidelity of the aeroplane model – the effect of simplifications of the model (e.g., ignoring flap track fairings, vortex generators, small gaps, etc., how the engines are modeled, aeroelastic effects, other differences between the actual aeroplane and the digital model used in the analysis).
c. CFD modeling errors, particularly in turbulence modeling.
d. Location of the trip point from laminar to turbulent flow.
e. Boundary conditions (e.g., ensuring that far field conditions are applied sufficiently far away).

3. A vibration analysis, usually based on the results of the flowfield analysis addressed in (2).

4. Flight testing to a speed from which the analyses described in paragraph (1), (2) and (3) can be used to extrapolate the findings to V_{DF}/M_{DF}. As a minimum, flight testing must include the critical flight conditions to cover the complete flight domain from low speed to speeds up to and including V_{MO}/M_{MO} which may include high lift configurations, landing gear extended and sideslips which could be experienced in service.

Associated Interpretative Material to Equivalent Safety Finding ESF-B25.251-01

The associated Interpretative Material is published for awareness only and is not subject to public consultation.

CFD Code Validation

To use a CFD tool in showing that the design change does not affect compliance with CS 25.251(b), or CS 25.251(b) and (d), or to extrapolate findings beyond V_{MO}/M_{MO}, the applicant should show that the tool is valid for its intended use. The CFD tool needs to be capable of accurately assessing whether a shock is present, including its strength and location, and the area of separated flow.
Generally, a full Navier-Stokes code with robust turbulence modelling is needed for such an analysis. Validation using flight test data is preferred, but suitable wind tunnel data may be acceptable.
Code validation includes:

1. Showing that the code accurately models flow phenomena of interest (e.g. transonic shocks, shock induced flow separation, shock-boundary layer interaction and separated flows) that may result from the modification.

2. Showing that the person/organization performing the analysis is experienced and qualified to properly run the code and interpret the results.

   The accuracy of the modelling of the flow field phenomena of interest should be demonstrated by comparing flow field characteristics (e.g., pressure distributions, shock strength/location, etc.) predicted by the model to flight test or wind tunnel data for a configuration (including shape, location, and airframe) similar to the modification being evaluated at airspeeds up to V_{DF}/M_{DF}.

   In addition, if there are no significant flow field phenomena of interest (e.g. transonic shocks, shock induced flow separation, shock-boundary layer interaction and separated flows) shown with the configuration being evaluated, a comparison should be made to another configuration that does exhibit such phenomena. (The validation depends on the flow phenomena of interest being present to show that the code will accurately model such flow phenomena.)
   Known limitations and characteristics of the model should be addressed, such as grid sizes and spacing, geometric fidelity of the aeroplane model, turbulence modelling fidelity, boundary conditions, and strength and location of shocks/ recovery.

   The test cases used to validate the code should be agreed to in advance by the EASA.

Aerodynamic Analysis

An aerodynamic analysis using the validated code may be used to show that compliance with CS 25.251(b), or CS 25.251(b) and (d), will not be affected by the modification provided the code validation has been accepted by the EASA.

The aerodynamic analysis need not cover all flight conditions. The critical flight conditions should be identified and those that need to be analysed in detail selected. The applicant should document how these critical flight conditions have been identified.

The applicant should analyse the effects of all simplifications or assumptions applied to the aerodynamic model (i.e., the analytical representation of the modified and unmodified aeroplanes) and show that these simplifications would not lead to an inappropriate conclusion.

After EASA acceptance of both the code validation and the results of the aerodynamic analysis, it is not required to perform:

- a flight test to V_{MO}/M_{MO} to show that no buffeting condition exists up to that speed to show compliance with CS 25.251(d) and/or
- a flight test to V_{DF}/M_{DF} to show that the modification did not affect compliance with CS 25.251(b).