5.2.3. Ground vibration Tests.

5.2.3.1. Ground vibration tests (GVT) or modal response tests are normally conducted on the complete conforming aeroplane. A GVT may be used to check the mathematical structural model. Alternatively, the use of measured modal data alone in aeroelastic stability analyses, instead of analytical modal data modified to match test data, may be acceptable provided the accuracy and completeness of the measured modal data is established. Whenever structural modifications or inertia changes are made to a previously certified design or a GVT validated model of the basic aeroplane, a GVT may not be necessary if these changes are shown not to affect the aeroelastic stability characteristics.

5.2.3.2. The aeroplane is best supported such that the suspended aeroplane rigid body modes are effectively uncoupled from the elastic modes of the aeroplane. Alternatively, a suspension method may be used that couples with the elastic aeroplane provided that the suspension can be analytically de-coupled from the aeroplane structure in the vibration analysis. The former suspension criterion is preferred for all ground vibration tests and is necessary in the absence of vibration analysis.

5.2.3.3. The excitation method needs to have sufficient force output and frequency range to adequately excite all significant resonant modes. The effective mass and stiffness of the exciter and attachment hardware should not distort modal response. More than one exciter or exciter location may be necessary to insure that all significant modes are identified. Multiple exciter input may be necessary on structures with significant internal damping to avoid low response levels and phase shifts at points on the structure distant from the point of excitation. Excitation may be sinusoidal, random, pseudo-random, transient, or other short duration, non stationary means. For small surfaces the effect of test sensor mass on response frequency should be taken into consideration when analysing the test results.

5.2.3.4. The minimum modal response measurement should consist of acceleration (or velocity) measurements and relative phasing at a sufficient number of points on the aeroplane structure to accurately describe the response or mode shapes of all significant structural modes. In addition, the structural damping of each mode should be determined.

5.2.4. Flutter Model Tests.

5.2.4.1. Dynamically similar flutter models may be tested in the wind tunnel to augment the flutter analysis. Flutter model testing can substantiate the flutter margins directly or indirectly by validating analysis data or methods. Some aspects of flutter analysis may require more extensive validation than others, for example control surface aerodynamics, T-tails and other configurations with aerodynamic interaction and compressibility effects. Flutter testing may additionally be useful to test configurations that are impractical to verify in flight test., such as fail-safe conditions or extensive store configurations. In any such testing, the mounting of the model and the associated analysis should be appropriate and consistent with the study being performed.

5.2.4.2. Direct substantiation of the flutter margin (clearance testing) implies a high degree of dynamic similitude. Such a test may be used to augment an analysis and show a configuration flutter free throughout the expanded design envelope. All the physical parameters which have been determined to be significant for flutter response should be appropriately scaled. These will include elastic and inertia properties, geometric properties and dynamic pressure. If transonic effects are important, the Mach number should be maintained.

5.2.4.3. Validation of analysis methods is another appropriate use of wind tunnel flutter testing. When the validity of a method is uncertain, correlation of wind tunnel flutter testing results with a corresponding analysis may increase confidence in the use of the analytical tool for certification analysis. A methods validation test should simulate conditions, scaling and geometry appropriate for the intended use of the analytical method.

5.2.4.4. Trend studies are an important use of wind tunnel flutter testing. Parametric studies can be used to establish trends for control system balance and stiffness, fuel and payload variations, structural compliances and configuration variations. The set of physical parameters requiring similitude may not be as extensive to study parametric trends as is required for clearance testing. For example, an exact match of the Mach number may not be required to track the effects of payload variations on a transonic aeroplane.

5.2.5. Flight Flutter Tests.

5.2.5.1. Full scale flight flutter testing of an aeroplane configuration to V_{DF}/M_{DF} is a necessary part of the flutter substantiation. An exception may be made when aerodynamic, mass, or stiffness changes to a certified aeroplane are minor, and analysis or ground tests show a negligible effect on flutter or vibration characteristics. If a failure, malfunction, or adverse condition is simulated during a flight test, the maximum speed investigated need not exceed V_{FC}/M_{FC} if it is shown, by correlation of the flight test data with other test data or analyses, that the requirements of CS 25.629(b)(2) are met.

5.2.5.2. Aeroplane configurations and control system configurations should be selected for flight test based on analyses and, when available, model test results. Sufficient test conditions should be performed to demonstrate aeroelastic stability throughout the entire flight envelope for the selected configurations.

5.2.5.3. Flight flutter testing requires excitation sufficient to excite the modes shown by analysis to be the most likely to couple for flutter. Excitation methods may include control surface motions or internal moving mass or external aerodynamic exciters or flight turbulence. The method of excitation should be appropriate for the modal response frequency being investigated. The effect of the excitation system itself on the aeroplane flutter characteristics should be determined prior to flight testing.

5.2.5.4. Measurement of the response at selected locations on the structure should be made in order to determine the response amplitude, damping and frequency in the critical modes at each test airspeed. It is desirable to monitor the response amplitude, frequency and damping change as V_{DF}/M_{DF} is approached. In demonstrating that there is no large and rapid damping reduction as V_{DF}/M_{DF} is approached, an endeavour should be made to identify a clear trend of damping versus speed. If this is not possible, then sufficient test points should be undertaken to achieve a satisfactory level of confidence that there is no evidence of an adverse trend.

5.2.5.5. An evaluation of phenomena not presently amenable to analyses, such as shock effects, buffet response levels, vibration levels, and control surface buzz, should also be made during flight testing.

[Amdt 25/1]
[Amdt 25/6]
[Amdt 25/16]
[Amdt 25/18]
[Amdt 25/24]

CS 25.631 Bird strike damage

ED Decision 2016/010/R

(See AMC 25.631)

The aeroplane must be designed to assure capability of continued safe flight and landing of the aeroplane after impact with a 4 lb bird when the velocity of the aeroplane (relative to the bird along the aeroplane's flight path) is equal to V_C at sealevel or 0·85 V_C at 2438 m (8000 ft), whichever is the more critical. Compliance may be shown by analysis only when based on tests carried out on sufficiently representative structures of similar design.

[Amdt 25/18]

AMC 25.631 Bird strike damage

ED Decision 2003/2/RM

Consideration should be given in the early stages of the design to the installation of items in essential services, such as control system components, and items which, if damaged, could cause a hazard, such as electrical equipment. As far as practicable, such items should not be installed immediately behind areas liable to be struck by birds.

CONTROL SURFACES

CS 25.651 Proof of strength

ED Decision 2003/2/RM

(a) Limit load tests of control surfaces are required. These tests must include the horn or fitting to which the control system is attached.

(b) Compliance with the special factors requirements of CS 25.619 to 25.625 and 25.657 for control surface hinges must be shown by analysis or individual load tests.

CS 25.655 Installation

ED Decision 2003/2/RM

(a) Movable tail surfaces must be installed so that there is no interference between any surfaces when one is held in its extreme position and the others are operated through their full angular movement.

(b) If an adjustable stabiliser is used, it must have stops that will limit its range of travel to the maximum for which the aeroplane is shown to meet the trim requirements of CS 25.161.

CS 25.657 Hinges

ED Decision 2003/2/RM

(a) For control surface hinges, including ball, roller, and self-lubricated bearing hinges, the approved rating of the bearing may not be exceeded. For non-standard bearing hinge configurations, the rating must be established on the basis of experience or tests and, in the absence of a rational investigation, a factor of safety of not less than 6·67 must be used with respect to the ultimate bearing strength of the softest material used as a bearing.

(b) Hinges must have enough strength and rigidity for loads parallel to the hinge line.

CONTROL SYSTEMS

CS 25.671 General

ED Decision 2020/001/R

(See AMC 25.671)

(a) Each flight control system must operate with the ease, smoothness, and positiveness appropriate to its function. In addition, the flight control system shall be designed to continue to operate, respond appropriately to commands, and must not hinder aeroplane recovery, when the aeroplane is in any attitude or experiencing any flight dynamics parameter that could occur due to operating or environmental conditions.

(b) Each element of each flight control system must be designed to minimise the probability of incorrect assembly that could result in the failure or malfunctioning of the system. Distinctive and permanent marking may be used where design means are impractical, taking into consideration the potential consequence of incorrect assembly.

(c) The aeroplane must be shown by analysis, test, or both, to be capable of continued safe flight and landing after any of the following failures or jams in the flight control system within the normal flight envelope. In addition, it must be shown that the pilot can readily counteract the effects of any probable failure.

(1) Any single failure, excluding failures of the type defined in CS 25.671(c)(3);

(2) Any combination of failures not shown to be extremely improbable, excluding failures of the type defined in CS 25.671(c)(3); and

(3) Any failure or event that results in a jam of a flight control surface or pilot control that is fixed in position due to a physical interference. The jam must be evaluated as follows:

(i) The jam must be considered at any normally encountered position of the control surface, or pilot controls;

(ii) The jam must be assumed to occur anywhere within the normal flight envelope and during any flight phase from take-off to landing; and

In the presence of a jam considered under this sub-paragraph, any additional failure conditions that could prevent continued safe flight and landing shall have a combined probability of 1/1 000 or less.

(d) The aeroplane must be designed so that, if all engines fail at any time of the flight:

(1) it is controllable in flight;

(2) an approach can be made;

(3) a flare to a landing, and a flare to a ditching can be achieved; and

(4) during the ground phase, the aeroplane can be stopped.

(e) The aeroplane must be designed to indicate to the flight crew whenever the primary control means is near the limit of control authority.

(f) If the flight control system has multiple modes of operation, appropriate flight crew alerting must be provided whenever the aeroplane enters any mode that significantly changes or degrades the normal handling or operational characteristics of the aeroplane.

[Amdt 25/18]
[Amdt 25/24]

AMC 25.671 Control Systems — General

ED Decision 2021/015/R

1. PURPOSE

This AMC provides an acceptable means, but not the only means, to demonstrate compliance with the control system requirements of CS 25.671.

2. RELATED DOCUMENTS

a. Advisory Circulars, Acceptable Means of Compliance.

(1) FAA Advisory Circular (AC) 25-7D, dated 4 May 2018, Flight Test Guide for Certification of Transport Category Airplanes.

(2) AMC 25.1309 System Design and Analysis.

b. Standards.

(1) EUROCAE document ED-79A, Guidelines for Development of Civil Aircraft and Systems, issued in December 2010, or the equivalent SAE Aerospace Recommended Practice (ARP) 4754A.

(2) SAE Aerospace Recommended Practice (ARP) 4761, Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment, issued in December 1996.

3. APPLICABILITY OF CS 25.671

CS 25.671 applies to all flight control system installations (including primary, secondary, trim, lift, drag, feel, and stability augmentation systems (refer to CS 25.672)) regardless of implementation technique (manual, powered, fly-by-wire, or other means).

While CS 25.671 applies to flight control systems, CS 25.671(d) does apply to all control systems required to provide control, including deceleration, for the phases specified.

4. DEFINITIONS

The following definitions apply to CS 25.671 and this AMC. Unless otherwise stated, they should not be assumed to apply to the same or similar terms used in other rules or AMC.

a. *At-Risk Time.* The period of time during which an item must fail to cause the failure effect in question. This is usually associated with the final fault in a fault sequence leading to a specific failure condition. See also SAE ARP4761.

b. *Catastrophic Failure Condition.* Refer to AMC 25.1309 (Paragraph 7 FAILURE CONDITION CLASSIFICATIONS AND PROBABILITY TERMS).

c. *Continued Safe Flight and Landing.* The capability for continued controlled flight and landing at an aerodrome without requiring exceptional piloting skill or strength.

d. *Landing.* The phase following final approach and starting with the landing flare. It includes the ground phase on the runway and ends when the aeroplane comes to a complete stop on the runway.

e. *Latent Failure.* Refer to AMC 25.1309 (Paragraph 5 DEFINITIONS).

f. *Error.* Refer to AMC 25.1309 (Paragraph 5 DEFINITIONS).

g. *Event.* Refer to AMC 25.1309 (Paragraph 5 DEFINITIONS).

h. *Exposure Time.* The period of time between the time when an item was last known to be operating properly and the time when it will be known to be operating properly again. See also SAE ARP4761.

i. *Extremely Improbable.* Refer to AMC 25.1309 (Paragraph 7 FAILURE CONDITION CLASSIFICATIONS AND PROBABILITY TERMS).

j. *Failure.* Refer to AMC 25.1309 (Paragraph 5 DEFINITIONS).

The following types of failures should be considered when demonstrating compliance with CS 25.671(c). Since the type of failure and the effect of the failure depend on the system architecture, this list is not exhaustive, but serves as a general guideline.

(1) *Jam.* Refer to the definition provided below.

(2) *Loss of Control of Surface.* A failure that results in a surface not responding to commands. Failure sources can include mechanical disconnection, control cable disconnection, actuator disconnection, loss of hydraulic power, or loss of control commands due to computers, data path or actuator electronics failures. In these conditions, the position of the surface(s) or controls can be determined by analysing the system architecture and aeroplane aerodynamic characteristics; common positions include surface-centred (0°) or zero hinge-moment position (surface float).

(3) *Oscillatory Failure.* A failure that results in undue surface oscillation. Failure sources include control loop destabilisation, oscillatory sensor failure, oscillatory computer or actuator electronics failure. The duration of the oscillation, its frequency, and amplitude depend on the control loop, monitors, limiters, and other system features.

(4) *Restricted Control.* A failure that results in the achievable surface deflection being limited. Failure sources include foreign object interference, malfunction of a travel limiter, and malfunction of an envelope protection. This type of failure is considered under CS 25.671(c)(1) and CS 25.671(c)(2), as the system/surface can still be operated.

(5) *Runaway or Hardover.* A failure that results in uncommanded control surface movement. Failure sources include servo valve jams, computer or actuator electronics malfunctioning. The speed of the runaway, the duration of the runaway (permanent or transient), and the resulting surface position (full or partial deflection) depend on the available monitoring, limiters, and other system features. This type of failure is addressed under CS 25.671(c)(1) and (c)(2).

Runaways that are caused by external events, such as loose or foreign objects, control system icing, or any other environmental or external source are addressed in CS 25.671(c)(2).

(6) *Stiff or Binding Controls.* A failure that results in a significant increase in control forces. Failure sources include failures of artificial feel systems, corroded bearings, jammed pulleys, and failures causing high friction. This type of failure is considered under CS 25.671(c)(1) and CS 25.671(c)(2), as the system/surface can still be operated. In some architectures, higher friction may result in reduced centring of the controls.

k. *Failure Conditions.* As used in CS 25.671(c), this term refers to the sum of all failures and failure combinations contributing to a hazard, apart from the single failure (flight control system jam) being considered.

l. *Flight Control System.* Flight control system refers to the following: primary flight controls from the pilot's controllers to the primary control surfaces, trim systems from the pilot's trim input devices to the trim surfaces (including stabiliser trim), speed brake/spoiler systems from the pilot's control lever to the brake/spoiler panels or other drag/lift-dumping devices, high-lift systems from the pilot's controls to the high-lift surfaces, feel systems, and stability augmentation systems. Supporting systems (i.e. hydraulic systems, electrical power systems, avionics, etc.) should also be included if failures in these systems have an impact on the function of the flight control system.

Examples of elements to be evaluated under CS 25.671 include, but are not limited to:

— linkages,

— hinges,

— cables,

— pulleys,

— quadrants,

— valves,

— actuators (including actuator components),

— flap/slat tracks (including track rollers and movable tracks),

— bearings, axles and pins,

— control surfaces (jam and runaway only),

— attachment fittings.

m. *In-flight* is the time period from the time when the aeroplane is at 10 m (35 ft) above aerodrome level (AAL) following a take-off, up to the time when the aeroplane reaches 15 m (50 ft) AAL prior to landing, including climb, cruise, normal turns, descent, and approach.

n. *Jam.* A failure or event that results in either a control surface, a pilot control, or a component being fixed in one position.

(i) Control surfaces and pilot controls fixed in one position due to a physical interference are addressed under CS 25.671(c)(3). Causes may include corroded bearings, interference with a foreign or loose object, control system icing, seizure of an actuator, or disconnection that results in a jam by creating interference. Normally encountered positions are defined in paragraph 7.b of this AMC.

(ii) All other failures or events that result in either a control surface, a pilot control, or a component being fixed in one position are addressed under CS 25.671(c)(1) and 25.671(c)(2) as appropriate. Depending on the system architecture and the location of the failure or the event, some failures or events that cause a jam may not always result in a fixed surface or pilot control; for example, a jammed valve could result in a surface runaway.

o. *Landing* is the time period from the time when the aeroplane is at 15 m (50 ft) AAL prior to landing, up to the complete stop of the aeroplane on the runway.

p. *Probability versus Failure Rate.* Failure rate is typically expressed in terms of average probability of occurrence per flight hour. In cases where the failure condition is associated with a certain flight condition that occurs only once per flight, the failure rate is typically expressed as average probability of occurrence per flight (or per take-off, or per landing). Failure rates are usually the 'root' numbers used in a fault tree analysis prior to factoring in latency periods, exposure time, or at-risk time. Probability is non-dimensional and expresses the likelihood of encountering or being in a failed state. Probability is obtained by multiplying a failure rate by the appropriate exposure time.

q. *Take-off* is the time period from the brake release up to the time when the aeroplane reaches 10 m (35 ft) AAL.

5. EVALUATION OF FLIGHT CONTROL SYSTEM OPERATION — CS 25.671(a)

a. General.

Flight control systems should be designed such that when a movement to one position has been selected, a different position can be selected without waiting for the completion of the initially selected movement, and the system should arrive at the finally selected position without further attention. The movements that follow and the time taken by the system to allow the required sequence of selection should not adversely affect the controllability of the aeroplane.

b. Abnormal Attitude.

Compliance should be demonstrated by evaluation of the closed-loop flight control system. This evaluation is intended to ensure that there are no features or unique characteristics (including numerical singularities) which would restrict the pilot's ability to recover from any attitude.

Open-loop flight control systems should also be evaluated, if applicable.

For aeroplanes that are equipped with a flight control envelope protection, the attitudes of the aeroplane to be considered should include cases outside the protected envelope.

c. Parameters to be considered

The following relevant flight dynamic parameters should be considered by the applicant (non-exhaustive list):

— Pitch, Roll or Yaw rate

— Vertical load factor

— Airspeed

— Angle of attack

d. Operating and Environmental Conditions

The parameters in paragraph 5.c. above should be considered within the limit flight envelope, which is the flight envelope that is associated with the aeroplane design limits or the flight control system protection limits.

6. EVALUATION OF FLIGHT CONTROL SYSTEM ASSEMBLY — CS 25.671(b)

The intent of CS 25.671(b) is to minimise the risk by design that the elements of the flight control system are incorrectly assembled, such that this leads to significant safety effects. The intent is not to address configuration control (refer to CS 25.1301(a)(2)).

The applicant should take adequate precautions during the design process and provide adequate procedures in the instructions for continued airworthiness to minimise the risk of incorrect assembly (i.e. installation, connection, or adjustment) of elements of the flight control system during production and maintenance. The following steps should be used:

(1) assess the potential effects of potential incorrect assemblies of flight control systems elements and determine a classification of the severity of the associated failure conditions;

(2) when a failure condition is classified as catastrophic, hazardous, or major, EASA normally only accepts physical prevention means in the design of the elements to prevent an incorrect assembly. If, exceptionally, the applicant considers that providing such design prevention means is impractical, this should be presented to EASA. If agreed by EASA, the applicant may then use a distinctive and permanent marking of the involved elements.

(3) failure conditions that are classified either as minor or with no safety effect are not considered to have a significant safety effect.

Examples of significant safety effects:

(1) an out-of-phase action;

(2) reversal in the sense of the control;

(3) interconnection of the controls between two systems where this is not intended;

(4) loss of function.

7. EVALUATION OF FLIGHT CONTROL SYSTEM FAILURES — CS 25.671(c)

Development errors (e.g. mistakes in requirements, design, or implementation) should be considered when demonstrating compliance with CS 25.671(c). However, the guidance provided in this paragraph is not intended to address the means of compliance related to development errors. Development errors are managed through development assurance processes and system architecture. Some guidelines are provided in AMC 25.1309.

CS 25.671(c) requires that the aeroplane be shown by analysis, test, or both, to be capable of continued safe flight and landing following failures in the flight control system within the normal flight envelope.

CS 25.671(c)(1) requires the evaluation of any single failure, excluding the types of jams addressed in subparagraph CS 25.671(c)(3). CS 25.671(c)(1) requires to consider any single failure, suggesting that an alternative means of controlling the aeroplane or an alternative load path is provided in the case of a single failure. All single failures must be considered, even if they are shown to be extremely improbable.

CS 25.671(c)(2) requires the evaluation of any combination of failures not shown to be extremely improbable, excluding the types of jams addressed in CS 25.671(c)(3).

Some combinations of failures, such as dual electrical system or dual hydraulic system failures, or any single failure in combination with any probable electrical or hydraulic system failure, are normally not demonstrated as being extremely improbable.