Federal Aviation Administration

Memorandum

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To: Thomas Boudreau, Manager, Engine Certification Office (ECO), ANE-140

From: Fran A. Favara, Manager, Engine & Propeller Directorate, ANE-100

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Subject: INFORMATION: General Electric GEnx-2B Engine Certification Program (Project No. AT2432EN-E) Request for Review and Concurrence with Equivalent Level of Safety Finding to 14 CFR Part 33, Section (§)33.27(c) Turbine, Compressor, Fan and Turbo Supercharger Rotors - Rotor Integrity Overspeed Test

Memo No.: 8040-ELOS-09-NE01

Regulatory Reference: 14 CFR § 33.27

This memorandum informs the Engine Certification Office of an evaluation made by the Engine and Propeller Directorate on the establishment of an equivalent level of safety finding for the GEnx-2B engine.

Background

In accordance with the provisions of 14 CFR Part 21, §21.21(b)(1), the General Electric Company (GE) requested FAA approval of an alternate method of compliance to the requirements of § 33.27(c) by demonstrating an Equivalent Level of Safety (ELOS) using analysis instead of a test for the GEnx-2B67 engine model (herein called GEnx-2B).

GE proposed to show compliance to the overspeed requirements of §33.27(c) for the most critically stressed components in the Fan Booster (LPC), High Pressure Turbine (HPT) and the Low Pressure Turbine (LPT) rotor modules by an analysis that is supported by prior approved certification component test data. GE established the relevance of the data from prior tests in the GEnx-2B P3 Issue Paper. The analysis substantiates that all rotating disks and drums are designed to have adequate rotor burst speed margin and an acceptable growth at the overspeed conditions specified in §33.27(c).

Applicable Regulation(s)

14 CFR §33.27, Turbine, compressor, fan, and turbosupercharger rotors:

(c) The most critically stressed rotor component (except blades) of each turbine, compressor, and fan, including integral drum rotors and centrifugal compressors in an engine or turbosupercharger, as determined by analysis or other acceptable means, must be tested for a period of 5 minutes.

(1) At its maximum operating temperature, except as provided in paragraph (c)(2)(iv) of this section; and

(2) At the highest speed of the following, as applicable:

(i) 120 percent of its maximum permissible rpm if tested on a rig and equipped with blades or blade weights.

(ii) 115 percent of its maximum permissible rpm if tested on an engine

(iii) 115 percent of its maximum permissible rpm if tested on turbosupercharger driven by hot gas supply from a special burner rig.

(iv) 120 percent of the rpm at which, while cold spinning, it is subject to operating stresses that are equivalent to those induced at the maximum operating temperature and maximum permissible rpm.

(v) 105 percent of the highest speed that would result from failure of the most critical component or system in a representative installation of the engine.

(vi) The highest speed that would result from the failure of any component or system in a representative installation of the engine, in combination with any failure of a component or system that would not normally be detected during a routine preflight check or during normal flight operation.

Following the test, each rotor must be within approved dimensional limits for an overspeed condition and may not be cracked.

Regulation requiring ELOS

14 CFR §33.27(c)

Description of compensating factors or alternate standards that allows the granting of the ELOS finding (including design changes, limitations, or equipment need for equivalency)

GE used their Burst Margin Design Procedures to identify the most critical rotor component in each rotor module and their validated elastic plastic tool to predict the growth and burst margin for each disk and drum rotor using minimum material properties. GE proposed to show compliance with the overspeed requirements of 14 CFR §33.27 using:

1. an elastic/plastic finite element analysis that is calibrated to relevant component test data and,

2. an elastic bulk stress disk burst calculation (GE Design Practice Burst Methodology) that is validated by full scale component and sub-component testing.

An elastic/plastic analysis that is calibrated to FAA-approved component test data is used to show that a disk operating at the maximum overspeed condition of §33.27(c), with the speed compensated for engine operating boundary conditions, remains within approved dimensional limits in accordance with

14 CFR §33.27(c). The elastic/plastic analysis is also used to establish the maximum serviceable limits.

If the most critical component in an engine rotor cannot be represented using data from prior certification component tests because of differences in material, geometry, size or any other attribute that makes the component unique, then a test is required. For this reason, a spin pit test was conducted with the most critical disk in the integral 3-stage fan ring and the HPC rotor to show direct compliance to the requirements of 14 CFR §33.27(c).

The FAA concluded that an ELOS finding to §33.27(c) could be made using GE Design Practice Burst Methodology for the GEnx-2B LPC rotor, HPT rotor and LPT rotor. Where GE uses analysis, the validation of the suitability of that analysis should, at a minimum, demonstrate the ability to

a. develop data specific to the individual rotor component and operating environment,
b. accurately predict rotor burst speed and identify the rotor stage or component with the lowest burst margin within each rotor module,
c. develop a correlation to the new rotor design so it can accurately predict the dimensional growth versus rotor speed at critical rotor locations, and
d. reliably predict applicable results from engine tests or rig tests.

Also, the predicted residual growth of the rotor component was within prior, relevant GE test experience. GE also showed that the growth met approved dimensional limits. Limits are approved when it is shown that the predicted residual growth of the most critical rotor component after an overspeed event will not create a hazardous condition in the engine, will not result in any other damage that could create a hazardous condition in the engine and does not result in a cracked rotor component.

GE also uses the calibrated elastic/plastic analysis to substantiate serviceable growth that is below the approved limits. The predicted serviceable limits that will be included in the Instructions for Continued Airworthiness (ICA's) under 14 CFR §33.4 was within prior, relevant GE test experience. The following general criteria are provided to clarify the FAA position regarding the relevance of prior certification experience:

1) Rotor Similarity – each critical rotor component must have geometric and mechanical characteristics similar to a previously tested and certified rotor.

    a) Geometric similarity – the comparative description between each critical rotor and a geometrically similar tested rotor must focus on design features that affect local and average stress distributions and manufacturing process changes.
    b) Mechanical similarity – the comparative description between each critical rotor and a similar tested rotor must focus on material (including but not limited to ultimate strength and stress-strain curves), and manufacturing methods (including but not limited to material isotropy and bulk residual stresses).

2) Rotor Criticality – the analysis must show that each rotor being certified is not more critical, with respect to burst and growth, than any similar rotor for which substantiation has been demonstrated both by rotor test and model prediction based on the direct comparison of the following parameters at the test conditions:

    a) Stresses at limiting locations relative to allowable stresses.
    b) Deformations at critical locations relative to their acceptable growth limits.
    c) The ratio between the calculated burst speed at the test conditions and the actual test speed.

3) The predicted rotor growth must support the published serviceable limits in the Instructions for Continued Airworthiness under §33.4.

4) The analytical models that are used to create data for the ELOS assessment must be calibrated and validated using relevant FAA approved certification overspeed component test data.

5) The selection of the most critical rotor component from each module must consider both the lowest margin to burst and maximum plastic growth. If the lowest burst margin and highest allowable plastic growth occur in separate components in the same rotor module, then both components must be evaluated by an ELOS assessment to the requirements of 14 CFR §33.27(c)

Explanation of how compensating design features or alternative Methods of Compliance (MoC) provide an equivalent level of safety to the level of safety intended by the regulation

The safety objectives of §33.27(c) are to ensure that all rotor parts:

a. Possess sufficient burst margin above certified operating conditions and above failure conditions leading to rotor overspeed, and

b. Do not exhibit a level of growth or damage that could lead to a hazardous condition within the engine.

The FAA concurred with GE's proposal to use their Design Practice Burst methodology and their validated elastic plastic finite element tool to identify the most critical rotor component, relative to burst margin and plastic growth, in each engine rotor module using minimum material properties. GE evaluated burst margin using the GE Design Practice Burst Methodology and plastic growth using an elastic/plastic analysis that was validated and calibrated to relevant FAA-approved certification component test data. The FAA agreed that the GE design approach demonstrated an equivalence to testing the GEnx-2B's most critically stressed components in the LPC, HPT and LPT rotors, therefore meeting the criteria of §33.27(c).

FAA approval and documentation of the ELOS finding

In the GEnx-2B Issue Paper P-3, the FAA formally documented GE's proposal to show compliance to the §33.27(c) rotor integrity requirements by an ELOS assessment. This memorandum provides standardized documentation of the ELOS that is non-proprietary and can be made available to the

public. The FAA has assigned a unique ELOS Memorandum number, (8040-ELOS-09-NE01), to facilitate archiving and retrieval of this ELOS documentation. This ELOS Memorandum number will be listed in the Type Certificate Data Sheet as part of the certification basis for the GEnx-2B engine models as follows:

Equivalent Level of Safety Findings have been made for the following regulations:

14 CFR §33.27, Turbine, compressor, fan, and turbosupercharger rotors, par. (c), (documented in ELOS No. 8040-ELOS-09-NE01)

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7/16/10
Date