Federal Aviation Administration

Memorandum

Date: February 5, 2015

To: Manager, Engine Certification Office, ANE-140

From: Manager, Engine and Propeller Directorate, ANE-100

Prepared by: Kevin Dickert, ANE-141

Subject: INFORMATION**:** Equivalent Level of Safety (ELOS) finding for the GEnx-1B and -2B Series Engines

ELOS Memo#: TC2191EN-E-P1

Regulatory Ref: 14 CFR 21.21 and 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 (ELOS) for the GEnx-1B & GEnx-2B series engines, which include the following engine models: GEnx-1B54, GEnx-1B58, GEnx-1B64, GEnx-1B67, GEnx-1B70, GEnx-1B54/P1, GEnx-1B58/P1, GEnx-1B64/P1, GEnx-1B67/P1, GEnx-1B70/P1, GEnx-1B70/72/P1, GEnx-1B70/75/P1, GEnx-1B74/75/P1, GEnx-1B75/P1, GEnx-1B54/P2, GEnx-1B58/P2, GEnx-1B64/P2, GEnx-1B67/P2, GEnx-1B70/P2, GEnx-1B70/72/P2, GEnx-1B70/75/P2, GEnx-1B74/75/P2, GEnx-1B75/P2, GEnx-1B78/P2, GEnx-2B67, GEnx-2B67B, and GEnx-2B67/P.

Background

On September 8, 2014, the General Electric Company (GE) submitted an application to the ECO to amend the GEnx series Type Certificate to expand the original certification substantiation provided to show compliance of the high pressure turbine (HPT) rotor with the requirements of 33.27 on the GEnx-1B & -2B series of engines.

Title 14, Code of Federal Regulations (14 CFR) 33.27 requires the most critically stressed rotor component of each turbine rotor to be tested for a period of five minutes at the highest of six possible rotor speeds, one of which is 105% of highest speed that would result from failure of the most critical component or system in a representative installation of the engine.

GE proposed an ELOS to the requirements of § 33.27(c)(2)(v), using compensating factors in accordance with the provisions of 14 CFR 21.21(b)(1). The ELOS proposal included GE's design, manufacturing, and maintenance controls; their field experience on engines with similar HPT rotor designs; and specific design aspects of the GEnx HPT rotor to show that a failure of the excluded shaft element cannot be expected to occur during the life of the engine.

Applicable regulation(s)

14 CFR 21.21, 33.27

Regulation(s) requiring an ELOS finding

14 CFR 33.27(c)(2)(v)

Description of compensating design features or alternative Methods of Compliance (MoC) which allow the granting of the ELOS (including design changes, limitations or equipment need for equivalency)

To address the exclusion of a section of the HPT shaft system in determining the maximum required demonstration speed according to 33.27(c)(2)(v) by an ELOS, the FAA has identified the following compensating factors for the ELOS finding:

1. Type design drawing and production assembly process changes have been made to drive improvements into the HPT coupling nut assembly.

2. Similar Maintenance, Repair, and Overhaul (MRO) requirements and assembly process improvements are also being incorporated into the Instructions for Continued Airworthiness (ICA) defined assembly process.

3. The HPT aft shafts, by design, are secondary torque carrying components. This reduces the torsional shear stress and overall operating stresses in the shaft, resulting in high fatigue lives.

4. Robust design and manufacturing:
    a. Both shafts are integral elements of life-limited rotating parts and are subject to all of the controls of life-limited rotating parts and comply with § 33.14 (amendment 21) and CS-E 515.
    b. The materials and design features are commonly used across the GE product lines and are well understood.
    c. Environmental influences have been addressed in the design process. These include, but are not limited to, corrosion, wear, vibration, bearing failures, sump fires, over-heating, fatigue, overload, shock loading, contact with adjacent hardware, over-temperature, etc.

5. Lessons learned have been applied to the design of the GEnx HPT architecture from GE shaft experience. The GEnx shaft system was evaluated relative to historical GE HP shaft operational experience. The GEnx shaft is not susceptible to previously experienced failure modes.

6. GE Design Practices and operational experience with similar sump designs ensure the GEnx design is robust to sump fires.

7. The GEnx Airworthiness Limitations Section (ALS) contains mandatory piece-part level FPI of the entire stage 1 and stage 2 disks, including the shaft areas, as part of the maintenance plan.

8. The overall robustness of this shaft design is supported by successful relevant field experience on the GE90, GP7200, and GEnx engines. This architecture is similar in materials, temperatures, stress levels, LCF lives and damage tolerance capabilities with over 54 million hours / 8.1 million cycles of field operation with no HPT shaft failure or cracking events in operation.

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

1. In operation, the shaft section that is the subject of the ELOS is not the primary torque-carrying member between the HP stage 1 and HP stage 2 disks. This reduces the torsional shear stress and overall operating stresses in the shaft, resulting in high fatigue lives and damage tolerance capabilities.

2. GE Design Practices and operational experience with similar sump designs ensure the GEnx design is robust to sump fires. The GE design practices require buffer cavities and dedicated drain passages to carry oil overboard in the event of a failure or interruptions of the normal oil scavenge system. Analysis at all flight conditions shows that oil will not contact any surfaces hot enough to cause ignition. In the forward bearing sump there are features immediately outboard of the oil seals to catch any leaked oil and direct it to independent drain lines through the frame and overboard. Oil is prevented from entering the airstream and flowing back to the turbine.

3. The ELOS will not exclude the entire shaft and GE will show by engineering assessment that failure of the excluded shaft element(s) cannot be expected to occur during the life of the engine.

FAA approval and documentation of the ELOS finding:

The FAA has approved the aforementioned ELOS finding in GEnx-2B67, GEnx-2B67B and GEnx-2B67/P issue paper P-1. This memorandum provides standardized

documentation of the ELOS findings that are nonproprietary and can be made available to the public. The Engine & Propeller Directorate has assigned a unique ELOS Memorandum number (see front page) to facilitate archiving and retrieval of this ELOS. This ELOS Memorandum number will be listed in the Type Certificate Data Sheet under the Certification Basis. An example of an appropriate statement is provided below.

An Equivalent Level of Safety Finding has been made for the following regulation:

14 CFR 33.27 Turbine, Compressor, Fan, and Turbosupercharger Rotor Overspeed.- (documented in ELOS Memo TC2191EN-E-P1)

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Manager, Engine and Propeller Directorate
Aircraft Certification Service

Date

ELOS Originated by ACO: Engine Certification Office	ACO Manager: Diane Cook (Acting)	Routing Symbol: ANE-140