Federal Aviation Administration

Memorandum

Date: January 30, 2006

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

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

Prepared by: Mark Riley (ECO), ANE-142 / Robert Green (ECO), ANE-141

Subject: **ACTION**: Engine Alliance GP7200 Engine Certification Program – Request for Review and Concurrence with Equivalent Level of Safety Finding to 14 CFR Part 33, § 33.27(c) Turbine, Compressor, Fan and Turbo Supercharger Rotors - Rotor Integrity Overspeed Test

Memo No.: 8040-ELOS-05-NE-04

Background

In accordance with the provisions of 14 CFR Part 21, § 21.21(b)(1), the Engine Alliance (EA) requested an alternate method of compliance to the requirements of § 33.27(c) by demonstrating an Equivalent Level of Safety (ELOS) using analysis instead of test for the GP7270 and GP7277 engine models (herein called GP7200). EA proposed to demonstrate through engineering analyses that the most critically stressed GP7200 rotors meet the requirements of § 33.27(c). These analyses will show that all GP7200 rotating disks and drums were designed to have adequate rotor burst speed margin and acceptable growth at the anticipated overspeed conditions as specified in § 33.27(c).

Applicable Regulation(s)

§ 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(s) requiring ELOS
§ 33.27(c)

Description of compensating factors or alternate standards that allows the granting of the ELOS (including design changes, limitations, or equipment need for equivalency)
EA partner company Pratt & Whitney (EA-PW) proposed compliance with the overspeed requirements of § 33.27 by means of a P&W Elastic/Plastic (EP) finite element analysis methodology. The EP analysis predicts rotor burst margin and determines rotor growth, using minimum material properties, for critical rotor hardware installed in the GP7200 Fan, LPC, and LPT engine modules.

EA partner company General Electric (EA-GE) proposed compliance with the overspeed requirements of § 33.27 by means of GE's "Burst Margin Design Procedures" analytical methodology. The analysis predicts rotor burst margin and determines rotor growth, using minimum material properties, for rotor hardware installed in the GP7200 HPT engine module. A spin pit test was conducted for the HPC module for a direct finding of compliance to § 33.27(c).

The FAA concluded that an ELOS finding to § 33.27(c) can be made using the EA-PW EP methodology for the GP7200 Fan, LPC, and LPT critical rotors, and the EA-GE Burst Margin Design Procedure methodology for the GP7200 HPT critical rotor, providing the documentation shows successful demonstration of the accepted compensating factors as follows:

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) Predicted rotor growth must support the selection of the actual serviceable limits versus rotor overspeed level established within the Instructions for Continued Airworthiness under § 33.4.
4) The analysis methodology tool must be previously validated and calibrated based on prior overspeed test results.
5) Critical rotor components for each module must be evaluated considering both lowest margin to burst and total rotor growth.

Explanation of how compensating factors or alternative standards provide an equivalent level of safety to the level of safety intended by the regulation

The FAA concurred with the use of EA-PW's EP methodology to predict critical rotor burst margin and determine radial growth for the critical rotors of the Fan, LPC, and LPT modules. EA-PW provided substantiating data confirming that the EP methodology has been validated and calibrated using data from previous spin pit tests of similar rotors from legacy P&W engines. The FAA agreed with EA-PW that the EP methodology has demonstrated equivalence to testing for GP7200 critically stressed rotors, thus meeting the criteria of § 33.27(c).

The FAA concurred with the use of EA-GE's Burst Margin Design Procedure methodology to predict critical rotor burst margin and determine radial growth for the critical rotor in the HPT module. The methodology was shown to have been validated using data from previous spin pit tests of similar rotors from legacy GE engines. The FAA agreed with EA-GE that the Burst Margin Design Procedure methodology has demonstrated equivalence to testing for the GP7200 critically stressed rotors, meeting the criteria of § 33.27(c).

FAA approval and documentation of the ELOS

The FAA approved the proposed Equivalent Level of Safety finding as documented in GP7200 Issue Papers E-1 and E-2. This memorandum provides standardized documentation of the ELOS that is non-proprietary and can be made available to the public. The Engine & Propeller Directorate has assigned a unique ELOS Memorandum number, 8040-ELOS-05-NE-04, 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 GP7200 engine models as follows:

Equivalent Level of Safety Findings:

33.27, Rotor Integrity, par. (c), ELOS No. 8040-ELOS-05-NE-04

ELOS memo issue date discrepancy
This memo documents that the FAA has concluded that a finding of compliance for the proposed ELOS for § 33.27(c) has been made, and that the Engine & Propeller Directorate concurred with this finding prior to issuance of the GP7200 Type Certificate on December 29, 2005.

(Original signed by Thomas Boudreau)
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For Concurrence

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