2 To apply CS 25.341(a) gust conditions to CS 25.345(c), the speeds V_{FC} and V_{FD} should be determined for the flap positions selected in en-route conditions.

These procedures should ensure proper speed margins for flap retraction in the case of severe turbulence when the aeroplane is in a low speed en-route holding configuration.

3 The manoeuvre of CS 25.345(c)(1) is to be considered as a balanced condition. (See CS 25.331(b) for definition.)

CS 25.349 Rolling conditions

ED Decision 2016/010/R

(See AMC 25.349)

The aeroplane must be designed for loads resulting from the rolling conditions specified in sub-paragraphs (a) and (b) of this paragraph. Unbalanced aerodynamic moments about the centre of gravity must be reacted in a rational or conservative manner, considering the principal masses furnishing the reacting inertia forces.

(a) Manoeuvring. The following conditions, speeds, aileron deflections and cockpit roll control motions (except as the deflections and the motions may be limited by pilot effort) must be considered in combination with an aeroplane load factor of zero and of two-thirds of the positive manoeuvring factor used in design. For aeroplanes equipped with electronic flight controls, where the motion of the control surfaces does not bear a direct relationship to the motion of the cockpit control devices, these conditions must be considered in combination with an aeroplane load factor ranging from zero to two thirds of the positive manoeuvring factor used in design. In determining the required or resulting aileron deflections, the torsional flexibility of the wing must be considered in accordance with CS 25.301(b):

(1) Conditions corresponding to steady rolling velocities must be investigated. In addition, conditions corresponding to maximum angular acceleration must be investigated for aeroplanes with engines or other weight concentrations outboard of the fuselage, and for aeroplanes equipped with electronic flight controls, where the motion of the control surfaces does not bear a direct relationship to the motion of the cockpit control devices. For the angular acceleration conditions, zero rolling velocity may be assumed in the absence of a rational time history investigation of the manoeuvre.

(2) At V_A, a sudden deflection of the aileron to the stop is assumed.

(3) At V_C, the aileron deflection must be that required to produce a rate of roll not less than that obtained in sub-paragraph (a)(2) of this paragraph.

(4) At V_D, the aileron deflection must be that required to produce a rate of roll not less than one-third of that in sub-paragraph (a)(2) of this paragraph.

(5) For aeroplanes equipped with electronic flight controls, where the motion of the control surfaces does not bear a direct relationship to the motion of the cockpit control devices, in lieu of subparagraphs (a)(2), (a)(3), and (a)(4), the following apply:

(i) At V_A, movement of the cockpit roll control up to the limit is assumed. The position of the cockpit roll control must be maintained until a steady roll rate is achieved and then it must be returned suddenly to the neutral position.

(ii) At V_C, the cockpit roll control must be moved suddenly and maintained so as to achieve a roll rate not less than that obtained in subparagraph (a)(5)(i) of this paragraph. The return of cockpit control to neutral is initiated suddenly when steady roll rate is reached.

(iii) At V_D, the cockpit roll control must be moved suddenly and maintained so as to achieve a roll rate not less than one third of that obtained in subparagraph (a)(5)(i) of this paragraph.

The conditions specified in this subparagraph must be investigated without any corrective yaw control action (pilot or system induced) to maximise sideslip, and, as a separate condition, with corrective yaw control action (pilot or system induced) to reduce sideslip as far as possible. The first condition (without any corrective yaw control action) may be considered as a failure condition under CS 25.302.

(See AMC 25.349(a))

(b) *Unsymmetrical gusts.* The aeroplane is assumed to be subjected to unsymmetrical vertical gusts in level flight. The resulting limit loads must be determined from either the wing maximum airload derived directly from CS 25.341(a), or the wing maximum airload derived indirectly from the vertical load factor calculated from CS 25.341(a). It must be assumed that 100 percent of the wing airload acts on one side of the aeroplane and 80 percent of the wing airload acts on the other side.

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

AMC 25.349(a) Rolling conditions

ED Decision 2013/010/R

The physical limitations of the aircraft from the cockpit roll control device to the control surface deflection, such as control stops position, maximum power and displacement rate of the servo controls, and control law limiters, may be taken into account.

[Amdt 25/13]

CS 25.351 Yaw manoeuvre conditions

ED Decision 2013/010/R

(see AMC 25.351)

The aeroplane must be designed for loads resulting from the yaw manoeuvre conditions specified in subparagraphs (a) through (d) of this paragraph at speeds from V_{MC} to V_D. Unbalanced aerodynamic moments about the centre of gravity must be reacted in a rational or conservative manner considering the aeroplane inertia forces. In computing the tail loads the yawing velocity may be assumed to be zero.

(a) With the aeroplane in unaccelerated flight at zero yaw, it is assumed that the cockpit rudder control is suddenly displaced to achieve the resulting rudder deflection, as limited by:

(1) the control system or control surface stops; or

(2) a limit pilot force of 1335 N (300 lbf) from V_{MC} to V_A and 890 N (200 lbf) from V_C/M_C to V_D/M_D, with a linear variation between V_A and V_C/M_C.

(b) With the cockpit rudder control deflected so as always to maintain the maximum rudder deflection available within the limitations specified in subparagraph (a) of this paragraph, it is assumed that the aeroplane yaws to the overswing sideslip angle.

(c) With the aeroplane yawed to the static equilibrium sideslip angle, it is assumed that the cockpit rudder control is held so as to achieve the maximum rudder deflection available within the limitations specified in sub-paragraph (a) of this paragraph.

(d) With the aeroplane yawed to the static equilibrium sideslip angle of sub-paragraph (c) of this paragraph, it is assumed that the cockpit rudder control is suddenly returned to neutral.

[Amdt 25/13]

AMC 25.351 Yaw manoeuvre conditions

ED Decision 2013/010/R

The physical limitations of the aircraft from the cockpit yaw control device to the control surface deflection, such as control stops position, maximum power and displacement rate of the servo controls, and control law limiters, may be taken into account.

[Amdt 25/13]

CS 25.353 Rudder control reversal conditions

ED Decision 2018/010/R/R

(See AMC 25.353)

The aeroplane must be designed for loads, considered to be ultimate, resulting from the yaw manoeuvre conditions specified in sub-paragraphs (a) through (e) at speed from V_{MC} to V_C/M_C. Any permanent deformation resulting from these ultimate load conditions must not prevent continued safe flight and landing. These conditions are to be considered with the landing gear retracted and speed brakes (or spoilers when used as speed brakes) retracted. Flaps (or flaperons or any other aerodynamic devices when used as flaps) and slats-extended configurations are also to be considered if they are used in en-route conditions. Unbalanced aerodynamic moments about the centre of gravity must be reacted in a rational or conservative manner considering the aeroplane inertia forces. In computing the loads on the aeroplane, the yawing velocity may be assumed to be zero. The applicant must assume a pilot force of 890 N (200 lbf) when evaluating each of the following conditions:

(a) With the aeroplane in un-accelerated flight at zero yaw, it is assumed that the cockpit rudder control is suddenly and fully displaced to achieve the resulting rudder deflection, as limited by the control system or the control surface stops.

(b) With the aeroplane yawed to the overswing sideslip angle, it is assumed that the cockpit rudder control is suddenly and fully displaced in the opposite direction to achieve the resulting rudder deflection, as limited by the control system or the control surface stops.

(c) With the aeroplane yawed to the opposite overswing sideslip angle, it is assumed that the cockpit rudder control is suddenly and fully displaced in the opposite direction to achieve the resulting rudder deflection, as limited by the control system or the control surface stops.

(d) With the aeroplane yawed to the subsequent overswing sideslip angle, it is assumed that the cockpit rudder control is suddenly and fully displaced in the opposite direction to achieve the resulting rudder deflection, as limited by the control system or the control surface stops.

(e) With the aeroplane yawed to the opposite overswing sideslip angle, it is assumed that the cockpit rudder control is suddenly returned to neutral.

[Amdt No: 25/22]

AMC 25.353 Rudder control reversal conditions

ED Decision 2018/010/R10/R

1. Purpose.

This AMC describes acceptable means of compliance with the specifications of CS 25.353. These specifications provide structural design load conditions that apply to the airframe, and that occur as a result of multiple cockpit rudder control (e.g. pedal) inputs.

2. Related CS-25 specifications.

a. CS 25.351, Yaw manoeuvre conditions.

b. CS 25.353, Rudder control reversal conditions.

3. Background.

a. *Specifications*. CS 25.351 and CS 25.353 specify structural design load conditions that occur as a result of cockpit rudder control inputs. These conditions are intended to encompass all of the rudder manoeuvre loads expected to occur in service.

b. *Yaw manoeuvre conditions*. The design load conditions specified in CS 25.351 are considered to be limit load conditions, and a safety factor of 1.5 is applied to obtain the ultimate loads.

c. *Rudder control reversal load conditions*. The design load conditions specified in this CS 25.353 are more severe than those in CS 25.351, and include cockpit rudder control reversals. These conditions are anticipated to occur very rarely, and therefore these are considered to be ultimate load conditions, and no additional safety factor is applied.

d. *Overswing sideslip angle definition*: the maximum (peak) sideslip angle reached by the aeroplane with the cockpit rudder control displaced as specified in paragraph 4.b below.

4. Application of the specifications.

a. *General*

(1) The aeroplane must be designed for the cockpit rudder control reversal load conditions specified in CS 25.353. These are considered to be ultimate load conditions and, therefore, no additional safety factor is applied. However, any resulting permanent deformation must not prevent continued safe flight and landing.

(2) Design loads must be determined as specified in CS 25.321. The load conditions are considered from V_{MC} to V_C/M_C. A pilot force of 890 N (200 lbf) is assumed to be applied for all conditions. These conditions are to be considered with the landing gear retracted and speed brakes (or spoilers when used as speed brakes) retracted.

Flaps (or flaperons or any other aerodynamic devices when used as flaps) and slats-extended configurations are also to be considered if they are used in en-route conditions.

(3) System effects. System effects should be taken into account in the evaluation of this manoeuvre. For example, fly-by-wire aeroplanes should be analysed assuming that the aeroplane is in the normal control law mode. Any system function used to demonstrate compliance with these requirements should meet the following criteria:

(i) The system is normally operative during flight in accordance with the aeroplane flight manual procedures, although limited dispatch with the system inoperative could be allowed under applicable master minimum equipment list (MMEL) provisions, provided that the MMEL requirements are still complied with, taking into account the rudder reversal pedal inputs as the next critical event under dispatch configuration; and

(ii) Appropriate crew procedures should be provided in the event of a loss of function. If a loss of system function would not be detected by the flight crew, the probability of a loss of function (i.e. the failure rate multiplied by the maximum exposure period) should be less than 1/1000.

(4) Failure conditions. Assuming that the systems which are used to demonstrate compliance with CS 25.353 meet the criteria in 4.a(3)(i) and (ii) above, considering the very low probability of a full rudder control (e.g. pedal) doublet event, failure scenarios do not need to be addressed in combination with the rudder control reversal load conditions specified in CS 25.353.

b. *Yaw manoeuvre conditions*

Conditions (a) through (e) of CS 25.353 are intended to be a full displacement cockpit rudder control input followed by three cockpit rudder control reversals and a return to neutral.

The aeroplane airspeed should be kept reasonably constant throughout the manoeuvre using pitch control.

These conditions should be investigated assuming rational or conservative roll control input (pilot or system induced).

Refer to the illustration in Figure 1 below.

(1) *Rudder control input*. In the context of CS 25.353, 'suddenly' means as fast as possible within human and system limitations. In the absence of a rational analysis, the initial rudder control displacement is achieved in no more than 0.2 seconds, and full cockpit rudder control reversal displacement is achieved in 0.4 seconds. Alternatively, the applicant may assume that the rudder control is displaced instantaneously. The resulting rudder displacement should take into account any additional displacement caused by sideslip build-up, and the effects of flexibility should be considered when relevant.

(2) *Rudder control reversals*. As soon as the maximum overswing yaw angle is achieved, full opposite rudder control input is applied. The achieved rudder deflection may be limited by control laws, system architecture, or air loads, and may not be of the same magnitude as the initial rudder deflection prior to the rudder control reversal. For a critically damped aeroplane response, the maximum overswing yaw angle may be assumed to occur when the sideslip angle is substantially stabilised.

Two additional rudder control reversals are performed as defined in paragraph 4.b(1) above. After the second reversal, as soon as the aeroplane yaws to the opposite overswing yaw angle, the rudder control is suddenly returned to neutral.

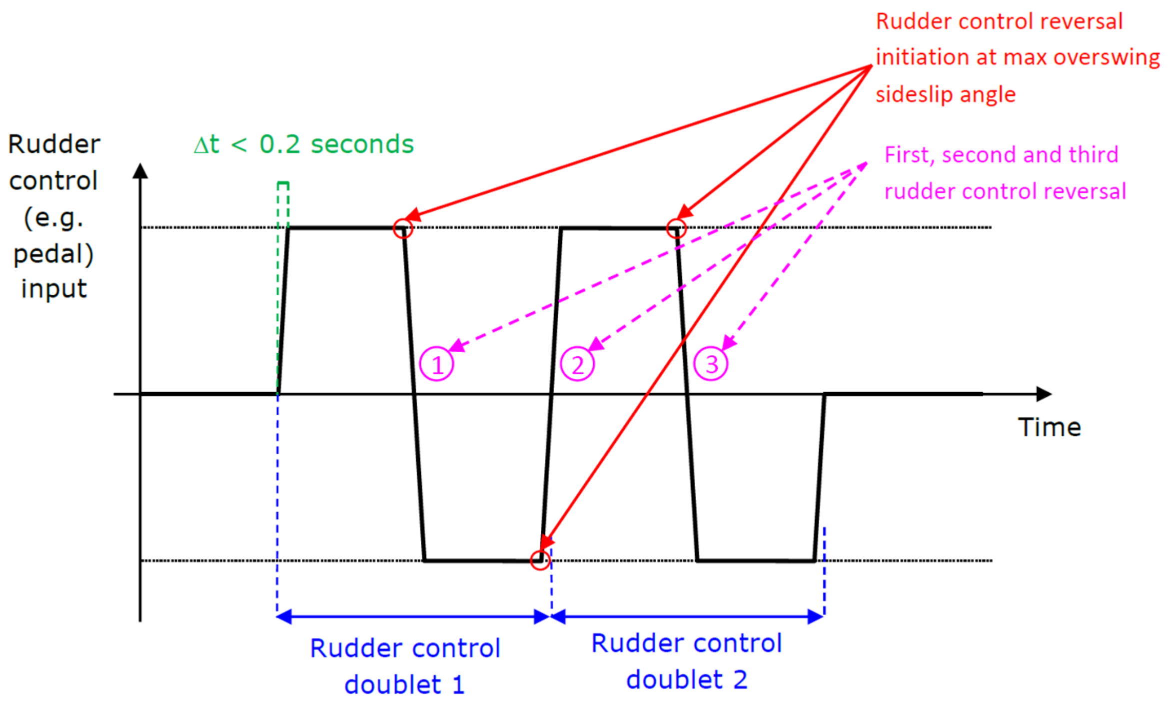

Figure 1: Illustration of the cockpit rudder control inputs

[Amdt No: 25/22]

SUPPLEMENTARY CONDITIONS

CS 25.361 Engine and auxiliary power unit torque

ED Decision 2009/017/R

(See AMC 25.361)

(a) For engine installations:

(1) Each engine mount, pylon and adjacent supporting airframe structures must be designed for the effects of –

(i) A limit engine torque corresponding to take-off power/thrust and, if applicable, corresponding propeller speed, acting simultaneously with 75% of the limit loads from flight condition A of CS 25.333(b);

(ii) A limit engine torque corresponding to the maximum continuous power/thrust and, if applicable, corresponding propeller speed acting simultaneously with the limit loads from flight condition A of CS 25.333(b); and

(iii) For turbo-propeller installations only, in addition to the conditions specified in subparagraphs (a)(1)(i) and (ii), a limit engine torque corresponding to take-off power and propeller speed, multiplied by a factor accounting for propeller control system malfunction, including quick feathering, acting simultaneously with 1 g level flight loads. In the absence of a rational analysis, a factor of 1·6 must be used.

(2) The limit engine torque to be considered under sub-paragraph (1) must be obtained by:

(i) for turbo-propeller installations, multiplying mean engine torque for the specified power/thrust and speed by a factor of 1·25.

(ii) for other turbine engines, the limit engine torque must be equal to the maximum accelerating torque for the case considered.

(3) The engine mounts, pylons, and adjacent supporting airframe structure must be designed to withstand 1g level flight loads acting simultaneously with the limit engine torque loads imposed by each of the following conditions to be considered separately:

(i) sudden maximum engine deceleration due to a malfunction or abnormal condition; and

(ii) the maximum acceleration of the engine.

(b) For auxiliary power unit installations:

The power unit mounts and adjacent supporting airframe structure must be designed to withstand 1g level flight loads acting simultaneously with the limit torque loads imposed by the following conditions to be considered separately:

(1) sudden maximum auxiliary power unit deceleration due to malfunction or abnormal condition or structural failure; and

(2) the maximum acceleration of the auxiliary power unit.

[Amdt 25/8]

AMC 25.361 Engine and auxiliary power unit torque

ED Decision 2009/017/R

CS 25.361(a)(1) is applicable to all engine installations, including turbo-fans, turbo-jets and turbo-propellers, except CS 25.361(a)(1)(iii) which applies only to turbo-propeller installations.

CS 25.361(a)(2)(i) - "Mean engine torque" refers to the value of the torque, for the specified condition, with any dynamic oscillations removed.

CS 25.361(a)(3)(i) - Examples are; high power compressor surges, blade tip rub during manoeuvres, small and medium bird encounters, or combinations of these events.

CS 25.361(a)(3)(ii) and (b)(2) - As an example, the term "maximum acceleration" is taken to be that torque seen by the engine mounts under a runaway of the fuel metering unit up to its maximum flow stop.

[Amdt 25/8]

CS 25.362 Engine failure loads

ED Decision 2009/017/R

(See AMC 25.362.)

(a) For engine mounts, pylons and adjacent supporting airframe structure, an ultimate loading condition must be considered that combines 1g flight loads with the most critical transient dynamic loads and vibrations, as determined by dynamic analysis, resulting from failure of a blade, shaft, bearing or bearing support, or bird strike event. Any permanent deformation from these ultimate load conditions should not prevent continued safe flight and landing.

(b) The ultimate loads developed from the conditions specified in paragraph (a) are to be:

 (1) multiplied by a factor of 1.0 when applied to engine mounts and pylons; and

 (2) multiplied by a factor of 1.25 when applied to adjacent supporting airframe structure.

[Amdt 25/8]

AMC 25.362 Engine Failure Loads

ED Decision 2009/017/R

1. PURPOSE. This AMC describes an acceptable means for showing compliance with the requirements of CS 25.362 "Engine failure loads". These means are intended to provide guidance to supplement the engineering and operational judgement that must form the basis of any compliance findings relative to the design of engine mounts, pylons and adjacent supporting airframe structure, for loads developed from the engine failure conditions described in CS 25.362.

2. RELATED CS PARAGRAPHS.

 a. CS-25:

 CS 25.361 "Engine and auxiliary power unit torque"

 CS 25.901 "Powerplant installation"

b. CS-E:

CS-E 520 "Strength"

CS-E 800 "Bird strike and ingestion"

CS-E 810 "Compressor and turbine blade failure"

CS-E 850 "Compressor, Fan and Turbine Shafts"

3. 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 AMC, the following definitions should be used.

a. Adjacent supporting airframe structure: Those parts of the primary airframe that are directly affected by loads arising within the engine.

b. Ground Vibration Test: Ground resonance tests of the aeroplane normally conducted for compliance with CS 25.629, "Aeroelastic stability requirements."

c. 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.

d. Windmilling engine 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 aeroplane.

4. BACKGROUND.

a. Requirements. CS 25.362 ("Engine failure loads") requires that the engine mounts, pylons, and adjacent supporting airframe structure be designed to withstand 1g flight loads combined with the transient dynamic loads resulting from each engine structural failure condition. The aim being to ensure that the aeroplane 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.

b. 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, it is considered necessary that the applicant performs a dynamic analysis to ensure that representative loads are determined during and immediately following an engine failure event.

A dynamic model of the aircraft and engine configuration should be sufficiently detailed to characterise the transient loads for the engine mounts, pylons, and adjacent supporting airframe structure during the failure event and subsequent run down.

c. Engine structural failure conditions. Of all the applicable engine structural failure conditions, design and test experience have shown that the loss of a fan blade is likely to produce the most severe loads on the engine and airframe. Therefore, CS 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 are applicable, and if they present a more critical load condition than blade loss. In accordance with CS-E 520(c)(2), other structural failure conditions that should be considered in this respect are:

— failure of a shaft, or

— failure or loss of any bearing/bearing support, or

— a bird ingestion.

5. EVALUATION OF TRANSIENT FAILURE CONDITIONS

a. Evaluation. The applicant's evaluation should show that, from the moment of engine structural failure and during spool-down to the time of windmilling engine rotational speed, the engine-induced loads and vibrations will not cause failure of the engine mounts, pylon, and adjacent supporting airframe structure. (Note: The effects of continued rotation (windmilling) are described in AMC 25-24).

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.

b. Blade loss condition. The loads on the engine mounts, pylon, and adjacent supporting airframe structure should be determined 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 approved per CS-E, and over the full range of blade release angles to allow determination of the critical loads for all affected components.

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

The calculation of transient dynamic loads should consider:

— the effects of the engine mounting station on the aeroplane (i.e., right side, left side, inboard position, etc.); and

— the most critical aeroplane mass distribution (i.e., fuel loading for wing-mounted engines and payload distribution for fuselage-mounted engines).

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