c. Other failure conditions. As identified in paragraph 4(c) above, if any other engine structural failure conditions, applicable to the specific engine design, could result in higher loads being developed than the blade loss condition, they should be evaluated by dynamic analysis to a similar standard and using similar considerations to those described in paragraph 5.b., above.

6. ANALYSIS METHODOLOGY.

a. 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 CS 25.901 (“Powerplant installation”), loads and accelerations may also need to be produced for evaluating the continued function of aircraft systems, including those related to the engine installation that are essential for immediate flight safety (for example, fire bottles and fuel shut off valves).

b. Scope of the analysis. The analysis of the aircraft 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 run-down.

7. MATHEMATICAL MODELLING AND VALIDATION

a. Components of the integrated dynamics model. The applicant should calculate airframe dynamic responses with an integrated model of the engine, engine mounts, pylon, and adjacent supporting airframe structure. The model should provide 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). The integrated dynamic model used for engine structural failure analyses should be representative of the aeroplane 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).

b. Airframe Structural Model and Validation

(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. The 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 aeroplane model is not usually necessary for the engine failure analysis, and it is normally not necessary to consider the whole aircraft response, the effects of automatic flight control systems, or unsteady aerodynamics.

(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 CS 25.629 ("Aeroelastic stability requirements") should be used to validate the analytical model.

(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% 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.

c. Propulsion Structural Model and Validation

For propulsion structural model and validation, see AMC 25-24.

[Amdt 25/8]

CS 25.363 Side load on engine and auxiliary power unit mounts

ED Decision 2003/2/RM

(a) Each engine and auxiliary power unit mount and its supporting structure must be designed for a limit load factor in a lateral direction, for the side load on the engine and auxiliary power unit mount, at least equal to the maximum load factor obtained in the yawing conditions but not less than –

(1) 1·33; or

(2) One-third of the limit load factor for flight condition A as prescribed in CS 25.333(b).

(b) The side load prescribed in sub-paragraph (a) of this paragraph may be assumed to be independent of other flight conditions.

CS 25.365 Pressurised compartment loads

ED Decision 2016/010/R

(See AMC 25.365)

For aeroplanes with one or more pressurised compartments the following apply:

(a) The aeroplane structure must be strong enough to withstand the flight loads combined with pressure differential loads from zero up to the maximum relief valve setting.

(b) The external pressure distribution in flight, and stress concentrations and fatigue effects must be accounted for.

(c) If landings may be made with the compartment pressurised, landing loads must be combined with pressure differential loads from zero up to the maximum allowed during landing.

(d) The aeroplane structure must be strong enough to withstand the pressure differential loads corresponding to the maximum relief valve setting multiplied by a factor of 1·33, omitting other loads.

(e) Any structure, component or part, inside or outside a pressurised compartment, the failure of which could interfere with continued safe flight and landing, must be designed to withstand the effects of a sudden release of pressure through an opening in any compartment at any operating altitude resulting from each of the following conditions:

(1) The penetration of the compartment by a portion of an engine following an engine disintegration.

(2) Any opening in any pressurised compartment up to the size Ho in square feet; however, small compartments may be combined with an adjacent pressurised compartment and both considered as a single compartment for openings that cannot reasonably be expected to be confined to the small compartment. The size Ho must be computed by the following formula:

$$H_0 = PA_s$$

where,

H_o = maximum opening in square feet, need not exceed 20 square feet.

P = $\frac{A_s}{6240} + .024$

As = maximum cross sectional area of the pressurised shell normal to the longitudinal axis, in square feet; and

(3) The maximum opening caused by aeroplane or equipment failures not shown to be extremely improbable. (See AMC 25.365(e).)

(f) In complying with sub-paragraph (e) of this paragraph, the fail-safe features of the design may be considered in determining the probability of failure or penetration and probable size of openings, provided that possible improper operation of closure devices and inadvertent door openings are also considered. Furthermore, the resulting differential pressure loads must be combined in a rational and conservative manner with 1 g level flight loads and any loads arising from emergency depressurisation conditions. These loads may be considered as ultimate conditions; however, any deformation associated with these conditions must not interfere with continued safe flight and landing. The pressure relief provided by the intercompartment venting may also be considered.

(g) Bulkheads, floors, and partitions in pressurised compartments for occupants must be designed to withstand conditions specified in sub-paragraph (e) of this paragraph. In addition, reasonable design precautions must be taken to minimise the probability of parts becoming detached and injuring occupants while in their seats.

[Amdt 25/18]

AMC 25.365(e) Pressurised compartment loads

ED Decision 2003/2/RM

The computed opening size from 25.365(e)(2) should be considered only as a mathematical means of developing ultimate pressure design loads to prevent secondary structural failures. No consideration need be given to the actual shape of the opening, nor to its exact location on the pressure barrier in the compartment. The damage and loss of strength at the opening location should not be considered.

A hazard assessment should determine which structures should be required to withstand the resulting differential pressure loads. The assessment of the secondary consequences of failures of these structures should address those events that have a reasonable probability of interfering with safe flight and landing, for example failures of structures supporting critical systems. For this assessment the risk of impact on the main structure from non critical structures, such as fairings, detached from the aircraft due to decompression need not be considered.

CS 25.367 Unsymmetrical loads due to engine failure

ED Decision 2003/2/RM

(a) The aeroplane must be designed for the unsymmetrical loads resulting from the failure of the critical engine. Turbo-propeller aeroplanes must be designed for the following conditions in combination with a single malfunction of the propeller drag limiting system, considering the probable pilot corrective action on the flight controls:

(1) At speeds between V_{MC} and V_D, the loads resulting from power failure because of fuel flow interruption are considered to be limit loads.

(2) At speeds between V_{MC} and V_C, the loads resulting from the disconnection of the engine compressor from the turbine or from loss of the turbine blades are considered to be ultimate loads.

(3) The time history of the thrust decay and drag build-up occurring as a result of the prescribed engine failures must be substantiated by test or other data applicable to the particular engine-propeller combination.

(4) The timing and magnitude of the probable pilot corrective action must be conservatively estimated, considering the characteristics of the particular engine-propeller-aeroplane combination.

(b) Pilot corrective action *may* be assumed to be initiated at the time maximum yawing velocity is reached, but not earlier than two seconds after the engine failure. The magnitude of the corrective action may be based on the control forces specified in CS 25.397(b) except that lower forces may be assumed where it is shown by analysis or test that these forces can control the yaw and roll resulting from the prescribed engine failure conditions.

CS 25.371 Gyroscopic loads

ED Decision 2005/006/R

The structure supporting any engine or auxiliary power unit must be designed for the loads, including gyroscopic loads, arising from the conditions specified in CS 25.331, CS 25.341, CS 25.349, CS 25.351, CS 25.473, CS 25.479, and CS 25.481, with the engine or auxiliary power unit at the maximum rpm appropriate to the condition. For the purposes of compliance with this paragraph, the pitch manoeuvre in CS 25.331(c)(1) must be carried out until the positive limit manoeuvring load factor (point A_2 in CS 25.333(b)) is reached.

[Amdt 25/1]

CS 25.373 Speed control devices

ED Decision 2005/006/R

If speed control devices (such as spoilers and drag flaps) are installed for use in en-route conditions:

(a) The aeroplane must be designed for the symmetrical manoeuvres and gusts prescribed in CS 25.333, CS 25.337, the yawing manoeuvres in CS 25.351, and the vertical and lateral gust and turbulence conditions prescribed in CS 25.341(a) and (b) at each setting and the maximum speed associated with that setting; and

(b) If the device has automatic operating or load limiting features, the aeroplane must be designed for the manoeuvre and gust conditions prescribed in sub-paragraph (a) of this paragraph, at the speeds and corresponding device positions that the mechanism allows.

[Amdt 25/1]

CONTROL SURFACE AND SYSTEM LOADS

CS 25.391 Control surface loads: general

ED Decision 2005/006/R

The control surfaces must be designed for the limit loads resulting from the flight conditions in CS 25.331, CS 25.341(a) and (b), CS 25.349 and CS 25.351, considering the requirements for:

(a) Loads parallel to hinge line, in CS 25.393;

(b) Pilot effort effects, in CS 25.397;

(c) Trim tab effects, in CS 25.407;

(d) Unsymmetrical loads, in CS 25.427; and

(e) Auxiliary aerodynamic surfaces, in CS 25.445.

[Amdt 25/1]

CS 25.393 Loads parallel to hinge line

ED Decision 2016/010/R

(See AMC 25.393)

(a) Control surfaces and supporting hinge brackets must be designed for inertia loads acting parallel to the hinge line. (See AMC 25.393(a).)

(b) In the absence of more rational data, the inertia loads may be assumed to be equal to KW, where –

(1) K = 24 for vertical surfaces;

(2) K = 12 for horizontal surfaces; and

(3) W = weight of the movable surfaces.

[Amdt 25/18]

AMC 25.393(a) Loads parallel to hinge line

ED Decision 2003/2/RM

The loads parallel to the hinge line on primary control surfaces and other movable surfaces, such as tabs, spoilers, speedbrakes, flaps, slats and all-moving tailplanes, should take account of axial play between the surface and its supporting structure in complying with CS 25.393(a). For the rational analysis, the critical airframe acceleration time history in the direction of the hinge line from all flight and ground design conditions (except the emergency landing conditions of CS 25.561) should be considered. The play assumed in the control surface supporting structure, should include the maximum tolerable nominal play and the effects of wear.

CS 25.395 Control system

ED Decision 2003/2/RM

(a) Longitudinal, lateral, directional and drag control systems and their supporting structures must be designed for loads corresponding to 125% of the computed hinge moments of the movable control surface in the conditions prescribed in CS 25.391.

(b) The system limit loads of paragraph (a) need not exceed the loads that can be produced by the pilot (or pilots) and by automatic or power devices operating the controls.

(c) The loads must not be less than those resulting from application of the minimum forces prescribed in CS 25.397(c).

CS 25.397 Control system loads

ED Decision 2016/010/R

(a) *General.* The maximum and minimum pilot forces, specified in sub-paragraph (c) of this paragraph, are assumed to act at the appropriate control grips or pads (in a manner simulating flight conditions) and to be reacted at the attachment of the control system to the control surface horn.

(b) *Pilot effort effects.* In the control surface flight loading condition, the air loads on movable surfaces and the corresponding deflections need not exceed those that would result in flight from the application of any pilot force within the ranges specified in sub-paragraph (c) of this paragraph. Two-thirds of the maximum values specified for the aileron and elevator may be used if control surface hinge moments are based on reliable data. In applying this criterion, the effects of servo mechanisms, tabs, and automatic pilot systems, must be considered.

(c) *Limit pilot forces and torques.* The limit pilot forces and torques are as follows:

Control	Maximum forces or torques	Minimum forces or torques
Aileron: Stick Wheel*	 445 N (100 lbf) 356 DNm (80 D in.lb)**	 178 N (40 lbf) 178 DNm (40 D in.lbf)
Elevator: Stick Wheel (symmetrical) Wheel (unsymmetrical)†	 1112 N (250 lbf) 1335N(300 lbf)	 445 N (100 lbf) 445 N(100 lbf) 445 N (100 lbf)
Rudder	1335 N (300 lbf)	578 N 130 lbf

*The critical parts of the aileron control system must be designed for a single tangential force with a limit value equal to 1·25 times the couple force determined from these criteria.

**D = wheel diameter in m (inches)

†The unsymmetrical forces must be applied at one of the normal handgrip points on the periphery of the control wheel.

(d) For aeroplanes equipped with side stick controls, designed for forces to be applied by one wrist and not by the arms, the limit pilot forces are as follows:

(1) For all components between and including the handle and its control stops:

PITCH		ROLL	
Nose Up	890 N (200 lbf)	Roll Left	445 N (100lbf)
Nose Down	890 N (200 lbf)	Roll Right	445 N (100 lbf)

(2) For all other components of the side stick control assembly, but excluding the internal components of the electrical sensor assemblies, to avoid damage as a result of an in-flight jam:

PITCH		ROLL	
Nose Up	556 N (125 lbf)	Roll Left	222 N (50 lbf)
Nose Down	556 N (125 lbf)	Roll Right	222 N (50 lbf)

[Amdt 25/13]
[Amdt 25/18]

CS 25.399 Dual control system

ED Decision 2006/005/R

(a) Each dual control system must be designed for the pilots operating in opposition, using individual pilot forces not less than –

(1) 0·75 times those obtained under CS 25.395; or

(2) The minimum forces specified in CS 25.397(c).

(b) The control system must be designed for pilot forces applied in the same direction, using individual pilot forces not less than 0·75 times those obtained under CS 25.395.

[Amdt 25/2]

CS 25.405 Secondary control system

ED Decision 2007/010/R

Secondary controls, such as wheel brake, spoiler, and tab controls, must be designed for the maximum forces that a pilot is likely to apply to those controls. The following values may be used:

PILOT CONTROL FORCE LIMITS (SECONDARY CONTROLS).

Control	Limit pilot forces
Miscellaneous: *Crank, wheel, or lever.	$\left(\frac{25.4 + R}{76.2}\right) x\ 222\ N\ (50\ lbf),$ but not less than 222 N (50 lbf) nor more than 667 N (150 lbf) (R = radius in mm). (Applicable to any angle within 20° of plane of control).
Twist	15 Nm (133 in.lbf)
Push-pull	To be chosen by applicant.

*Limited to flap, tab, stabiliser, spoiler, and landing gear operation controls.
[Amdt. 25/3]

CS 25.407 Trim tab effects

ED Decision 2003/2/RM

The effects of trim tabs on the control surface design conditions must be accounted for only where the surface loads are limited by maximum pilot effort. In these cases, the tabs are considered to be deflected in the direction that would assist the pilot, and the deflections are –

(a) For elevator trim tabs, those required to trim the aeroplane at any point within the positive portion of the pertinent flight envelope in CS 25.333(b), except as limited by the stops; and

(b) For aileron and rudder trim tabs, those required to trim the aeroplane in the critical unsymmetrical power and loading conditions, with appropriate allowance for rigging tolerances.

CS 25.409 Tabs

ED Decision 2003/2/RM

(a) *Trim tabs.* Trim tabs must be designed to withstand loads arising from all likely combinations of tab setting, primary control position, and aeroplane speed (obtainable without exceeding the flight load conditions prescribed for the aeroplane as a whole), when the effect of the tab is opposed by pilot effort forces up to those specified in CS 25.397(b).

(b) *Balancing tabs.* Balancing tabs must be designed for deflections consistent with the primary control surface loading conditions.

(c) *Servo tabs.* Servo tabs must be designed for deflections consistent with the primary control surface loading conditions obtainable within the pilot manoeuvring effort, considering possible opposition from the trim tabs.

CS 25.415 Ground gust conditions

ED Decision 2016/010/R

(See AMC 25.415)

(a) The flight control systems and surfaces must be designed for the limit loads generated when the aircraft is subjected to a horizontal 33.44 m/sec (65 knots) ground gust from any direction, while taxying with the controls locked and unlocked and while parked with the controls locked.

(b) The control system and surface loads due to ground gust may be assumed to be static loads and the hinge moments H, in Newton metres (foot pounds), must be computed from the formula:

$$H = K\ 1/2\rho_o V^2 cS$$

where:

K = hinge moment factor for ground gusts derived in subparagraph (c) of this paragraph

ρ_o = density of air at sea level = 1.225 (kg/m^3) (0.0023769 (slugs/ft^3) = 0.0023769 (lb-sec^2/ ft^4))

V = 33.44 m/sec (65 knots = 109.71 fps) relative to the aircraft

S = area of the control surface aft of the hinge line (m^2) (ft^2)

c = mean aerodynamic chord of the control surface aft of the hinge line (m) (ft)

(c) The hinge moment factor K for ground gusts must be taken from the following table:

Surface	*K*	Position of controls
(a) Aileron	0.75	Control column locked or lashed in mid-position.
(b) Aileron	*±0.50	Ailerons at full throw.
(c) Elevator	*±0.75	Elevator full down.
(d) Elevator	*±0.75	Elevator full up.
(e) Rudder	0.75	Rudder in neutral.
(f) Rudder	0.75	Rudder at full throw.

* A positive value of K indicates a moment tending to depress the surface, while a negative value of K indicates a moment tending to raise the surface.

(d) The computed hinge moment of subparagraph (b) must be used to determine the limit loads due to ground gust conditions for the control surface. A 1.25 factor on the computed hinge moments must be used in calculating limit control system loads.

(e) Where control system flexibility is such that the rate of load application in the ground gust conditions might produce transient stresses appreciably higher than those corresponding to static loads, in the absence of a rational analysis an additional factor of 1.60 must be applied to the control system loads of subparagraph (d) to obtain limit loads. If a rational analysis is used, the additional factor must not be less than 1.20.

(f) For the condition of the control locks engaged, the control surfaces, the control system locks and the parts of the control systems (if any) between the surfaces and the locks must be designed to the respective resultant limit loads. Where control locks are not provided then the control surfaces, the control system stops nearest the surfaces and the parts of the control systems (if any) between the surfaces and the stops must be designed to the resultant limit loads. If the control system design is such as to allow any part of the control system to impact with the stops due to flexibility, then the resultant impact loads must be taken into account in deriving the limit loads due to ground gust.

(g) For the condition of taxying with the control locks disengaged, the following apply:

(1) The control surfaces, the control system stops nearest the surfaces and the parts of the control systems (if any) between the surfaces and the stops must be designed to the resultant limit loads.

(2) The parts of the control systems between the stops nearest the surfaces and the cockpit controls must be designed to the resultant limit loads, except that the parts of the control system where loads are eventually reacted by the pilot need not exceed:

(i) The loads corresponding to the maximum pilot loads in CS 25.397(c) for each pilot alone; or

(ii) 0.75 times these maximum loads for each pilot when the pilot forces are applied in the same direction

[Amdt 25/18]

AMC 25.415 Ground gust conditions

ED Decision 2006/005/R

1. PURPOSE. This AMC sets forth acceptable methods of compliance with the provisions of CS-25 dealing with the certification requirements for ground gust conditions. Guidance information is provided for showing compliance with CS 25.415, relating to structural design of the control surfaces and systems while taxying with control locks engaged and disengaged and when parked with control locks engaged. Other methods of compliance with the requirements may be acceptable.

2. RELATED CERTIFICATION SPECIFICATIONS.

CS 25.415 “Ground Gust Conditions”.

CS 25.519 “Jacking and Tie-down Provisions”

3. BACKGROUND.

a. The requirement to consider the effects of ground gusts has been applied to large/transport aeroplanes since 1950. The purpose of the requirement was to protect the flight control system from excessive peak ground wind loads while the aeroplane is parked or while taxying downwind. For developing the original regulation, the control surface load distribution was considered to be triangular with the peak at the trailing edge representing reversed flow over the control surface. This assumption, along with assumptions about the wind approach angle and typical control surface geometries were developed into a table of hinge moment factors and set forth in the regulation. These hinge moment factors have been carried forward to the existing table in CS 25.415. The maximum design wind speed was originally set at 96 km/h (88 feet per second (52 knots)) under the presumption that higher speeds were predictable storm conditions and the aircraft owner could take additional precautions beyond engaging the standard gust locks.

b. The conditions of CS 25.519 require consideration of the aeroplane in a moored or jacked condition in wind speeds up to 120 km/h (65 knots). In order to be consistent in the treatment of ground winds, the wind speeds prescribed by CS 25.415, concerning ground gust conditions on control surfaces, was increased to 120 km/h (65 knots) at Change 15 of JAR-25.

c. There have been several incidents and accidents caused by hidden damage that had previously occurred in ground gust conditions. Although many of these events were for aeroplanes that had used the lower wind speeds from the earlier rules, analysis indicates that the most significant contributor to the damage was the dynamic load effect. The dynamic effects were most significant for control system designs in which the gust locks were designed to engage the control system at locations far from the control surface horn. Based on these events additional factors are defined for use in those portions of the system and surface that could be affected by dynamic effects.

d. The flight control system and surface loads prescribed by CS 25.415 are limit loads based on a peak wind speed of 120 km/h (65 knots) EAS. In operation, the peak wind speed would most often be caused by an incremental fluctuation in velocity imposed on top of a less rapidly changing mean wind speed. Therefore, an appropriate peak wind speed limitation should be reflected in the applicable documents, when there is a potential risk of structural damage.

4. COMPLIANCE.

a. The ground gust requirements take into account the conditions of the aeroplane parked with controls locked, and taxying with controls either locked or unlocked. In either of the locked conditions the control surface loads are assumed to be reacted at the control system locks. In the unlocked condition the pilot is assumed to be at the controls and the controls are assumed to be powered, if applicable. In the latter condition, the control surface loads are assumed to be reacted, if necessary, at the cockpit controls by the pilot(s) up to the limits of the maximum pilot forces and torques given in CS 25.397(c).

b. Where loads are eventually reacted at the cockpit controls, the loads in those parts of the control system between the control system stops nearest the control surfaces and the cockpit controls need not exceed those that would result from the application of the specified maximum pilot effort effects. However, higher loads can be reacted by the control system stops. Those parts of the control system from the control surfaces to the control system stops nearest the surfaces should be designed to the resultant limit loads including dynamic effects, if applicable, and regardless of pilot effort limitations. Similarly, pilot effort limitations would not apply to parts of control systems where the loads are not eventually reacted at the cockpit controls, for example an aileron control