Certification Authorities for Large Transport Aircraft (CATA)

CATA Worklist Item FAA-005 – Flight Control System – Operation Tests

Date Raised:	23 Nov 2018		Status:	**Closed – Rev 1**
Date Revised	14 Oct 2022: Rev 1 removed footnote 2, which was obsolete			
Subject:	**Flight Control System - Operation Tests**			
Reference Requirements/ Guidance:	CS/RBAC/AWM/14 CFR (5)25.683(a), (5)25.671 and (5)25.681			
Related Issue(s): (Identify Discussion Paper number, if any)	None			

Description of Issue(s):

The FAA harmonized with EASA by adopting 14 CFR 25.683(b) and (c) in 2014. 14 CFR 25.683 and CS 25.683 are now identical. However, there are differences and some uncertainty in the interpretation of this regulation, which have also impacted validation activities with ANAC and TCCA. Validation efficiency will be improved if all four authorities develop a consistent approach for dealing with the four issues identified in the Background section of this CWI.

Background:

The CATA working group agreed to discuss the following:

A. Application of CS/RBAC/AWM/14 CFR (5)25.683(a) to fly-by-wire control systems.
B. To which control systems does 25.683(a) apply?
C. Does 25.683(b) apply to high lift control systems?
D. When is testing necessary to show compliance with 25.683(b)?

SME Recommendation:

(Recommendations from SME Working Group; may contain links and/or embedded documents)

The working group recommends issuance of the policy statements shown in Appendices A, B and C. The policies described below do not supersede regulatory requirements or existing policies.

Final CATA Position:

(Explain agreement, dissent or conclusion on this IP)

The CATA accept the SME team's recommendation and proposed guidance paper. The guidance paper is appended directly to this CWI.

The CWI represents an agreement that the guidance paper is harmonized and accepted by all CMT authorities.

The CWI form, including the appended guidance, document a CMT member authority agreement that member authorities may reference when they are acting as the certificating authority (CA). Following CA endorsement for a particular project, the other CMT member authorities, when acting as validating authority, will accept the approach.

If any member-authority under CATA becomes aware of circumstances that make it apparent that following the guidance paper would not result in compliance with the member-authority's applicable

airworthiness standards, then the use of this guidance paper is non-binding and the member-authority may require additional substantiation or design changes as a basis for finding compliance.

This CWI is closed.

CATA Signatures:

CATA Representative	Name	Signature	Date
ANAC	Daniel Pessoa	/s/	Sept. 28, 2022
	Willian Tanji	/s/	Sept. 28, 2022
EASA	Colin Hancock	/s/	Sept. 27, 2022
	Mathilde Labatut	/s/	Sept. 28, 2022
FAA	Suzanne Masterson	/s/	Sept. 25, 2022
	Hung Cao	/s/	Sept. 26, 2022
TCCA	Canh Nham	/s/	Sept. 29, 2022
	André Celere	/s/	Sept. 29, 2022

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Appendix A

Operation tests – Compliance with CS/RBAC/AWM/14 CFR (5)25.683(a), and related regulations CS/RBAC/AWM/14 CFR (5)25.671 and CS/RBAC/AWM/14 CFR (5)25.681

Summary

On airplanes that incorporate fly-by-wire (FBW) control systems, there are unique considerations for compliance with the operation test requirement of CS/RBAC/AWM/14 CFR (5)25.683(a), and related regulations CS/RBAC/AWM/14 CFR (5)25.671 and CS/RBAC/AWM/14 CFR (5)25.681. While the focus of this policy is FBW control systems, paragraphs 1, 3 and 4 below would also apply to non-FBW control systems.

Background

CS/RBAC/AWM/14 CFR (5)25.683(a) requires operation tests to show that when the control system subject to pilot effort loads is loaded to 80 percent of limit load, and the powered portions of the control system are loaded to the maximum load expected in normal operation, the system is free from jamming, excessive friction, and excessive deflection.

CS/RBAC/AWM/14 CFR (5)25.683(a) was originally intended to address mechanical control systems and was based on the assumption that the pilot control forces would be transmitted through mechanisms and control cables, and reacted through the control surface horn, artificial feel and centering units, or both. Applying CS/RBAC/AWM/14 CFR (5)25.683(a) to a fly-by-wire control system is not as straightforward given the unique characteristics of those systems. For example, in some designs, there may be little or no mechanical controls or linkages beyond the pilot control device (rudder pedal, control column, or side stick, etc.). Also, the unpowered portions of the control system are only subject to very low artificial feel forces, and pilot loads that exceed those forces are reacted by mechanical system stops.

Policy

1. CS/RBAC/AWM/14 CFR (5)25.683(a) applies to primary and secondary flight control systems, including the elevator, horizontal stabilizer, aileron, flaperon and rudder systems, as well as flaps, slats, tabs, spoilers and speed brakes. While similar operations tests and criteria (free from jamming, excessive friction, and excessive deflection) may be needed on other mechanical systems, these would be addressed by compliance to different requirements; for example, CS/RBAC/AWM/14 CFR (5)25.1309(a), 25.729(d) and CS 25.745.

2. Compliance with CS/RBAC/AWM/14 CFR (5)25.683(a) for portions of a fly-by-wire control system subject to pilot effort loads.

2.1 In these portions of a FBW control system, the highest control system loads expected in normal operation (without failures or jamming) are typically the maximum feel forces generated by the system in reaction to pilot input.

2.2 The regulation indicates that the control system subject to pilot effort loads should be loaded to 80% of limit load. The 80% value was originally associated with higher control system loads when the pilot control inceptors were mechanically connected to the control surfaces – see CS/RBAC/AWM/14 CFR (5)25.395, which includes an additional 125% factor on limit loads. For systems in which the control inceptors are not connected to the control surfaces, the 80% value is no longer meaningful and maximum feel forces should be used in lieu of 80% of limit load.

2.3 The applicant should demonstrate by test that the system is free from jamming, excessive friction and excessive deflection at the highest feel forces that the artificial feel system can generate during normal operation (including trim) and under envelope protection conditions such as stall and overspeed, if the aircraft is equipped with envelope protection logics. The applicant should test the system through its range of travel at the maximum feel forces.

2.4 Maximum feel forces should be determined considering control displacement and any other system feedback. The rate of control movement should be considered if damping characteristics could affect the results.

2.5 Once the control reaches the stops, the following pilot forces should be applied to ensure that excessive deflection in the control system does not occur: For conventional primary controls, 80% of the maximum pilot forces specified in CS/RBAC/AWM/14 CFR (5)25.397(c); and, for side stick controls, 80% of the pilot forces specified in CS 25.397(d)(1).

3. Compliance with CS/RBAC/AWM/14 CFR (5)25.683(a) for the powered portions of a control system.

3.1 Section 25.683(a) states that the powered portions of the control system must be tested with the system loaded to the maximum load expected in normal operation. The "maximum load expected in normal operation" means the limit loads specified for the system in question, without failures or jamming (per 25.681, see 4.1 below).

3.2 For the powered portion of the control system, the test conditions should include maximum control system load as well as full deflection of the control surface.

4. Other testing requirements.

4.1 Section 25.681 states: "Compliance with the limit load requirements of this Part must be shown by tests …." The limit loads referenced in 25.681 include all the control system load requirements specified in 25.391 through 25.459.

4.2 Functional tests may also be necessary to demonstrate compliance with the failure and jamming requirements in 25.671(c).

4.2.1 Section 25.671(c)(1) and (2): Some failures in the flight control system may result in higher than normal pilot forces.

4.2.2 Section 25.671(c)(3): Many designs rely on dedicated breakout mechanisms as mitigation to ensure continued safe flight and landing after the occurrence of flight control jams. Some of these mechanisms require the pilots to apply a higher than normal force to the inceptor to activate the breakout mechanism.

4.2.3 To ensure compliance with the failure requirements of CS/RBAC/AWM/14 CFR (5)25.671(c), the control system may need to be tested to demonstrate the system functions properly considering the higher control forces resulting from failures and jams. The applicant should demonstrate that the system is free from additional jamming, excessive friction and excessive deflection[1] to the extent that it does not impair continued safe flight and landing following:

a) activation of any jam alleviation device or any device that may increase the control forces needed to displace the control through full travel, and

b) any single failure or other failure condition not shown to be extremely improbable which could result in an increase in pilot control forces needed to displace the control through full travel (e.g. if the artificial feel system has a failure mode that could lead to higher pilot forces).

[1] The use of the phrase "jamming, excessive friction and excessive deflection" may cause confusion since these terms are used in 25.683. These terms are used here to provide added criteria for compliance with 25.671 continued safe flight and landing, and do not imply a link with 25.683, nor that compliance with 25.683 must be demonstrated in the presence of failures.

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Appendix B

Application of CS/RBAC/AWM/14 CFR (5)25.683(b) to High Lift Control Systems

Background

CS/RBAC/AWM/14 CFR (5)25.683(b) is harmonized. The regulation requires the applicant show that in the presence of structural deflections due to pitch, roll, and yaw limit maneuver loads, applied separately, the control system can be exercised about all control axes and remain free from jamming, excessive friction, disconnection, and any form of permanent damage.

EASA, ANAC, TCCA and FAA differ on whether (5)25.683(b) applies to high lift control systems. EASA, ANAC and TCCA have determined that CS/RBAC/AWM (5)25.683(b) applies to high lift control systems, while the FAA position is that § 25.683(b) does not apply to high lift control systems.

Policy

While the authorities differ on the applicability of the subject requirement, they agree that high lift control systems must be designed to operate without jamming, excessive friction, disconnection or permanent damage in normal operation when the airframe undergoes deformation induced by limit maneuver loads. EASA, ANAC and TCCA ensure this objective is achieved by applying CS/RBAC/AWM (5)25.683(b) to high lift control systems.

The FAA ensures the equivalent objective is achieved by application of other regulations, such as 14 CFR 25.305 and 25.1309.

14 CFR 25.305 Amdt. 25-86 includes:

> (a) The structure must be able to support limit loads without any detrimental permanent deformation. *At any load up to limit loads, the deformation may not interfere with safe operation.*

14 CFR 25.1309(a) Amdt. 25-123 states:

> The equipment, systems, and installations whose functioning is required by this subchapter, must be designed to ensure that they perform their intended functions under any foreseeable operating condition.

Section 25.305 requires that the high lift system and structure be designed for the limit loads defined mainly under 14 CFR 25.345, and that the effects of deformation, including wing deflection, be considered. In addition, 14 CFR 25.1309(a) requires the applicant to show that the high lift control system performs its intended functions under any foreseeable operating

condition, which would include up to the limit load specified in 14 CFR 25.345, or up to the maximum system operating capability.[2]

While the authorities differ on which requirements address this concern, the design and compliance intent is harmonized between authorities, and therefore the authorities do not envisage that distinct demonstrations of compliance would be needed.

[2] The requirements referenced in this appendix generally require that high lift control systems operate without failure, jamming, excessive friction, disconnection or permanent damage up to the limit load maneuver requirements. However, some airplanes are equipped with high lift actuation load limiters (typically torque limiters), which may limit operation of the high lift actuation below a point at which the limit loads specified under 25.345 would be reached. For airplanes so equipped, the operational test requirements need not extend beyond the system operational capability. All authorities agree to this point.

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Appendix C

Compliance with CS/RBAC/AWM/14 CFR (5)25.683(b) by Analysis and Test

Background

CS/RBAC/AWM/14 CFR (5)25.683(b) states that compliance must be shown by "analysis and, where necessary, by tests." This policy describes the conditions under which analysis may be used and when testing may be required.

Control systems are typically attached to or routed through adjacent aircraft structure in the wing and empennage. CS/RBAC/AWM/14 CFR (5)25.683(b) requires that deflections of the adjacent structure due to external loading do not adversely affect the safe operation of the control system through its operational range of deflections (i.e. without causing jamming, excessive friction, disconnection and any form of permanent damage) when the control system is loaded to obtain these structural deflections.

Policy

In general, the authorities will accept analysis if it has been validated by test data; i.e. if the analysis / model has been shown adequately representative of the aircraft characteristics over the range of conditions considered. The authority may accept this validated analysis alone as means of compliance, or may determine that (additional) testing is necessary to show compliance.

The applicant and the authorities should consider the following when determining whether (additional) testing is required:

- Are there areas highlighted by the analysis or design review identified as susceptible to jamming, friction, disconnection or damage?
- How well is the analysis verified and validated? What is the accuracy of the analysis and what are its limitations?
- What is the complexity of the installation and kinematics, extent of clearances, extent of wing deflection, etc.?
- What is the extent of similarity with previously tested configurations? Any similarity argument should be detailed and supported, and account for both similarity of design and similarity of loading conditions.

Testing may include component testing or full-scale ground and/or flight tests.

For a new airplane and for major derivatives, some level of structural testing of the fixed surfaces (wing, vertical tail, or horizontal tail) under load is usually necessary for compliance with CS/RBAC/AWM/14 CFR (5)25.307. The applicant can perform operation tests to show compliance with CS/RBAC/AWM/14 CFR (5)25.683(b) during these structural proof tests, if the test article is so equipped. With the fixed surface deflected up to limit load, the control surfaces are displaced through their full operational range of deflections. If possible given the testing apparatus, the control surfaces should be loaded as well, but may be unloaded provided the

control surface loading is accounted for in the analysis. If full deflection of the control surface under load is not possible due to the constraints of the loading apparatus, the control surface should remain unloaded so that full deflection can be achieved.

Also, during flight testing, the applicant could demonstrate safe operation of the control system in accordance with § 25.683(b) at or near limit manoeuvre load levels. The applicant should ensure that instrumentation for such testing is adequate to evaluate the control system operation. Some ground testing or analysis should be conducted prior to this flight testing to ensure safety of flight. In addition, a detailed inspection of the airplane after the flight testing may be used to support compliance. The inspection should look for evidence of unwanted contact, friction, or damage. Further tests or analysis would be required to cover the full operational range of deflections, where not reached during the flights.

Whether by test, analysis, or a combination thereof, the applicant should present their proposed methodology to the authority for approval. Where analysis and modeling are used, the methodology should include discussion of the following items:

- General description of the models, as well as software tools used
- Previous experience of the applicant in performing such analyses
- Code, data, model and solution/calculation verification activities performed
- How errors and uncertainties in both analysis results and test data are addressed
- Assumptions (and simplifications) in the modelling
  - Model accuracy (geometrical representativeness and accuracy of parts and kinematics, geometric and material non-linearities, contact and fastener modelling, pre-stressing, friction, etc.)
  - Consideration of the aeroplane structure/control surface/hinge line manufacturing tolerances and actuator and surface rigging tolerances
- Validation strategy of the models vs test results; for example, the building block approach, validation metrics and accuracy requirements
- Validation of the model, including external loads, fixed surface deflections, stiffness, actuation forces and torques, clearances, spline-shaft engagement (if applicable), over the range of conditions considered
- Identification of key model parameters including sensitivity analysis
- Consideration for thermal effects
- Pass/Fail criteria for contact/interference
- Limitations of models/analyses identified
- Evaluation of excessive friction:
  - Comparison of tested and simulated/calculated actuation forces/torques.
  - Evaluation of clearances/clash/restrictions including kinematic analysis of angles of universal joints, spherical bearings, etc.