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

Advisory Circular

Subject: Engine Failure Loads

Date: 12/12/14
Initiated By: ANM-115

AC No: 25.362-1

1 PURPOSE.

This advisory circular (AC) describes an acceptable means for showing compliance with the requirements of Title 14, Code of Federal Regulations (14 CFR) 25.362, *Engine failure loads*. Section 25.362 specifies the engine failure dynamic load conditions that apply to the engine mounts, pylons, and adjacent supporting airframe structure.

2 APPLICABILITY.

2.1 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.

2.2 The material in this AC is neither mandatory nor regulatory in nature and does not constitute a regulation. While these guidelines are not mandatory, they are derived from extensive FAA and industry experience in determining compliance with the relevant regulations. These means are issued, in the interest of standardization, for guidance purposes and to outline a method that has been found acceptable in showing compliance with the standards set forth in the rule. If, however, we become aware of circumstances that convince us that following this AC would not result in compliance with the applicable regulations, we will not be bound by the terms of this AC, and we may require additional substantiation or design changes as a basis for finding compliance.

2.3 The material in this AC does not change or create any additional regulatory requirements, nor does it authorize changes in, or permit deviations from, existing regulatory requirements.

3 RELATED REGULATIONS.

The following 14 CFR regulations are related to this AC. The full text of these regulations can be downloaded at the U.S. Government Printing Office e-CFR. You can order a paper copy by sending a request to the U.S. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402-0001; or by calling telephone number (202) 512-1800; or by sending a request by facsimile to (202) 512-2250.

3.1 Part 25.

- Section 25.361, *Engine and auxiliary power unit torque*.
- Section 25.629, *Aeroelastic stability requirements*.
- Section 25.901, *Installation*.

3.2 Part 33.

- Section 33.23, *Engine mounting attachments and structure*.
- Section 33.65, *Surge and stall characteristics*.
- Section 33.76, *Bird ingestion*.
- Section 33.94, *Blade containment and rotor unbalance tests*.

4 DEFINITIONS.

Some new terms have been defined for the transient engine failure conditions in order to present criteria in a precise and consistent manner in the following pages. In addition, some terms are employed from other fields and may not necessarily be in general use. For the purposes of this AC, the following definitions should be used:

4.1 Adjacent Supporting Airframe Structure.

Those parts of the primary airframe that are directly affected by loads arising within the engine.

4.2 Ground Vibration Test.

Ground resonance tests of the airplane normally conducted for compliance with § 25.629.

4.3 Transient Failure Loads.

Those loads occurring from the time of the engine structural failure up to the time at which the engine stops rotating or achieves a steady windmilling rotational speed.

4.4 Windmilling Rotational Speed.

The speed at which the rotating shaft systems of an unpowered engine will rotate due to the flow of air into the engine as a result of the forward motion of the airplane.

5 BACKGROUND.

5.1 Requirements.

Section 25.362 requires that the engine mounts, pylons, and adjacent supporting airframe structure be designed to withstand 1g flight loads combined with transient dynamic loads resulting from the specified engine structural failure conditions. The objective is to ensure that the airplane is capable of continued safe flight and landing after sudden engine stoppage or engine structural failure, including ensuing damage to other parts of the engine.

5.2 Engine Failure Loads.

Turbine engines have experienced failure conditions that have resulted in sudden engine deceleration and, in some cases, seizures. These failure conditions are usually caused by internal structural failures or ingestion of foreign objects, such as birds or ice. Whatever the source, these conditions may produce significant structural loads on the engine, engine mounts, pylon, and adjacent supporting airframe structure. With the development of larger, high-bypass ratio turbine engines, it became apparent that engine seizure torque loads alone did not adequately define the full loading imposed on the engine mounts, pylons, and adjacent supporting airframe structure. The progression to high-bypass ratio turbine engines of larger diameter and fewer blades with larger chords has increased the magnitude of the transient loads that can be produced during and following engine failures. Consequently, the applicant should perform a dynamic analysis to ensure that representative loads are determined during and immediately following an engine failure event. A dynamic model of the airplane and engine configuration should be sufficiently detailed to characterize the transient loads for the engine mounts, pylons, and adjacent supporting airframe structure during the failure event and subsequent run-down.

5.3 Engine Structural Failure Conditions.

5.3.1 Of all the applicable engine structural failure conditions, design and test experience have shown that the loss of a blade is likely to produce the most severe loads on the engine and airframe. Therefore, § 25.362 requires that the transient dynamic loads from these blade failure conditions be considered when evaluating structural integrity of the engine mounts, pylons, and adjacent supporting airframe structure. However, service history shows examples of other severe engine structural failures where the engine thrust-producing capability was lost, and the engine experienced extensive internal damage. For each specific engine design, the applicant should consider whether these types of failures present a more critical load condition than blade loss. Examples of other engine structural failure conditions that should be considered in this respect are failure of a shaft, failure or loss of any bearing or bearing support, and bird ingestion. When evaluating bird ingestion, the bird weight and quantity requirements specified in § 33.76 should be used.

5.3.2 Other engine failure conditions that should be considered include partial blade loss and bird strike in which the engine continues to rotate at high speed with significant imbalance before being shut down. If an engine contains fused or frangible bearing supports, and if the engine can run on with a partial blade loss just below the fuse release threshold, significant loads can develop before the engine is shut down. Depending on system modal characteristics, the run-on loads in some parts of the system may exceed the transient loads during a design full blade loss.

6 EVALUATION OF TRANSIENT FAILURE CONDITIONS.

6.1 Evaluation.

6.1.1 The applicant's evaluation should show that, from the moment of engine structural failure and during rundown to the time of windmilling rotational speed, the engine-induced loads and vibrations will not cause failure of the engine mounts, pylon, or adjacent supporting airframe structure. Note that the effects of continued rotation (windmilling) are described in AC 25-24, *Sustained Engine Imbalance*, dated August 2, 2000, or later revision.

6.1.2 Major engine structural failure events are considered as ultimate load conditions, since they occur at a sufficiently infrequent rate. For design of the engine mounts and pylon, the ultimate loads may be taken without any additional multiplying factors. At the same time, protection of the basic airframe is assured by using a multiplying factor of 1.25 on those ultimate loads for the design of the adjacent supporting airframe structure.

6.2 Blade Loss Condition.

6.2.1 The applicant should determine loads on the engine mounts, pylon, and adjacent supporting airframe structure by dynamic analysis. The analysis should take into account all significant structural degrees of freedom. The transient engine loads should be determined for the blade failure condition and rotor speed, as specified in § 33.94, and over the full range of blade release angles to allow determination of the critical loads for all affected components.

6.2.2 The loads to be applied to the pylon and airframe should be determined by the applicant based on the integrated model, which includes the validated engine model supplied by the engine manufacturer.

6.2.3 The calculation of transient dynamic loads should consider the effects of the engine mounting station on the airplane (i.e., right side, left side, inboard position, etc.) and the most critical airplane mass distribution (i.e., fuel loading for wing-mounted engines and payload distribution for fuselage-mounted engines).

6.2.4 For calculation of the combined ultimate airframe loads, the 1g component may be associated with typical flight conditions.

6.3 Other Failure Conditions.

As identified in paragraph 5.3 of this AC, if any of the other engine structural failure conditions specified in § 25.362, applicable to the specific engine design, could result in higher loads being developed than the blade loss condition, those conditions should be evaluated by dynamic analysis to a similar standard and using similar considerations to those described in paragraph 6.2 of this AC.

7 ANALYSIS METHODOLOGY.

7.1 Objective of the Methodology.

The objective of the analysis methodology is to develop acceptable analytical tools for conducting investigations of dynamic engine structural failure events. The goal of the analysis is to produce loads and accelerations suitable for evaluations of structural integrity. However, where required for compliance with § 25.901 regarding powerplant installation, loads and accelerations may also need to be produced for evaluating the continued function of airplane systems related to the engine installation that are essential for immediate flight safety (for example, fire bottles and fuel shut-off valves).

7.2 Scope of the Analysis.

The analysis of the airplane and engine configuration should be sufficiently detailed to determine the transient and steady-state loads for the engine mounts, pylon, and adjacent supporting airframe structure during the engine failure event and subsequent rundown.

8 MATHEMATICAL MODELING AND VALIDATION.

8.1 Components of the Integrated Dynamic Model.

The applicant should calculate airframe dynamic responses with an integrated model of the engine, engine mounts, pylon, and adjacent supporting airframe structure. The integrated dynamic model used for engine structural failure analyses should be representative to the highest frequency needed to accurately represent the transient response. The integrated dynamic model consists of the following components that must be validated:

- Airframe structural model.
- Propulsion structural model (including the engine model representing the engine type design).

8.2 Airframe Structural Model and Validation.

8.2.1 An analytical model of the airframe is necessary in order to calculate the airframe responses due to the transient forces produced by the engine failure event. Airframe manufacturers currently use reduced, lumped-mass finite element analytical models of the airframe for certification of aeroelastic stability (flutter) and dynamic loads. A typical model consists of relatively few lumped masses connected by weightless beams. A full airplane model is not usually necessary for the engine failure analysis, and it is normally not necessary to consider the whole airplane response, the effects of automatic flight control systems, or unsteady aerodynamics.

8.2.2 A lumped mass beam model of the airframe, similar to that normally used for flutter analysis, is acceptable for frequency response analyses due to engine structural failure conditions. However, additional detail may be needed to ensure adequate fidelity for the engine structural failure frequency range. In particular, the engine structural failure analysis requires calculating the response of the airframe at higher frequencies than are usually needed to obtain accurate results for the other loads analyses, such as dynamic gust and landing impact. The applicant should use finite element models as necessary. As far as possible, the ground vibration tests normally conducted for compliance with § 25.629 should be used to validate the analytical model.

8.2.3 Structural dynamic models include damping properties, as well as representations of mass and stiffness distributions. In the absence of better information, it will normally be acceptable to assume a value of 0.03 (i.e., 1.5 percent equivalent critical viscous damping) for all flexible modes. Structural damping may be increased over the 0.03 value to be consistent with the high structural response levels caused by extreme failure loads, provided it is justified.

8.3 **Propulsion Structural Model and Validation.**

8.3.1 The airframe and engine manufacturers should mutually agree upon the definition of the model, based on test and experience.

8.3.2 Engine manufacturers construct various types of dynamic models to determine loads and to perform dynamic analyses on the engine rotating components, its static structures, mounts, and nacelle components. Dynamic engine models can range from a centerline two-dimensional (2D) model, to a centerline model with appropriate three-dimensional (3D) features, such as mount and pylon, up to a full 3D finite element model with explicit time integration used to capture the physics of short duration impact events such as blade loss and bird strike.

8.3.3 These models typically include all major components of the propulsion system, such as the nacelle intake, fan cowl doors, thrust reverser, common nozzle assembly, all structural casings, frames, bearing housings, rotors, and a representative pylon. Gyroscopic effects are included. The models provide for representative connections at the engine-to-pylon interfaces, as well as all interfaces between components (e.g., inlet-to-engine and engine-to-thrust reverser).

8.3.4 Features that should be modeled specifically for blade loss analysis typically include fan imbalance, rotor deceleration rates, component failure and wear, rubs (blade-to-casing, and intershaft), and resulting stiffness changes. Manufacturers whose engines fail the rotor support structure by design during the blade loss event should also evaluate the effect of the loss of support on engine structural response.

8.3.5 The model should be validated based on vibration tests and results of the blade loss test required for compliance with § 33.94, giving due allowance for the effects of the test mount structure. The model should be capable of accurately predicting the transient loads from blade release through rundown to steady state. In cases where compliance with § 33.94 is granted by similarity instead of test, the model should be correlated to prior experience. For compliance with § 25.362, the engine model, once validated, should be modified to include the influence of representative adjacent supporting airframe structure.

8.3.6 Validation of the engine model static structure, including the pylon, is achieved by a combination of engine and component tests that include structural tests on major load path components. The adequacy of the engine model to predict rotor critical speeds and forced response behavior is verified by measuring engine vibratory response when imbalances are added to the fan and other rotors. Vibration data are routinely monitored on a number of engines during the engine development cycle, thereby providing a solid basis for model correlation.

8.3.7 Correlation of the model against the § 33.94 blade loss engine test is a demonstration for which the model accurately predicts initial blade release event loads, any rundown resonant response behavior, frequencies, potential structural failure sequences, and general engine movements and displacements. To enable this correlation to be performed, instrumentation of the blade loss engine test should be used (e.g., use of high-speed cinema and video cameras, accelerometers, strain gauges, continuity wires, and shaft speed tachometers). This instrumentation should be capable of measuring loads on the engine attachment structure.

If you have any suggestions for improving this AC, you may use the Advisory Circular Feedback form at the end of this AC.

Jeffrey E. Duven
Manager, Transport Airplane Directorate
Aircraft Certification Service

Advisory Circular Feedback

If you find an error in this AC, have recommendations for improving it, or have suggestions for new items/subjects to be added, you may let us know by (1) emailing this form to 9-AWA-AVS-AIR500-Coord@faa.gov or (2) faxing it to the attention of the Aircraft Certification Service Directives Management Officer at (202) 267-3983.

Subject: AC 25.362-1, Engine Failure Loads Date: ____________________

Please check all appropriate line items:

☐ An error (procedural or typographical) has been noted in paragraph ______________ on page ________________.

☐ Recommend paragraph _____________ on page ___________ be changed as follows:

☐ In a future change to this AC, please cover the following subject:
(Briefly describe what you want added.)

☐ Other comments:

☐ I would like to discuss the above. Please contact me.

Submitted by: _________________________________ Date: __________________________