U.S. Department
of Transportation
**Federal Aviation
Administration**

Advisory Circular

Subject: TURBINE ENGINE ROTOR BLADE CONTAINMENT/DURABILITY

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Initiated by: ANE-110
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Change:

1. PURPOSE. This advisory circular (AC) provides guidance and acceptable methods, but not the only methods, that may be used by an applicant in showing compliance with the turbine engine rotor blade containment requirements of Part 33 of the Federal Aviation Regulations (FAR).

2. RELATED FAR. Part 33 Airworthiness Standards: Aircraft Engines, Sections 33.19, Durability, Paragraph (a); 33.75, Safety Analysis; and 33.94, Blade Containment and Rotor Unbalance Tests.

3. RELATED READING MATERIAL. Additional information on rotor blade containment may be found in the following publications.

a. FAA-RD-77-44, Study to Improve Airframe Turbine Engine Rotor Blade Containment.

b. FAA-RD-77-100, Study to Improve Turbine Engine Rotor Blade Containment.

c. NASA report, CR-159544, Containment of Composite Fan Blades - Final Report.

d. Society of Automotive Engineers, Aerospace Information Report No. AIR 4003, Report on Aircraft Engine Containment.

4. BACKGROUND. On February 23, 1984, the Federal Aviation Administration (FAA) published Amendment 10 to FAR Part 33 to update and modernize the technical requirements applicable to the type certification of aircraft engines. The portions applicable to the containment of rotor blade failures modified the requirements for turbine engines, FAR 33.19(a), and added new Section 33.94, Blade Containment and Rotor Unbalance Tests. The guidance in this AC supersedes the rotor blade containment portions of AC No. 33-1B, Turbine Engine Foreign Object Ingestion and Rotor Blade Containment Type Certification Procedures.

5. DEFINITIONS. The following are defined for the purposes of this AC.

a. Maximum permissible rpm means the maximum rotor speed, including transient speeds, as specified by the type certificate data sheet.

b. Critical rotor blade means the compressor or fan blade, and the turbine blade, which when released provides the most challenge to the containment structure (i.e., the least difference between the penetration capability of the resultant material released and the containment capability of the surrounding engine structure) and the most rotor imbalance. The penetration capability of the material released is affected by its shape, orientation at impact, material properties, and kinetic energy.

c. Contained means that no fragments are released through the engine structure, but fragments may be ejected out the engine air inlet or exhaust.

d. Engine structure means the engine structure surrounding the main rotors and extending from the forward-most case flange through the rear-most flange, as defined by the type design.

6. DISCUSSION.

a. General.

(1) The potential hazard resulting from an uncontained turbine engine rotor blade failure has been a long-term concern of the FAA. Part 33 of the FAR has always required the engine to be designed to contain damage resulting from rotor blade failure. Amendment 10 to FAR Part 33 introduced new Section 33.94 which requires blade containment and rotor unbalance tests.

(2) The containment of failed rotor blades is a complex process which involves high energy, high speed interactions of numerous locally and remotely located engine components (e.g., failed blade, other blades, containment structure, adjacent cases, bearings, bearing supports, shafts, vanes, and externally mounted components). Once the failure event starts, secondary events of a random nature may occur whose course and ultimate conclusion cannot be precisely predicted. Some of the structural interactions that have been observed to affect containment are the deformation and/or deflection of blades, cases, rotor, frame, inlet, casing rub strips, and the containment structure.

b. Design and Construction.

(1) FAR Section 33.19(a), Durability, requires that:

(i) The engine design and construction must minimize the development of an unsafe condition between overhaul periods.

(ii) The design of the engine cases must provide for the containment of damage from rotor blade failures.

(iii) The energy levels and trajectories of fragments resulting from a rotor blade failure that lie outside the compressor and turbine rotor cases must be defined.

(2) FAR Sections 33.19 and 33.94 affect the following:

(i) The design of engine structure to contain failed blades.

(ii) The design of engine cases, rotor and static structure, shafts, bearings, and mounts to withstand the resulting loads without hazard to the aircraft.

(3) The applicant should provide as part of the certification data, the necessary information to permit assessment of the critical rotor blade. Analysis of the critical blade should include, as a minimum, the following considerations:

(i) The containment structure should be at the worst temperature and stress condition associated with operation at maximum permissible rpm. The effective structure thickness should be at the minimum allowed by the type design.

(ii) The maximum permissible rpm should be used for each rotor stage evaluated.

(iii) It is possible that the maximum containment structure temperature will not result in the least resistance to blade penetration and rotor unbalance loads. A few structural materials (notably carbon composites) actually increase in strength with increasing temperature. Therefore, if there is a worse realistic combination (of rotor rpm, and containment structure temperature and stress) for the particular type design than (i) and (ii) above, it should also be included in the analysis. (However, it is believed to be unlikely that a lower rpm/temperature combination will produce a worse overall threat to engine structural integrity because of the accompanying decreases in projectile kinetic energy and rotor unbalance loads.)

(iv) The mass of the initial failed blade should be the maximum allowed by the type design, with the failure location as defined in FAR 33.94(a). It is possible that a blade with an integral tip shroud will produce less of a penetration threat than a lighter blade without an integral tip shroud (owing to the latter's smaller shear-plug area and higher contact pressure). In this case, both blades should be considered in the analysis.

(v) Effects of the secondary damage, if any, resulting from the failure of one blade should be evaluated. For example, if a single blade failure liberates part or all of the remaining blades in that stage or other stages, the resultant liberated mass, kinetic energy, and unbalance loads should be considered in determining criticality. There may be development experience with the subject type design, or service experience with a similar type design, that will provide insight to these effects.

(vi) The maximum kinetic energy (translational and rotational) of a single blade failure without dissipation during secondary damage (i.e., maximum piercing potential) should be used.

c. Engine Tests.

(1) Engine Configuration. The engine used for the containment and unbalance tests must meet the type design for those items deemed influential to the test results. Influential items include, but are not limited to, case thickness, retention of external components, blade design, rotor structure, and rotor support structure. A typical aircraft inlet and typical aircraft exhaust nozzle/ducting, or equivalent (i.e., having the same attachment loads and reactions which influence engine case deflections, containment capability, and engine vibratory response), should be used.

(2) Conditions. The engine may be tested at nominal sea level conditions, and:

(i) The critical blade should be released at the maximum permissible rpm with the engine rotor and static structure at the worst associated operating temperatures and stresses, or at any other realistic combination of rpm, temperature, and stress agreed to be more critical.

(ii) High speed photography and witness shields are recommended as means of determining the trajectories and energy levels of fragments that might be ejected out the engine air inlet or exhaust, or that might be released through the wall(s) of the engine casing. Any fragment(s) penetrating and escaping through the engine casing (including any containment wrapping that is partof the engine type design) will normally be cause for failing the test. Even if the penetrating fragments have low retained kinetic energy (after exiting), the engine's containment capability must be considered extremely marginal. The energy levels and trajectories of any fragments exiting the inlet or exhaust should be included in the engine installation manual for consideration by the airframe engineers.

(iii) For some engine type designs, it may be necessary to conduct tests which are more severe than the release of one blade. For example, a certain turbine may be designed to prevent disk burst, upon loss of output shaft load, by shedding its blades. Containment would be required for this condition by FAR 33.75. If the same turbine blade were found to be the most critical under FAR 33.94, and a loss of load / blade shedding test successfully demonstrated structural integrity, it would not be necessary to perform the 33.94 test for the turbine because the demonstrated kinetic energy for penetration and unbalance loads would exceed the FAR 33.94 requirements.

(iv) Following release of the critical blade, no engine control may be adjusted by the operator for at least 15 seconds after indication of excessive vibration or other evidence that would be available to the pilot, in order to simulate crew recognition and reaction time and determine the short term effects of operation with this unbalance.

(3) <u>Test Results</u>. The engine is acceptable if:

(i) At completion of the test, the damage resulting from a critical rotor blade failure is contained by the engine structure, and

(ii) The resultant loads do not cause: distortion of the engine casing, separation of case flanges, rotor unstacking, or other damage, if any of the foregoing would result in a hazardous condition for a typical installation; fire (external or internal); or failure of the engine mounting attachments; and

(iii) Either the engine continues to run for at least 15 seconds after indication of excessive vibration or other evidence that would be available to the pilot, and then can be successfully shut down; or the resulting engine damage induces a self-shutdown anytime after initial blade release.

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