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PROJECT: ST9514SC-T Delta G Design Inc. Airbus A340-200

ITEM: F-1 **STAGE:** 4 **DATE:** 10 October 2012

SUBJECT: Vibration/Buffeting Compliance Criteria, Radome Installed on Airbus A340-200

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ISSUE PAPER

PROJECT: Delta G Design Inc.
Airbus A340-200
Project No. ST9514SC-T

ITEM: F-1
STAGE: 4

DATE: 1 October 2012

REG. REF.: § 25.251

ISSUE STATUS: Closed

NATIONAL POLICY REF.: AC 25-7B

BRANCH ACTION: ASW-190, ANM-111, ANM-113, SEA-AEG

SUBJECT: Vibration/Buffeting Compliance Criteria, Radome Installed on Airbus A340-200 Airplanes

COMPLIANCE TARGET: Pre-STC

Equivalent Safety Finding

STATEMENT OF ISSUE:

The applicant proposes installation of an external Esterline/CMC CMA-21 02SB SATCOM Antenna located at frame C30 to C34. The radome is approximately 67 inches long, 18.5 inches wide, and 4.75 inches in height with an approximate weight of 8 pounds. Compliance must be shown to Title 14, Code of Federal Regulations (14 CFR) 25.251(b), which states that each part of the airplane must be demonstrated in flight to be free from excessive vibration under any appropriate speed and power conditions up to V_{DF}/M_{DF}. The applicant requests the use of an equivalent level of safety finding to show by means other than flight testing that the installation of this antenna would not cause excessive vibration under any appropriate speed and power conditions up to V_{DF}/M_{DF}. This issue paper identifies how the applicant can show an equivalent level of safety to § 25.251(b) in lieu of demonstration by flight at speeds up to V_{DF}/M_{DF}.

BACKGROUND:

The means of demonstrating compliance with § 25.251(b) is cited in the rule ("each part of the airplane must be **demonstrated in flight** to be free from excessive vibration under any appropriate speed and power conditions up to V_{DF}/M_{DF}"). Therefore, a flight demonstration out to V_{DF}/M_{DF} is required to demonstrate compliance with the rule.

When external modifications are made to an existing type design, compliance with § 25.251(b) must be addressed. The FAA has determined that if it can be shown by an acceptable method that the original compliance finding for this rule remains valid (i.e., no vibration/buffet issues exist due to the change), an equivalent level of safety has been shown. However, if the original certification for this rule does not remain valid due to potential effects of the external modification, direct compliance with the rule must be re-demonstrated.

FAA POSITION (1 October 2012):

Criteria for Demonstrating an Equivalent Level of Safety to § 25.251(b)

For an external modification to an existing approved design, such as the one proposed, an evaluation must be performed to determine whether or not the modification could affect compliance with § 25.251(b). If so, then compliance must be re-demonstrated, and the only means for accomplishing this is by an in-flight demonstration at speeds up to V_{DF}/M_{DF}.

The FAA considers that the extent of the airplane modifications proposed by the applicant, particularly the size and location of the antenna with respect to the unmodified airplane, may cause significant changes in the aerodynamic flow field around the airplane at high speed, which may lead to excessive vibration. Potential vibration sources include unsteady flow conditions on the antenna, fuselage, tail assembly, or control surfaces arising from shocks, flow separation or other unsteadiness in the flow. Because of these potential effects, the FAA has determined that the original demonstration of compliance for § 25.251(b) may not be valid for the modified airplanes. Therefore, unless it can be shown that the modification would not affect the original § 25.251(b) compliance demonstration, compliance must be re-demonstrated by flight testing at speeds up to V_{DF}/M_{DF}.

Currently, there are no valid analytical methods of substantiating that there is no excessive vibration at V_{DF}/M_{DF} other than flight testing to V_{DF}/M_{DF}. Analysis tools may be helpful, however, in determining whether a given modification may affect the original § 25.251(b) compliance finding.

To evaluate whether the modification could affect the original compliance finding, the applicant may propose to use any suitable combination of the following:

1. Similarity to other approved designs. (Consider the size, shape, and location of the respective modification, the airplanes they are installed on, the respective V_{DF}/M_{DF} speeds, and the method of compliance used for the approved designs.)
2. Flowfield analysis using an acceptable computational fluid dynamics tool (CFD). 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 airplane 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 airplane 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 flowfield analysis results addressed in (2).

4. Flight testing to a speed from which the analyses described in this paragraph can be used to extrapolate the findings to V_{DF}/M_{DF}. As a minimum, flight testing must be conducted to at least V_{MO}/M_{MO}.

CFD Code Validation

To use a CFD tool in showing that the modification does not affect compliance with § 25.251(b), the tool, 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 modeling is needed for such an analysis. Validation using flight test data is preferred, but suitable wind tunnel data may be acceptable.

Code validation includes:

- 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.
- 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 modeling 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. (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 airplane model, turbulence modeling 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 FAA.

Aerodynamic Analysis

An aerodynamic analysis using the validated code may be used to show that compliance with § 25.251(b) will not be affected by the modification provided the code validation has been accepted by the FAA.

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

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

After FAA acceptance of both the code validation and the results of the aerodynamic analysis, it is not required to perform a flight test to V_{DF}/M_{DF} to show that the modification did not affect compliance with § 25.251(b). However, a flight test to V_{MO}/M_{MO} should be performed with a qualitative assessment that no buffeting condition exists up to that speed to show compliance with § 25.251(d).

APPLICANT POSITION

The Applicant proposes to demonstrate that the modifications to this aircraft have not affected the A340-200 compliance with § 25.251(b) using a systematic program of analysis and flight testing. This approach will demonstrate that the modified aircraft will be free from excessive vibration under any appropriate speed up to V_{DF}/M_{DF}.

First, a computational fluid dynamic (CFD) analysis will be performed using the validated AVUS CFD (Navier-Stokes) code. This analysis will be performed by personnel with significant experience with CFD analyses and that have successfully completed similar analyses on previous FAA programs having demonstrated competence. The analysis of the A340-200 will not rely upon previous STCs. CFD analysis of the baseline and modified airplanes to V_D/M_D will be carried out based on the A340-200 approved flight envelope and will include 23 cases. Conditions 1 thru 23 will evaluate aerodynamic design loads. Conditions 13 through 16, 19, 22 and 23 will evaluate vibration/buffet. Conditions were determined using Airbus Performance Engineers Program for the A340 aircraft The results of this analysis will include examination of the convergence behavior of the CFD solutions to determine the presence of low frequency forcing functions in the flow that could excite structural vibrations, changes in lift due to the modification that could adversely affect the recovery from a dive, and the location of separated flows or wakes that could adversely affect airplane components downstream of the modifications.

Next, flight testing will be completed up to V_{MO}/M_{MO} to allow the affect of the modification on airplane vibration and buffet to be demonstrated.

Test instrumentation consists only of production cockpit instrumentation. The pitot system is leak-checked and the barometric altimeter calibrated within 6 months of all flight test activities, in accordance with FAR Part 43 requirements.

<u>Proposed Flight Test Regime</u>:

Tests are conducted in compliance with FAR Part 25 requirements and AC 25-7B suggested methods. The flight test will be accomplished as follows:

(a) Establish the airplane in high-speed cruise flight at FL350 (or above as required to establish a descent at M_{MO}). The use of maximum continuous thrust will be utilized to establish high-speed cruise. Set trims.

(b) Establish a shallow descent in order to attain M_{MO} (and prior to reaching an altitude where V_{MO} is attained first). Maintain M_{MO}.

1. (0.86M) in a steady descent without trimming.

Acceptance criteria:

a. Delegated Flight Test DER observation: "No qualitative difference in noise or vibration noted at V_{MO}/M_{MO} ".

The extension of the flight test results will be through analysis using the validated AVUS CFD code. A final report detailing the CFD results and their interpretation as they apply to § 25.251(b) will be submitted to the FAA for approval.

Applicant proposes that the Flight Test DER be delegated to approve the finding in the Flight Test Report that, based upon both approved CFD report and satisfactory flight test, this installation has not affected the original compliance of the aircraft to § 25.251(b) and therefore is in compliance with this regulation.

CONCLUSION: The FAA concurs with Delta G Design Corporation's proposed equivalent level of safety.

Delta G Design Corporation may follow this same equivalent safety finding, until further notice, for future installations on any transport category airplane* with the understanding that additional compliance documentation will be required for each installation. The magnitude and scope of this additional documentation will depend on the differences between the various installations.

Reference to the use of this issue paper for equivalent level of safety findings should be included in the certification plan and compliance documentation for any future installations. The applicant should contact the FAA to ensure that the FAA position on this issue has not changed. Any subsequent modifications to these installations should be reviewed for continued adherence to this issue paper.

* Note – You must verify that the amendment level for the requirements referenced in this issue paper are the same as the certification basis for a subsequent airplane model installation.

Paul Bernado for Steve Boyd — 30 Nov 12

Transport Airplane Directorate — Date
Aircraft Certification Service

Note: *The use of "should" refers to actions that need to be done to comply with the means of compliance contained in this issue paper. The use of "must" refers to regulatory requirements.*

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