Federal Aviation Administration

Memorandum

Original Date: March 13, 2008

Revised Date: May 1, 2008

To: Manager, Engine & Propeller Directorate Standards Staff, ANE-110
Manager, Engine & Propeller Directorate, ANE-100

From: Manager, Engine Certification Office (ECO), ANE-140

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Revised by: Keith Lardie (ECO), ANE-142
Revised memorandum to remove references to proprietary data.

Subject: **ACTION**: Pratt & Whitney (P&W) Global Material Solutions (GMS) Program (Project # ST2509EN-E) Request for Review and Concurrence with Equivalent Level of Safety Finding to 14 CFR Part 33, § 33.27 (a) and (c) Turbine, Compressor, Fan, and Turbosupercharger Rotors - Rotor Integrity Overspeed Test

ELOS Memo No.: 8040-ELOS-08-NE-01

Background

In accordance with the provisions of 14 CFR Part 21, § 21.21(b)(1), P&W GMS requested an alternate method of compliance (MoC) to the requirements of § 33.27 (a) and (c) by demonstrating an Equivalent Level of Safety (ELOS) using analysis instead of test.

P&W proposed to use an analytical model as a means of compliance for the most critically stressed GMS replacement component in the low pressure compressor (LPC) booster spool. P&W has shown that this analysis can be used to calculate dimensional growth and determine if a part is cracked when applied to rotors with material, manufacturing, geometry, stress, and temperature conditions that are representative of the rotor tests that were used to develop and validate this analytical technique.

Applicable Regulation(s)

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

(a) Turbine, compressor, fan, and turbosupercharger rotors must have sufficient strength to withstand the test conditions specified in paragraph (c) of this section.

(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(s) requiring ELOS

§ 33.27(a) and (c)

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

The FAA determined that an ELOS finding to § 33.27(c) can be made using P&W's analytical model for the most critically stressed GMS replacement LPC booster spool component, providing the documentation shows successful demonstration of the following compensating factors:

1. The use of analytical methods is limited to rotors with material, manufacturing, geometry, stress, and temperature conditions that are representative of the rotor tests that were used to develop and validate the analytical technique.

2. Each certification rotor must be adequately similar to a previously tested and certified rotor with respect to each of the following criteria:

   a. Rotor Similarity: Each critical rotor component must have geometric and mechanical characteristics similar to a previously tested and certified rotor.

      i. Geometry Similarity: The comparative description between each critical rotor and a geometrically similar tested rotor must focus on design features that affect:

1. Local and average stress distributions, and
2. Manufacturing process changes.

ii. Mechanical Similarity: The comparative description between each critical rotor and a similar tested rotor must focus on:
1. Material (including but not limited to, ultimate strength and stress-strain curves)
2. Manufacturing methods (including but not limited to, material isotropy and bulk residual stresses)

b. Rotor Criticality: The analysis must show that each certification rotor 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:
i. Strains at limiting locations relative to allowable strains.
ii. Deformations at critical locations relative to their acceptable growth limits.
iii. The ratio between the calculated burst speed at the test conditions and the actual test speed.

3. P&W must also show that the predicted rotor growth supports the selection of the actual serviceable limits versus rotor overspeed level established within the Instructions for Continued Airworthiness under 14 CFR 33.4.

4. For the purposes of analysis and to ensure that consistent comparison techniques are employed, P&W must show that the same current practices and methods being applied to the replacement rotors were used for components of other engines that are part of, and contributed to, this MoC.

5. Though the most critically stressed rotor component of each rotor module is usually the one with the lowest margin to burst, it may not be the most critical rotor with respect to growth. To determine the most critical rotor with respect to growth for compliance with 14 CFR 33.27(c), P&W must also consider the components surrounding each rotor (i.e., clearances, effects of hard contacts between parts, etc.).

Explanation of how compensating factors or alternative standards 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 P&W's proposal to use their analytical model, to identify the most critical rotor component, relative to burst margin and plastic growth, for the GMS replacement LPC booster spool. P&W provided substantiating data confirming that the methodology was validated and calibrated using data from previous FAA-approved

certification component tests. The FAA agreed that P&W's analytical model demonstrated equivalence to testing the GMS critically stressed LPC booster spool component, thus meeting the criteria of § 33.27 (a) and (c).

FAA approval and documentation of the ELOS

The FAA concludes that P&W's proposal to show compliance to the rotor integrity requirements of §33.27 (a) and (c) by an ELOS assessment is an acceptable. 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-08-NE-01, to facilitate archiving and retrieval of this ELOS. This ELOS Memorandum number will be listed in the Type Certificate Data Sheet as part of the certification basis for the P&W GMS program as follows:

Equivalent Level of Safety Findings:

33.27, Turbine, compressor, fan, and turbosupercharger rotors, par. (a) and (c), ELOS No. 8040-ELOS-08-NE-01

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For Concurrence

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