



Advisory Circular

Subject: MINIMIZING THE HAZARDS
FROM PROPELLER BLADE AND HUB
FAILURES

Date: 9/27/00

AC No: 25.905-1

Initiated By: ANM-110

Change:

1. PURPOSE.

a. This Advisory Circular (AC) describes an acceptable means for showing compliance with the requirements of §25.905, "Propellers," of Title 14, Code of Federal Regulations (CFR) part 25. Part 25 contains the airworthiness standards applicable to transport category airplanes. The means of compliance described in this document provides guidance to supplement the normal engineering and operational judgment that forms the basis of any compliance finding. It also provides guidance on design precautions to take to minimize the hazards that could occur to an airplane if a propeller blade fails or is released by a hub failure. In accordance with § 25.905(d), the hazards that must be considered include damage to structure and vital systems due to the impact of a failed or released blade, and the consequent unbalance created by such failure or release. This AC addresses the hazard associated with impact damage; however, it does not address the hazard associated with unbalance created by such failure or release.

b. The guidance provided in this document is directed to airplane and engine manufacturers, modifiers, foreign regulatory authorities, and Federal Aviation Administration (FAA) transport airplane type certification engineers and their designees.

c. As of the issuance date, the guidance provided in this AC was harmonized with that of the European Joint Aviation Authorities (JAA) and provides a method of compliance that has both the FAA and JAA finds acceptable.

d. Like all advisory circular material, this AC is not, in itself, mandatory, and does not constitute a regulation. It describes an acceptable means, but not the only means, for showing compliance with the requirements for transport category airplanes. Terms such as "shall" and "must" are used only in the sense of ensuring applicability of this particular method of compliance when the acceptable method of compliance described in this document is used. While these guidelines are not mandatory, they are derived from extensive Federal Aviation Administration and industry experience in determining compliance with the relevant regulations.

e. This advisory circular does not change, create any additional, authorize changes in, or permit deviations from, regulatory requirements.

2. APPLICABILITY. This AC applies to transport category airplanes type certificated under 14 CFR part 25 (and airplanes type-certificated under predecessor parts 3 and 4b of the Civil Air Regulations) for which an applicant requests a new, amended, or supplemental type certificate. It also applies where major modification to the propulsion system has been made, such as re-engining, installation of a new propeller, or conversion from a reciprocating engine to a turbine engine.

3. RELATED DOCUMENTS.

a. Title 14, Code of Federal Regulations (14 CFR):

§ 25.571 Damage-tolerance and fatigue evaluation of structure

§ 25.903 Engines

§ 25.905 Propellers

b. FAA Advisory Circulars (AC). You can obtain a copy of any of the AC listed below by sending a request to the U.S. Department of Transportation, Subsequent Distribution Center, SVC-121.23, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, Maryland 20785.

AC 20-128A Design Considerations for Minimizing the Hazards Caused by Uncontained Turbine Engine and Auxiliary Power Unit Rotor and Fan Blade Failure, March 25, 1997.

4. DEFINITIONS.

a. Critical Component. Any component whose failure would contribute to or cause a failure condition that would prevent the continued safe flight and landing of the airplane. These components should be considered individually and in relation to other components that could be damaged by the same fragment or by other fragments from the same uncontained event.

b. Fragment Spread Angle. The angle measured fore and aft from the propeller plane of rotation as inscribed by the propeller blade pitch change axis as it rotates about the propeller shaft centerline.

c. Impact Area. The area of the airplane likely to be impacted by uncontained fragments generated in the event of a failed propeller blade or a propeller blade released by a hub failure.

d. Propeller Blade. The complete blade from the airfoil surface to the retention and pitch change portion of the blade that may be contained within the hub. Included are all components attached to the blade, such as counterweights, clamps, erosion shields, cuffs, de-ice boots, and pitch change pins.

e. Uncontained Failure. For the purpose of airplane assessments in accordance with this AC: Any failure that results in the release of fragments from the propeller blade, including the entire blade and hub assembly.

5. BACKGROUND.

a. Regulatory Background. The FAA issued amendment 25-45 to 14 CFR part 25 in 1978, which required that propeller damage considerations under the requirements of § 25.571(e)(2) include considering structural damage that would likely occur following a propeller failure. At that time, paragraph (e) of § 25.571 stated:

“(e) Damage-tolerance (discrete source) evaluation. The airplane must be capable of successfully completing a flight during which likely structural damage occurs as a result of--

(1) Impact with a 4-pound bird at likely operational speeds at altitudes up to 8,000 feet;

(2) Propeller and uncontained fan blade impact;

(3) Uncontained engine failure; or

(4) Uncontained high energy rotating machinery failure.”

(1) Amendment 25-23 also required that the design of turbine engine installations must consider ways to minimize the damage that could be caused by engine debris from an uncontained engine failure. This requirement is stated in §25.903(d) as follows:

“(d) Turbine engine installations. For turbine engine installations--

(1) Design precautions must be taken to minimize the hazards to the airplane in the event of an engine rotor failure or of a fire originating within the engine which burns through the engine case.

(2) The powerplant systems associated with engine control devices, systems, and instrumentation, must be designed to give reasonable assurance that those engine operating limitations that adversely affect turbine rotor structural integrity will not be exceeded in service.”

(2) The FAA later issued amendment 25-72 in 1990, and deleted the requirement to address damage from a failed propeller blade under the discrete damage evaluation criteria defined in § 25.571. Instead, that amendment added a new paragraph (d) to § 25.905, “Propellers,” which broadened the scope of protecting the airplane from damage due to propeller impact. Paragraph 25.905(d) states:

“(d) Design precautions must be taken to minimize the hazards to the airplane in the event a propeller blade fails or is released by a hub failure. The hazards which must be considered include damage to structure and vital systems due to impact of a failed or released blade, and the unbalance created by such failure or release.”

(3) Paragraph 25.905(d) addresses not only *structural damage* that may occur, but also damage that may result in a *hazard to the airplane*, including:

- damage to vital systems, and
- hazards created by propeller unbalance resulting from the failure or release of a propeller blade.

(4) Accountability for propeller damage was removed from § 25.571(e)(2) because the FAA determined that it is not always practicable to assure structural integrity following failure of the large propeller blades that are in use today. [Previously, the FAA routinely granted exemptions from § 25.571(e)(2) to applicants for certification of propeller-driven airplanes in consideration of this issue.] The FAA did determine, however, that it was both technically possible and economically justifiable to require airplane manufacturers to minimize the hazard from propeller blade/hub failures.

(5) The intent of §25.905(d), then, is to ensure that damage from the failure or release of a propeller blade is addressed, in principle, in the same manner that damage from uncontained engine debris is addressed under § 25.903(d).

b. Relevant Existing Guidance. Advisory Circular 20-128A (Design Considerations for Minimizing Hazards Caused by Uncontained Turbine Engine and Auxiliary Power Unit Rotor and Fan Blade Failures) describes techniques for minimizing the hazards to the airplane following an uncontained engine rotor failure. The techniques described in it are also applicable when minimizing the damage from propeller blades. Those techniques include:

- separating critical systems,
- isolating functions,
- incorporating redundant functions, and
- shielding.

(1) Paragraph 6.g. of AC 20-128A defines the area that is likely to be impacted by debris from an uncontained engine event. The impact area that should be consider

propeller blade failures, however, may vary with size, shape, and composition of the blade or blade fragment. The propeller fragment impact zone that should be considered for traditional “straight” propeller blades is based on a spread angle of ± 5 degrees.

(2) However, non-traditional, composite, wide chord, highly-swept propeller blades (for example, propfan, unducted fans, or scimitar-shaped propeller blade designs) have experienced blade failures with trajectories up to 25 degrees forward of the plane of rotation. Based on this information, the impact area for airplanes with non-traditional blades should be evaluated on an individual basis. Applicants should establish the impact area based on test, analysis, or both. Applicants may use data from propellers with similar physical and operating characteristics to establish the impact area.

6. PROPELLER FRAGMENT MODEL. Applicants may use the following propeller failure model when conducting a safety analysis as described in paragraph 7. of this AC, below. When using the specific means of compliance described in this AC, the applicant’s safety analysis should use that propeller’s failure model, unless relevant service experience, design data, test results, or other evidence for the particular propeller type concerned would call for the use of a different, more appropriate propeller model.

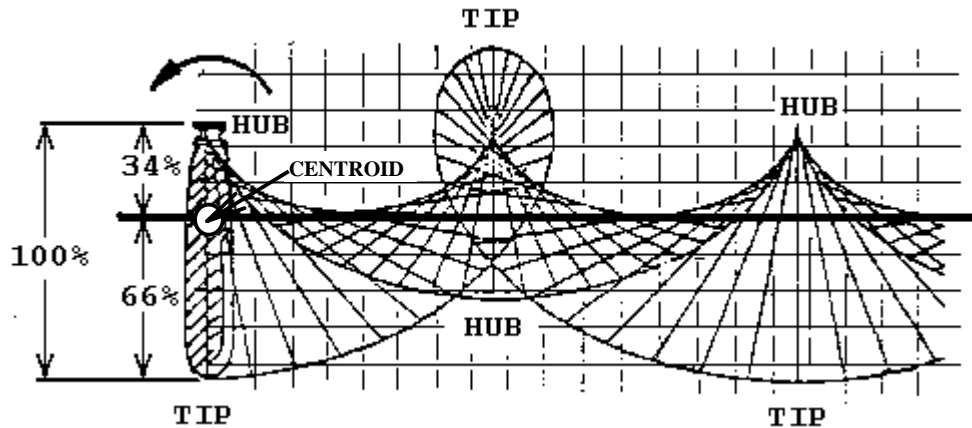
a. **Impact Damage Zone.** Applicants should take design precautions within an impact zone defined by the region between the surfaces created by lines passing through the center of the propeller hub, making angles of ± 5 degrees (see Note, below) forward and aft of the plane of rotation of each propeller.

NOTE: If the propeller or installation has novel or unusual features (for example, propfan, unducted fans, or scimitar-shaped propeller blade designs), the debris trajectories could be different from ± 5 degrees. In this case, the installer should seek the advice of the propeller manufacturer and propeller certifying authority about the correct threat model that should be considered. Applicants should get early agreement with the airplane certification authority for any non-traditional propeller blade fragment threat model that they propose to use in showing compliance with this requirement.

b. **Propeller Blade Path.** The propeller failure model shown in Figure 1, below, is based on a kinematic analysis of an entire released blade, with its centroid traveling in a straight line tangent to the original centroid path. Figure 1 shows that a blade tumbles as it travels tangentially. Therefore, the blade may impact the airplane in a complex manner that will depend on the “clock position” at release and the distance from the point of impact. In addition, aerodynamic loads may affect the blade trajectory. The effect of aerodynamic loads increases as the blade or fragment density decreases.

FIGURE 1

**Graphical Depiction:
Direction of Propeller Rotation**



7. DESIGN PRACTICES TO MINIMIZE BLADE FRAGMENT HAZARD.

a. General. As stated previously, applicants should consider, in principle, the hazards associated with released propeller blades in the same manner as they would consider the hazards of uncontained engine debris, as addressed under the provisions of § 25.903(d).

(1) Techniques defined in AC 20-128A for minimizing the hazards following an uncontained engine rotor failure (i.e., separation of critical systems, isolation of functions, redundancy of functional elements, or shielding) are also applicable when minimizing damage from propeller blade fragments. However, the numerical assessment of fragment size defined in paragraph 9. of AC 20-128A is not applicable for the propeller.

(2) Applicants should take all practical precautions in the airplane's design to minimize, based on good engineering judgment, the risk of catastrophic effects due to the release of part of a blade or a complete blade. The damage to the airplane is variable, depending on the dynamics of the impact. For example, in some cases, the tip of the tumbling blade has impacted the fuselage and the blade has rotated around the outside of the fuselage; this has caused multiple penetration sites and damage to multiple systems that were separated but located near the fuselage skin. In other cases, the tumbling blade has passed through the fuselage, leaving entry and exit holes nearly as long as the blade length. Therefore, when developing minimization techniques used for propeller blade failures, applicants should consider propeller blade dynamics. (Locating separated controls behind airplane structure may provide additional minimization for this unique fragment threat.)

b. Propeller Installation. Applicants should assess an airplane for compliance with § 25.905(d) early in the airplane design process. The applicant's assessment should consider those design features of the propeller installation, including its controls system, that are considered to influence the occurrence of propeller debris release, and the modes of such a failure. Items that should be considered include:

(1) **The vulnerability of critical components and systems** (for example, location, duplication, separation, and protection). Applicants should consider the guidance material contained in AC 20-128A, as appropriate and applicable.

(2) **The fire risk in the event of the release of flammable fluid in association with potential ignition sources** (for example, location, protection, and shut-off means). As an example, applicants should consider locating flammable fluid shutoff means outside the threat from both the engine and propeller fragments threat trajectory areas.

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