Federal Aviation Administration

Memorandum

Date: May 3, 2016

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

From: Ann Mollica, Acting Manager, Engine & Propeller Directorate, ANE-100

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Subject: INFORMATION Equivalent Level of Safety (ELOS) finding for the CFM LEAP-1B Series Engines

ELOS Memo#: LEAP1B-2014-TC-01-P-3

Regulatory Ref: 14 CFR 21.21 and 33.83

This memorandum informs the Engine Certification Office, of an evaluation made by the Engine & Propeller Directorate on the establishment of an equivalent level of safety finding for the CFM LEAP-1B series engine models, which include the following engine models: LEAP-1B28 AND LEAP-1B28B2.

Background

CFM proposed a ELOS to the requirements of § 33.83(a) and (b), using compensating factors in accordance with the provisions of 14 CFR 21.21(b)(1). The proposal was to use validated analysis to determine the LPT stages 1 and 2 blades vibration stresses throughout the LEAP-1B operating range up to 105% of the physical and corrected redline speeds.

Applicable regulation(s)

14 CFR 21.21, 33.83

Regulation(s) requiring an ELOS finding

14 CFR 33.83(a), (b)

Description of compensating factors which allow the granting of the ELOS

CFM proposed to show compliance of the LEAP-1B engine to the vibration test requirements of 14 CFR 33.83 (a) and (b) by utilizing validated analysis in lieu of engine test data to determine the LPT stages 1 and 2 blades vibration stresses throughout the LEAP-1B operating range up to 105% of the physical and corrected redline speeds. The analysis includes 3D computation fluid dynamics (CFD) and mechanical finite element model analysis and was calibrated and validated based on engine test data from the LEAP-1A LPT stage 1-4 blades and disks, the LEAP-1B LPT stage 3 blade and LPT stage 1-3 disks and component test data. The compensating factors which allow the granting of this ELOS are:

1. The LEAP-1B engine is similar with the LEAP-1A baseline engine that completed an engine vibration test in compliance with 33.83 requirements. Similarity of the LEAP-1A and LEAP-1B engines is established on the basis of engine and component comparisons, including test data. Demonstration of similarity includes the following:
    a. Engine architecture – dual shaft rotor with a scaled core and turbine center frame immediately upstream of the LPT stage 1 nozzle
    b. Identical LPT blade and disk material
    c. Design approach and 3D geometry of the LPT blades including blade to vane spacing, blade profile, trailing edge thickness, and shroud design
    d. Blade interface with adjacent components and damping technology
    e. Method of fixing the blades in the disk
    f. Strouhal values and Reynolds numbers
    g. Engine operating characteristics including LP rotation speeds at cruise, takeoff, and redline; flowpath pressure, temperature, flow, and area; engine thrust level
    h. Blade and vane count and upstream excitation sources
    i. Blade thermal conditions and allowable vibratory stress
    j. Mode shapes and location of resonant interactions in engine speed and frequency

2. Completion of a LEAP-1B and LEAP-1A instrumented engine test to 105% LP physical and corrected speed that provide the basis for conservatively calibrating and validating the analysis for similar blade modes and excitation sources. Strain gauge data was recorded from all stages during the LEAP-1B test, including all LPT disks and stages 3, 4, and 5 blades and the LPT shaft. Strain gauge data was recorded on all disk, blade stages, and shaft during the LEAP-1A test.

3. CFM developed a validated analysis using LEAP-1B and LEAP-1A engine test data based on CFM's extensive successful experience and design practices for LPT design and HP/LP rotor interaction derived from over 790,000,000 flight hours of service experience. The validated analysis was used to conservatively assess the stress levels of all expected resonant responses, determined by component test and analysis, and engine dynamics forced responses. The validated analysis includes the following elements:

    a. Prediction of the LEAP-1B resonant mode responses based on transposition from measured responses on similar LEAP-1A and LEAP-1B LPT blades. The transposition was applied to measured results of the same mode and excitation as the response being determined. The method accounted for differences in axial spacing, airfoil geometry, and stage pressure by comparing adjacent nozzle pressure wake excitations using 3D CFD analysis combined with correlated engine performance data. Differences in modal stresses were accounted for using finite element model results correlated by 3D laser measurements.

b. The transposition method for aerodynamic excitations was validated by application of the method to measured responses on multiple LEAP-1A and LEAP-1B LPT blades, and comparing the calculated response to the measured value. A calibration factor was determined and applied to all predicted responses. Comparison of predicted responses to measured responses showed the transposition method to be conservative in all cases. The transposition method was then applied to predict stress levels for all required stage 1 and stage 2 responses. If more than one applicable measured response was available, the highest measured response was used.
c. Forced responses and blade/disk mode stresses for the LPT stage 1 and 2 blades were calculated directly using measured disk strain gage data from that stage, incorporating a tuning factor determined using finite element analysis and measured blade/disk stress data from other similar stages.
d. For resonant responses at high rotational speed and high frequency and low engine speed, a conservative assessment of response level was made based on comparative analysis to LEAP-1A and other legacy CFM models designed using similar design practices that also completed instrumented engine tests.

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

The safety objective of § 33.83 is to acquire vibration characteristics of the engine and its component via an engine test (33.83(a)); then use this data to show that the engine is free from high cycle fatigue (HCF) and other harmful effects of vibration. This safety objective is met by satisfying the compensating factors described above. CFM's analysis used data from within the LEAP-1B and from the similar LEAP-1A engine that the LEAP-1B is derived from. The LEAP-1A and LEAP-1B engine architectures, relevant features and operating characteristics are similar. Other than the proposed ELOS, the LEAP-1B and LEAP-1A engines completed instrumented vibration testing throughout the operating range up to 105% of the physical and corrected redline speeds. Prediction of the LEAP-1B resonant mode responses is based on transposition from measured responses on similar LEAP-1A and LEAP-1B LPT blades. The transposition method for aerodynamic excitations was validated by application of the method to measured responses on multiple LEAP-1A and LEAP-1B LPT blades, and comparing the calculated response to the measured value. Forced responses and blade/disk mode stresses for the LPT stage 1 and 2 blades were calculated directly using disk strain gage data from that stage of the LEAP-1B. For resonant responses at high rotational speed and high frequency and low engine speed, a conservative assessment of response level was made based on comparative analysis to LEAP-1A and other legacy CFM models designed using similar design practices that also completed instrumented engine tests.

FAA approval and documentation of the ELOS finding:

The FAA has approved the aforementioned ELOS finding in CFM LEAP-1B issue paper P-3. 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 33.83 Vibration Test, (documented in ELOS Memo LEAP1B-2014-TC-01-P-3)

This ELOS is initially applicable to the engine model(s) listed herein. When the type certificate for that engine model is amended to include other engine model(s) where we find that the compensating factors described herein constitute an ELOS, we will apply this ELOS to the additional engine model(s). In that case, the complete list of models incorporating this ELOS is included in the certification basis section of the Type Certificate Data Sheet.

For Manager, Engine & Propeller Directorate
Aircraft Certification Service

5/3/16
Date