STEPLESS
High-Lift Devices with Stepless Operation: Certification Requirements

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Abstract

STEPLESS introduces a novel, dynamic approach to flap and slat deployment to optimise aircraft energy management during descent and approach while reducing fuel and noise. To achieve this goal, a concept for stepless flaps is introduced. Currently, the certification specifications foresee specific flap positions. For the introduction of a concept for stepless flaps, important requirements are identified and, where necessary, adaptations are proposed, or an alternative certification process suggested.

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STEPLESS

STEPLESS HIGH-LIFT CONFIGURATIONS FOR OPTIMISED AIRCRAFT ENERGY MANAGEMENT IN THE TMA

STEPLESS

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1 Introduction

The project STEPLESS aims to optimise the aircraft energy management during the flight phases descent and approach. For that purpose, the aim is to design an aircraft concept with stepless positioning of high-lift devices. Currently, high-lift devices have discrete settings unlike primary flight controls like aileron, rudder and elevator. By enabling stepless positioning, the project seeks to improve the overall efficiency and performance of the aircraft during these flight phases.

The requirements that aircraft of the type addressed in this project must comply with are outlined in the **Certification Specifications and Acceptable Means of Compliance for Large Aeroplanes (CS-25)**, specifically with the current version being **Amendment 28**, effective as of 15 December 2023. This regulatory framework, established by the European Union Aviation Safety Agency (EASA), provides the standards and guidelines that large aeroplanes must meet to ensure safety and airworthiness. Compliance with CS-25 is mandatory for the certification and operation of large aeroplanes. In case of new technology, which cannot fully be covered with the certification basis, the process of a Certification Review Item (CRI) for an Equivalent Safety Finding (ESF) can be followed as part of the certification process.

The intention of this report is to provide an overview of the requirements that must be considered for the design of a system incorporating stepless high-lift devices. Furthermore, it aims to propose targeted adaptations to existing requirements where necessary, such as revising paragraphs that specifically reference fixed flap settings or positions, to accommodate the concept of stepless high-lift devices. This will facilitate the integration of this technology into the regulatory framework, ensuring safety and compliance with aviation standards. However, the adaptations are considered a theoretical theme and fulfil the purpose to evaluate the impact of stepless high-lift devices on the certification basis, which is a task of the project. For a more practical roadmap to certification, the Certification Review Item should be considered.

The original version of this document provided an analysis for EASA's review and comment. EASA's feedback was partly implemented into this analysis, influencing the project's outcome. This process ensures the project meets regulatory requirements and safety standards, contributing to a safe and compliant aircraft design. Especially, the Certification Review Item was added as a valid process for a roadmap to certification. Furthermore, the list with important requirements was reviewed and updated, while the adaptations to certain requirements were not further revised in order to keep them as indications for potential issues of the certification basis when looking at stepless high-lift devices.

This document is structured with three main parts as followed: First, an overview of requirements of the CS-25, which are relevant for the implementation of stepless high-lift devices, are pointed out. This shows which paragraphs need to be considered for safety purposes. Second, the relevant paragraphs, which provide necessary safety standards, are given. This part comprises important requirements specific for the design of a system with stepless high-lift devices, but which do not need to be adapted. Third, potential adaptations to the CS-25 are addressed to provide a basis for a design with stepless flaps. Finally, a conclusion about the findings is given.

2 Overview Requirements

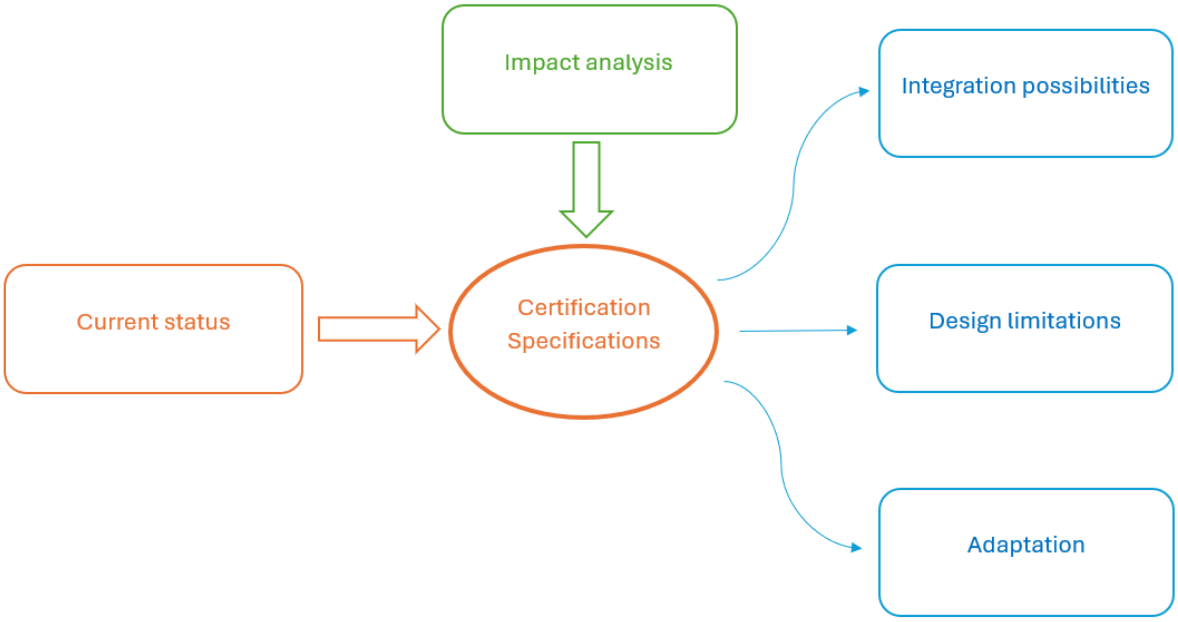

Figure 1: Certification Specifications and Impact

The current certification specifications for large aeroplanes, the CS-25, are designed based on the actual technology level. New technology might require adaptations, since the technology was not foreseen at the time of the formulation of the certification specifications. Nevertheless, the certification specifications establish a safety standard that any new aircraft design must fulfil. The current technology status has influenced the certification specifications, as can be seen in Figure 1. With an impact analysis, the new technology, here stepless flaps, will be analysed and their influence on the certification specifications will be evaluated. This analysis will provide integration possibilities of stepless flaps in the current rules, but also design limitations can be indicated. Further, an adaptation of particular paragraphs of the CS-25 will be proposed to provide a basis for the development of an aircraft design with stepless flaps. This analysis does not include the rulemaking process.

In case new regulations or adaptations should be implemented in the certification specifications, a rulemaking process has to be followed. This process comprises the consultation of relevant legislation and international standards. Furthermore, feedback from stakeholders is acquired (see https://www.easa.europa.eu/en/document-library/rulemaking-process-overview/rulemaking-explained).

The Certification Review Item (CRI) provides a possibility for certification of designs, which are not fully covered by the certification specifications. During the certification process, an Equivalent Safety Finding can be requested. This allows to develop alternative requirements, where no compliancy to the certification specifications can be shown, provided that an equivalent level of safety can be achieved.

In the following overview, a comprehensive analysis of all parts of the CS-25 certification will be conducted. The relevant paragraphs that pertain to the implementation of stepless high-lift devices will be identified and highlighted, with indications of potential modifications or other critical aspects that require attention. The paragraphs are commented with 'consider', which implies what relevant parts have to be taken into account during the design of a system with stepless high-lift devices, or 'change', which gives an indication that some parts of the paragraph might not be suitable for stepless high-lift devices without a change. This examination will provide an understanding of the existing regulatory framework and its implications for the design and certification of aircraft featuring stepless flaps.

2.1 Subpart A – General

No specific requirements or considerations related to stepless flaps are identified in Subpart A.

2.2 Subpart B – Flight

2.2.1 Certification Specifications

Paragraph	Name	Comment
CS 25.101	General (Performance)	To consider: Selection of take-off, en-route, approach, and landing configuration
CS 25.125	Landing	To consider: landing distance determination in landing configuration -> wing-flap setting
CS 25.143	General (Controllability and Manoeuvrability)	To consider: controllability in every flight condition (flap settings)
CS 25.145	Longitudinal control	Change: specific high-lift device positions
CS 25.147	Directional and lateral control	Change: Wing-flaps in approach position
CS 25.149	Minimum control speed	Change or specify: take-off, landing, approach configuration
CS 25.175	Demonstration of static longitudinal stability	Change: Wing-flaps in the approach/landing position
CS 25.177	Static directional and lateral stability	Change: Specific wing-flap positions
CS 25.201	Stall demonstration	Change: Specific flap positions to continuous settings

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CS 25.207	Stall warning	Change: flap in any normal position
CS 25.251	Vibration and buffeting	To consider: free of vibration in any flight situation (configuration of flaps)

2.2.2 AMCs

Paragraph	Name	Comment
AMC 25.21(g)	Performance and handling in icing conditions	To consider: definition of the configuration for stepless flap settings
AMC 25.101(g)	Go-around	To consider: landing/approach configuration for stepless flap settings
AMC 25.125(b)(3)	Change of configuration	To consider: changes of configurations for stepless flaps
AMC 25.143(b)(1)	Control Following Engine Failure	Change: take-off flap setting to continuous setting
AMC 25.145(b)(2)	Longitudinal control	To consider for changes in flap positions
AMC 25.145(e)	Longitudinal control	To consider: selecting the correct position of the high-lift devices to a correct range
AMC 25.147(d)	Lateral control: Roll capability	To consider: wing-flaps in the most critical take-off position
AMC 25.147(f)	Lateral control: All engines operating	Change: wing-flaps en-route/landing positions
AMC 25.149(f)	Minimum Control Speed during Approach and Landing	Change: define flap approach and landing settings
AMC 25.149(g)	Minimum Control Speed with Two Inoperative Engines during Approach and Landing	Define: landing configuration for stepless flaps
AMC 25.177(d)	Full Rudder Sideslips	Change: all flap positions

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AMC 25.201(a)(2)	Stall demonstration	To consider or define: flap position
AMC 25.201(b)(1)	Stall demonstration	Change: all flap positions to a continuous setting

2.3 Subpart C – Structure

2.3.1 Certification Specifications

Paragraph	Name	Comment
CS 25.333	Flight manoeuvring envelope	To consider: Wing-flaps in the envelope
CS 25.335	Design airspeeds	Change: specific wing-flap positions
CS 25.345	High lift devices	Change: specific wing-flap positions
CS 25.373	Speed control devices	Change: specific device positions
CS 25.457	Wing-flaps	Change: specific wing-flap positions

2.3.2 AMCs

Paragraph	Name	Comment
AMC 25.345(c)	High lift devices (Procedure flight condition)	To consider: en-route conditions for stepless flaps
AMC 25.353	Rudder control reversal conditions	To consider: flaps in en-route conditions

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2.4 Subpart D – Design and Construction

2.4.1 Certification Specifications

Paragraph	Name	Comment
CS 25.697	Lift and drag devices, controls	To consider or adapt: specific device positions
CS 25.699	Lift and drag device indicator	To consider or adapt: indication of device position
CS 25.703	Take-off warning system	To consider: warning for wing-flaps outside range of take-off positions
CS 25.781	Cockpit control knob shape	To consider: shape of knob

2.5 Subpart E – Powerplant

No specific requirements or considerations related to stepless flaps are identified in Subpart E.

2.6 Subpart F – Equipment

2.6.1 Certification Specifications

Paragraph	Name	Comment
CS 25.1302	Installed systems and equipment for use by the flight crew	To consider for new systems
CS 25.1309	Equipment, systems and installations	To consider for new systems
CS 25.1322	Flight Crew Alerting	To consider for new systems
CS 25.1329	Flight Guidance System	To consider for requirements for the flight guidance system

2.6.2 AMCs

Paragraph	Name	Comment
AMC 25.1302	Installed systems and equipment for use by the flight crew	To consider for the design of new systems
AMC 25.1309	System design and analysis	To consider for the design of new systems
AMC 25.1322	Alerting Systems	To consider for the design of new systems
AMC No. 1 to CS 25.1329	Flight Guidance System	To consider for design of approach conditions
AMC No. 2 to CS 25.1329	Flight Testing of Flight Guidance Systems	To consider for design of approach conditions

2.7 Subpart G – Operating Limitations and Information

2.7.1 Certification Specifications

Paragraph	Name	Comment
CS 25.1511	Flap extended speed	Change: specific wing-flap position to continuous setting
CS 25.1545	Airspeed limitation information	To consider: understanding of airspeed limitations
CS 25.1563	Airspeed placard	Change and consider: maximum airspeeds for specific positions
CS 25.1583	Operating limitations	Change: speeds for wing-flap positions
CS 25.1585	Operating procedures	To consider: Development of operating procedures
CS 25.1587	Performance information	To consider or change: specification of landing/approach configuration

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2.7.2 AMCs

Paragraph	Name	Comment
AMC 25.1581	Aeroplane flight manual	Change: airspeed limitations for each flap position
AMC 25.1583(i)	Manoeuvring Flight Load Factors	To consider for continuous flap settings (e.g. max value)
AMC 25.1587(c)	Landing distances in abnormal configurations	To consider: flaps in landing configurations

2.8 Subpart H – Electrical Wiring Interconnection Systems

No specific requirements or considerations related to stepless flaps are identified in Subpart H.

2.9 Subpart J – Auxiliary Power Unit Installations

No specific requirements or considerations related to stepless flaps are identified in Subpart J.

2.10 Appendices to CS-25

No specific requirements or considerations related to stepless flaps are identified in the Appendices to CS-25.

2.11 General AMCs

Paragraph		Name	Comment
AMC 25-11		Electronic Flight Deck Displays	
	Appendix 1	Primary Flight Information	To consider: Presentation of airspeed information
	Appendix 6	Head-up Displays	To consider: Presentation of information

3 Review of Applicable Regulatory Requirements

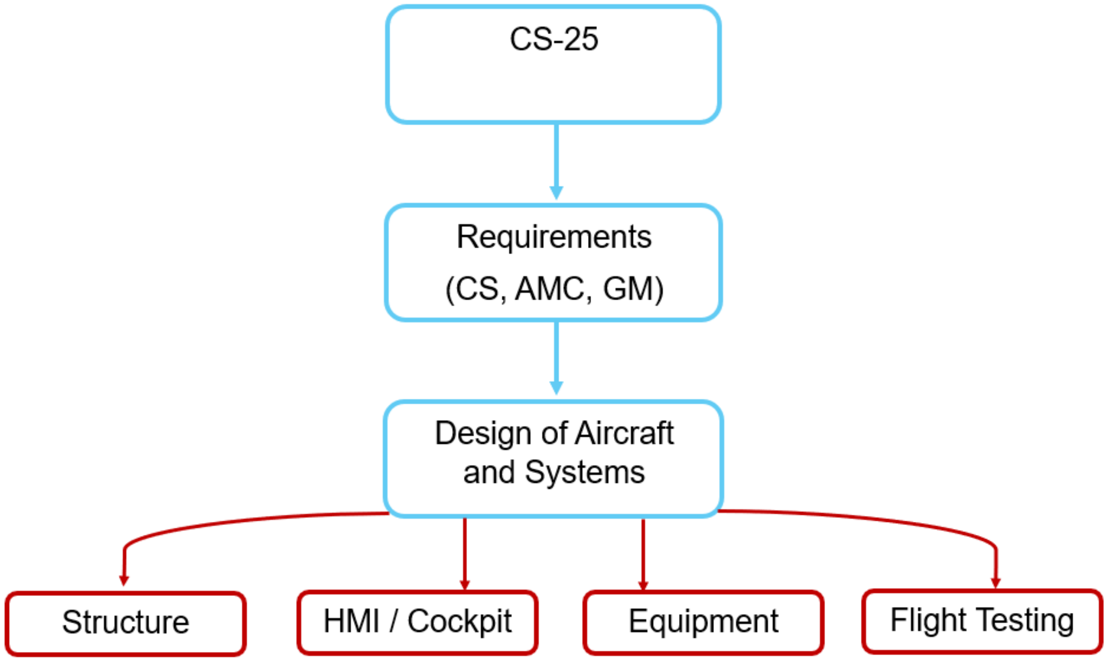

Figure 2: Influence of the CS-25 on various parts of aircraft design

The CS-25 provides a set of requirements for the design of large aeroplanes, as illustrated in Figure 2. These requirements are initially outlined in the form of certification specifications (CS), which are then supplemented by acceptable means of compliance (AMC) and guidance material (GM). It is mandatory for new aircraft designs or systems to comply with these requirements. The CS-25 addresses several aspects of the aircraft, including its structure, which is particularly relevant for stepless flaps due to airspeed and flap deflection limitations. Additionally, the Human-Machine-Interface (HMI) or cockpit design is subject to specific requirements, which must be adapted for stepless flaps to ensure compliance. Other equipment or systems that are modified or introduced to support stepless flaps must also adhere to the corresponding design requirements. The performance and handling qualities of the aircraft, some of which are verified through flight testing, must meet the defined standards of the CS-25. Since these qualities are dependent on the aircraft's configuration, including flap settings or the range of stepless flaps, demonstrating compliance with these regulations is crucial. This involves considering the characteristics of stepless flaps and ensuring that they are integrated into the aircraft design in a way that fulfils all applicable requirements, thereby guaranteeing safety standards.

The following analysis of the CS-25 provides important requirements which have to be considered while implementing stepless flaps in an aircraft design. Parts where changes are necessary are not addressed here, but in the following chapter. Nevertheless, the paragraphs with necessary changes

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are also part of the important requirements, which have to be addressed with the design of a stepless flap system.

3.1 Subpart B – Flight

3.1.1 Certification Specifications

3.1.1.1 CS 25.101 General (Performance)

CS 25.101 outlines the performance requirements for large aeroplanes under various ambient atmospheric conditions and still air, considering factors such as engine power, relative humidity, and installation losses. The regulation requires applicants to select specific configurations for take-off, en-route, approach, and landing, and to establish procedures for accelerate-stop distances, take-off flight paths, and landing distances. These procedures must be executable by average-skilled crews and account for factors such as fully worn brake assemblies, to ensure safe and reliable operation of the aeroplane. This paragraph is relevant for the design of an aircraft with stepless flaps because of the configurations, which have to be selected. The settings of flaps or, in the case of stepless flaps, the valid range of flap positions has to be selected per configuration.

3.1.1.2 CS 25.125 Landing

CS 25.125 requires determining the horizontal distance needed to land and come to a complete stop, considering both non-icing and icing conditions. The regulation specifies approach speeds, configurations, and procedures for determining landing distance, ensuring safe and reliable operation under various conditions. It is relevant for the case of stepless flaps since the landing configuration, and thus, also the corresponding flap settings, valid range of positions, or extreme positions, have to be taken into account.

3.1.1.3 CS 25.143 General (Controllability and Manoeuvrability)

This paragraph states general requirements for the controllability and manoeuvrability. It is important for the stepless flaps since it has to be demonstrated that the controllability has to be sufficient in every flight status, and therefore also in the valid ranges for flap positions. For demonstration purposes, extreme positions of flaps should be chosen and intermediate positions depending on behaviour.

3.1.1.4 CS 25.251 Vibration and Buffeting

This paragraph describes the requirement that the aircraft has to be free of any vibration or buffeting, which prevents a safe flight. Stepless flaps may introduce new sources of vibration or buffeting, especially during transition between different flap settings or during certain flight regimes. Ensuring compliance with CS 25.251 is crucial to guarantee that the aircraft remains safe and controllable throughout its operational envelope, including when stepless flaps are deployed.

3.1.2 AMCs

3.1.2.1 AMC 25.21(g) Performance and handling in icing conditions

This AMC gives instructions on which requirements have to be fulfilled in icing conditions. Several conditions involve the use of specific configurations, which are relevant for the selection of an adequate flap position.

3.1.2.2 AMC 25.101(g) Go-around

This AMC describes procedures for demonstration the go-around. It is important to consider the choice of the flap positions.

3.1.2.3 AMC 25.125(b)(3) Change of configuration

This AMC gives the altitude requirement (15 m (50 ft)) when no configuration change should be made. This is relevant for consideration that stepless flaps are kept at one position when reaching this altitude.

3.1.2.4 AMC 25.145(b)(2) Longitudinal control

This AMC gives additional information about the previous defined stall limits, allowing some reduction in the margin with high-lift devices being retracted, and thus, also relevant for the movement of stepless flaps.

3.1.2.5 AMC 25.145(e) Longitudinal control

For gated high-lift devices, CS 25.145(e) requires that the first gate from the maximum landing position corresponds to a go-around configuration. When multiple go-around configurations exist, factors such as frequency of use, potential errors, pilot selection likelihood, and gate assistance in selecting correct high-lift device positions should guide gate placement selection.

3.1.2.6 AMC 25.147(d) Lateral control: Roll capability

This AMC describes an acceptable method of demonstrating compliance with CS 25.147(d) and uses a configuration with wing-flaps in the most critical take-off position.

3.2 Subpart C – Structure

3.2.1 Certification Specifications

3.2.1.1 CS 25.333 Flight manoeuvring envelope

This paragraph gives information about the flight envelope. It is important for a stepless flap system for the airspeed and load limits.

3.2.2 AMCs

3.2.2.1 AMC 25.345(c) High lift devices (Procedure flight condition)

This AMC gives information about the conditions of high lift devices in en-route. Important speeds have to be selected for the valid flap positions in en-route. Therefore, also for stepless flaps, the valid range for flaps in en-route and corresponding speeds have to be selected.

3.2.2.2 AMC 25.353 Rudder control reversal conditions

In this AMC, information about structural design load conditions on the airframe which result from rudder inputs is given. It is mentioned that flaps have to be considered when used in en-route conditions. Therefore, this also applies for the use of stepless flaps in en-route.

3.3 Subpart D – Design and Construction

3.3.1 Certification Specifications

3.3.1.1 CS 25.703 Take-off warning system

CS 25.703 requires a warning system to alert pilots during take-off if critical systems like flaps are not set correctly for safe take-off. The system must provide an aural warning that continues until corrected or take-off is terminated, and function properly across all authorised take-off conditions. Also with stepless flaps, the system must be able to detect and warn if the flap setting is not within a safe range for take-off.

3.3.1.2 CS 25.781 Cockpit control knop shape

CS 25.781 specifies requirements for the shapes of cockpit controls. When designing the cockpit for a stepless flap system, these requirements must be considered to ensure intuitive and safe operation of the controls.

3.4 Subpart F – Equipment

3.4.1 Certification Specifications

3.4.1.1 CS 25.1302 Installed systems and equipment for use by the flight crew

CS 25.1302 requires that flight deck systems and equipment be designed to allow flight crew to safely perform tasks, providing clear information, predictable behaviour, and enabling effective intervention and error management. These requirements are relevant for the design of the used systems for the operation of stepless flaps.

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3.4.1.2 CS 25.1309 Equipment, systems and installations

CS 25.1309 requires that aeroplane equipment and systems be designed to function safely, with minimal risk of catastrophic failure, and provide essential information to the flight crew to prevent hazards and ensure continued airworthiness. These requirements are relevant for the systems designed for stepless flaps.

3.4.1.3 CS 25.1322 Flight Crew Alerting

CS 25.1322 provides requirements for alerts. Alerts are prioritised as warning, caution and advisory. Further requirements define the minimisation of effects of false alerts and the colour scheme of visual alerts. This paragraph is relevant for the design of a system for stepless flaps since it is likely that this system will be in need of specific alerts, which then have to fit into the overall alert scheme.

3.4.1.4 CS 25.1329 Flight Guidance System

This paragraph requires the flight guidance system to be designed to prevent errors and confusion, provide clear indications and warnings, and ensure safe operation under various conditions. The requirements have to be taken into account for the flight guidance system for stepless flaps.

3.4.2 AMCs

3.4.2.1 AMC 25.1302 Installed systems and equipment for use by the flight crew

This AMC describes the certification of systems and equipment used by the flight crew. It covers human factors and how to analyse systems used by humans. Stepless flaps require a modified cockpit design, respectively a modification for the use of stepless flaps. This system has to fulfil safety standards also with regard to human factors.

3.4.2.2 AMC 25.1309 System design and analysis

This AMC gives information about the necessary safety analysis of systems. It is relevant for a new design and, thus, also the design of a stepless flap system.

3.4.2.3 AMC 25.1322 Alerting Systems

This AMC provides information about the acceptable means of compliance for alerting systems. That includes elements for visual, aural, and tactile or haptic alerts, including the alert management, interfaces, integration and colour standardisation. Specific alerts to be designed for a stepless flap system have to fulfil the requirements and have to be integrated into the system of alerts to avoid misunderstandings.

3.4.2.4 AMC No. 1 to CS 25.1329 Flight Guidance System

This AMC provides information for the compliance of a flight guidance system. Since the flight guidance system is modified or redesigned in the concept for optimised approaches, this AMC is relevant for consideration.

3.4.2.5 AMC No. 2 to CS 25.1329 Flight Testing of Flight Guidance Systems

This AMC describes the necessary procedures to demonstrate compliance of the flight guidance system in flight testing. This is also relevant for the flight guidance system designed for stepless flaps.

3.5 Subpart G – Operating Limitations and Information

3.5.1 Certification Specifications

3.5.1.1 CS 25.1545 Airspeed limitation information

This paragraph gives the requirement that the airspeed limitations must be easily read and understood. This is especially relevant for stepless flaps since there are no clear airspeed limit per flap setting without fixed positions.

3.5.1.2 CS 25.1585 Operating procedures

This paragraph requires that operating procedures are provided for normal, non-normal, and emergency situations. These procedures must be relevant to airworthiness and crew control, excluding basic airmanship procedures. This includes that operating procedures are developed for the operation of stepless flaps.

3.5.2 AMCs

3.5.2.1 AMC 25.1583(i) Manoeuvring Flight Load Factors

This AMC gives information about which flight load factors to include in the aircraft flight manual. It is especially important for the definition of maximum approved flight load factors also outside the normal envelope.

3.5.2.2 AMC 25.1587(c) Landing distances in abnormal configurations

Here, information about the landing distances, which should be included in the flight manual, in abnormal configurations is given. It is relevant for stepless flaps since the landing configuration cannot be defined with a specific flap position. Further, the abnormal configurations have to be defined depending on a range of flap positions and an adequate representation in the flight manual has to be found.

3.6 General AMCs

3.6.1 AMC 25-11 Electronic Flight Deck Displays (Appendix 1, Appendix 6)

This AMC describes requirements about the Flight Deck Displays while especially the representation of information is relevant, since airspeed requirements for stepless flaps have to be presented in a proper understandable way.

4 Adaptations

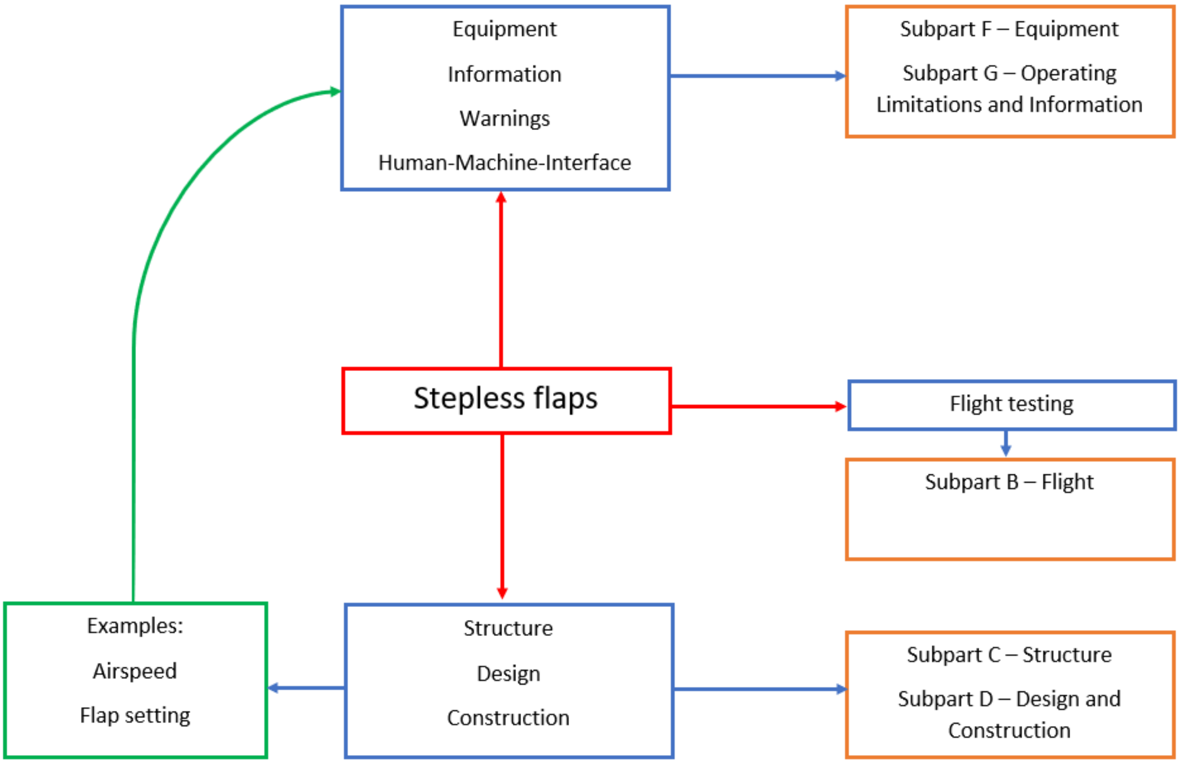

Figure 3: Impact of stepless flaps on the aircraft design

Stepless flaps have an impact on various parts of the aircraft design. Currently, the CS-25 is designed for flaps with fixed positions. For the implementation of stepless flaps, a couple of changes are necessary. Subpart B of the CS-25 is related to flight, and thus, the performance and handling qualities of an aircraft. In several flight tests according to the paragraphs of the CS-25, a specific position of the high-lift devices has to be tested. These paragraphs have to be adapted for the purpose of stepless flaps to a possibility to test relevant flap settings in a valid range of positions.

Stepless flaps also influence other parts of the aircraft design, e.g., the structure, design and construction. These parts are addressed in Subpart C and Subpart D of the CS-25. An example is the influence of flap settings on airspeed limitations, which influences then the equipment and cockpit design, e.g., with correct and understandable warnings.

A construction with stepless flaps also has an impact on other parts of the aircraft design, e.g., the cockpit design. In general, the Human-Machine-Interface has to be adapted for a design with stepless flaps. Further changes can be related to equipment and which information or warnings are given. These topics are addressed in Subpart F and Subpart G of the CS-25.

In the following sections, the considered certification specifications and acceptable means of compliance are given (long requirements are shortened to the most relevant parts). The parts, which are in need of adaptation, are marked in red. The suggested modification is given in blue. Suggestions include phrases like 'the most unfavourable position' or 'the most critical position'. Similar wording is already used for parameters without fixed positions, e.g., the centre of gravity. For stepless flaps, phrases like these have to be further defined by an applicant. Furthermore, it should be noted that the definition of 'configuration' needs to comprise a range of flap settings. With the modifications, the special case of stepless flaps is addressed and should cover the characteristics while ensuring a safety standard. Another possible way of addressing stepless high-lift devices in the certification specifications would be to implement a special requirement or AMC for the case of stepless high-lift devices. However, any change would have to undergo a rulemaking process (see https://www.easa.europa.eu/en/document-library/rulemaking-process-overview), involving further feedback steps. So, this list is intended to highlight potential issues when implementing a system of stepless high-lift devices.

However, it is important to note that there are in general no changes to the certification specifications necessary for the certification of an aircraft design with stepless high-lift devices. For the certification, the process of a Certification Review Item (see https://www.easa.europa.eu/en/document-library/certification-procedures/cri-and-cai-writing-and-management) can be followed. This means that the applicant can apply for an Equivalent Safety Finding (ESF) during the certification process. In consultation with the safety agency, alternative requirements to the certification specifications are defined, in case compliancy with the original certification specifications cannot be demonstrated. An Equivalent Safety Finding would also undergo a feedback process in order to acquire feedback from relevant stakeholder, e.g., manufacturers and industry. The fulfilment of these requirements ensures an equivalent safety standard.

4.1 Subpart B – Flight

4.1.1 Certification Specifications

4.1.1.1 CS 25.145 Longitudinal control

[…]

(e) (See AMC 25.145(e).) If gated high-lift device control positions are provided, sub-paragraph (c) of this paragraph applies to retractions of the high-lift devices from any position from the maximum landing position to the first gated position, between gated positions, and from the last gated position to the fully retracted position. The requirements of sub-paragraph (c) of this paragraph also apply to retractions from each approved landing position the most critical landing positions to the control position(s) associated with the high-lift device configuration(s) used to establish the go-around procedure(s) from that landing position. In addition, the first gated control position from the maximum landing position must correspond with a configuration of the high-lift devices used to establish a go-around procedure from a landing configuration. Each gated control position must require a separate and distinct motion of the control to pass through the gated position and must have features to prevent inadvertent movement of the control through the gated position. It must only be possible to make this separate and distinct motion once the control has reached the gated position.

(f) It must be possible to maintain adequate longitudinal and speed control under the following conditions without exceptional piloting skill, alertness, or strength, without danger of exceeding the aeroplane limit-load factor and while maintaining an adequate stall margin throughout the manoeuvre:

(1) Starting with the aeroplane in each approved approach and landing configuration the most critical approach and landing configurations, trimmed longitudinally and with the thrust or power setting per CS 25.161(c)(2), perform a go-around, transition to the next flight phase and level off at the desired altitude:

(i) with all engines operating and the thrust or power controls moved to the go-around power or thrust setting;

(ii) with the configuration changes, as per the approved operating procedures or conventional operating practices; and

(iii) with any practicable combination of Flight Guidance/Autothrust-throttle/Autopilot to be approved, including manual.

(2) Reasonably expected variations in service from the established approach, landing and go-around procedures for the operation of the aeroplane must not result in unsafe flight characteristics during the go-around.

4.1.1.2 CS 25.147 Directional and lateral control

(a) *Directional control; general.* (See AMC 25.147(a).) It must be possible, with the wings level, to yaw into the operative engine and to safely make a reasonably sudden change in heading of up to 15° in the direction of the critical inoperative engine. This must be shown at 1·3 V_{SR1}, for heading changes up to 15° (except that the heading change at which the rudder pedal force is 667 N (150 lbf) need not be exceeded), and with –

(1) The critical engine inoperative and its propeller (if applicable) in the minimum drag position;
(2) The power required for level flight at 1.3 V_{SR1}, but not more than maximum continuous power;
(3) The most unfavourable centre of gravity;
(4) Landing gear retracted;
(5) Wing-flaps in the approach position; and
Wing-flaps in the most unfavourable approach position; and
(6) Maximum landing weight.

[…]

4.1.1.3 CS 25.149 Minimum control speed

(a) In establishing the minimum control speeds required by this paragraph, the method used to simulate critical engine failure must represent the most critical mode of powerplant failure with respect to controllability expected in service.

(b) V_{MC} is the calibrated airspeed, at which, when the critical engine is suddenly made inoperative, it is possible to maintain control of the aeroplane with that engine still inoperative, and maintain straight flight with an angle of bank of not more than 5°.

(c) V_{MC} may not exceed 1·13 V_{SR} with –

(1) Maximum available take-off power or thrust on the engines;
(2) The most unfavourable centre of gravity;
(3) The aeroplane trimmed for take-off;
(4) The maximum sea-level take-off weight (or any lesser weight necessary to show V_{MC});
(5) The aeroplane in the most critical take-off configuration existing along the flight path after the aeroplane becomes airborne, except with the landing gear retracted;

(6) The aeroplane airborne and the ground effect negligible; and

(7) If applicable, the propeller of the inoperative engine –

(i) Windmilling;

(ii) In the most probable position for the specific design of the propeller control; or

(iii) Feathered, if the aeroplane has an automatic feathering device acceptable for showing compliance with the climb requirements of CS 25.121.

(d) The rudder forces required to maintain control at V_{MC} may not exceed 667 N (150 lbf) nor may it be necessary to reduce power or thrust of the operative engines. During recovery, the aeroplane may not assume any dangerous attitude or require exceptional piloting skill, alertness, or strength to prevent a heading change of more than 20°.

(e) V_{MCG}, the minimum control speed on the ground, is the calibrated airspeed during the take-off run at which, when the critical engine is suddenly made inoperative, it is possible to maintain control of the aeroplane using the rudder control alone (without the use of nose-wheel steering), as limited by 667 N of force (150 lbf), and the lateral control to the extent of keeping the wings level to enable the take-off to be safely continued using normal piloting skill. In the determination of V_{MCG}, assuming that the path of the aeroplane accelerating with all engines operating is along the centreline of the runway, its path from the point at which the critical engine is made inoperative to the point at which recovery to a direction parallel to the centreline is completed, may not deviate more than 9.1 m (30 ft) laterally from the centreline at any point. V_{MCG} must be established, with –

(1) The aeroplane in each take-off configuration or, at the option of the applicant, in the most critical take-off configuration;

(1) The aeroplane in the most extreme take-off configurations and intermediate steps or, at the option of the applicant, in the most critical take-off configuration;

(2) Maximum available take-off power or thrust on the operating engines;

(3) The most unfavourable centre of gravity;

(4) The aeroplane trimmed for take-off; and

(5) The most unfavourable weight in the range of take-off weights. (See AMC 25.149(e).)

(f) (See AMC 25.149(f)) V_{MCL}, the minimum control speed during approach and landing with all engines operating, is the calibrated airspeed at which, when the critical engine is suddenly made inoperative, it is possible to maintain control of the aeroplane with that engine still inoperative, and maintain straight flight with an angle of bank of not more than 5°. V_{MCL} must be established with –

(1) The aeroplane in the most critical configuration (or, at the option of the applicant, each configuration) for approach and landing with all engines operating;

(1) The aeroplane in the most critical configuration (or, at the option of the applicant, configurations with intermediate flap settings) for approach and landing with all engines operating;

(2) The most unfavourable centre of gravity;

(3) The aeroplane trimmed for approach with all engines operating;

(4) The most unfavourable weight, or, at the option of the applicant, as a function of weight;

(5) For propeller aeroplanes, the propeller of the inoperative engine in the position it achieves without pilot action, assuming the engine fails while at the power or thrust necessary to maintain a 3 degree approach path angle; and

(6) Go-around power or thrust setting on the operating engine(s).

(g) (See AMC 25.149(g)) For aeroplanes with three or more engines, V_{MCL-2}, the minimum control speed during approach and landing with one critical engine inoperative, is the calibrated airspeed at which, when a second critical engine is suddenly made inoperative, it is possible to maintain control of the aeroplane with both engines still inoperative, and maintain straight flight with an angle of bank of not more than 5°. V_{MCL-2} must be established with –

(1) The aeroplane in the most critical configuration (or, at the option of the applicant, each configuration) for approach and landing with one critical engine inoperative;

(1) The aeroplane in the most critical configuration (or, at the option of the applicant, configurations with intermediate flap settings) for approach and landing with one critical engine inoperative;

(2) The most unfavourable centre of gravity;

(3) The aeroplane trimmed for approach with one critical engine inoperative;

(4) The most unfavourable weight, or, at the option of the applicant, as a function of weight;

(5) For propeller aeroplanes, the propeller of the more critical engine in the position it achieves without pilot action, assuming the engine fails while at the power or thrust necessary to maintain a 3 degree approach path angle, and the propeller of the other inoperative engine feathered;

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(6) The power or thrust on the operating engine(s) necessary to maintain an approach path angle of 3o when one critical engine is inoperative; and

(7) The power or thrust on the operating engine(s) rapidly changed, immediately after the second critical engine is made inoperative, from the power or thrust prescribed in sub-paragraph (g)(6) of this paragraph to –

(i) Minimum power or thrust; and

(ii) Go-around power or thrust setting.

(h) In demonstrations of V_{MCL} and V_{MCL-2} –

(1) The rudder force may not exceed 667 N (150 lbf);

(2) The aeroplane may not exhibit hazardous flight characteristics or require exceptional piloting skill, alertness or strength;

(3) Lateral control must be sufficient to roll the aeroplane, from an initial condition of steady straight flight, through an angle of 20° in the direction necessary to initiate a turn away from the inoperative engine(s), in not more than 5 seconds (see AMC 25.149(h)(3)); and

(4) For propeller aeroplanes, hazardous flight characteristics must not be exhibited due to any propeller position achieved when the engine fails or during any likely subsequent movements of the engine or propeller controls (see AMC 25.149(h)(4)).

4.1.1.4 CS 25.175 Demonstration of static longitudinal stability

[…]

(c) *Approach.* The stick force curve must have a stable slope at speeds between V_{SW}, and 1·7 V_{SR1} with –

(1) Wing-flaps in the approach position;

(1) Wing-flaps in the most unfavourable approach position;

(2) Landing gear retracted;

(3) Maximum landing weight; and

(4) The aeroplane trimmed at 1·3 V_{SR1}, with enough power to maintain level flight at this speed.

(d) *Landing*. The stick force curve must have a stable slope and the stick force may not exceed 356 N (80 lbf) at speeds between V_{SW}, and 1·7 V_{SR0} with –

(1) Wing-flaps in the landing position;

(1) Wing-flaps in the most unfavourable landing position;

(2) Landing gear extended;

(3) Maximum landing weight;

(4) The aeroplane trimmed at 1·3 VSR0 with –

(i) Power or thrust off, and

(ii) Power or thrust for level flight.

4.1.1.5 CS 25.177 Static directional and lateral stability

(a) The static directional stability (as shown by the tendency to recover from a skid with the rudder free) must be positive for any landing gear and flap position any landing gear and most unfavourable flap positions and symmetrical power condition, at speeds from 1·13 V_{SR1}, up to V_{FE}, V_{LE}, or V_{FC}/M_{FC} (as appropriate).

(b) The static lateral stability (as shown by the tendency to raise the low wing in a sideslip with the aileron controls free) for any landing gear and wingflap position and symmetric power condition for any landing gear position and most unfavourable wingflap positions and symmetric power condition, may not be negative at any airspeed (except that speeds higher than V_{FE} need not be considered for wingflaps extended configurations nor speeds higher than V_{LE} for landing gear extended configurations) in the following airspeed ranges:

(1) From 1·13 V_{SR1} to V_{MO}/M_{MO}..

(2) From V_{MO}/M_{MO} to V_{FC}/M_{FC}, unless the divergence is –

(i) Gradual;

(ii) Easily recognisable by the pilot; and

(iii) Easily controllable by the pilot

(c) In straight, steady, sideslips over the range of sideslip angles appropriate to the operation of the aeroplane, the aileron and rudder control movements and forces must be substantially proportional to the angle of sideslip in a stable sense. The factor of proportionality must lie between limits found necessary for safe operation.

The range of sideslip angles evaluated must include those sideslip angles resulting from the lesser of:

(1) one-half of the available rudder control input; and

(2) a rudder control force of 180 pounds.

This requirement must be met for the configurations and speeds specified in sub-paragraph (a) of this paragraph. (See AMC 25.177(c).)

(d) For sideslip angles greater than those prescribed by sub-paragraph (c) of this paragraph, up to the angle at which full rudder control is used or a rudder control force of 801 N (180 lbf) is obtained, the rudder control forces may not reverse, and increased rudder deflection must be needed for increased angles of sideslip. Compliance with this requirement must be shown using straight, steady sideslips, unless full lateral control input is achieved before reaching either full rudder control input or a rudder control force of 801 N (180 lbf) ; a straight, steady sideslip need not be maintained after achieving full lateral control input. This requirement must be met at all approved landing gear and wingflap positions for the range of operating speeds and power conditions appropriate to each landing gear and wing-flap position with all engines operating. (See AMC 25.177(d).) This requirement must be met at all approved landing gear positions and wing-flaps in the range of wingflap positions for the range of operating speeds and power conditions appropriate to each landing gear and in the range of approved wing-flap positions with all engines operating.

4.1.1.6 CS25.201 Stall demonstration

(a) Stalls must be shown in straight flight and in 30° banked turns with –

(1) Power off; and

(2) The power necessary to maintain level flight at 1·5 V_{SR1} (where VS_{R1} corresponds to the reference stall speed at maximum landing weight with flaps in the approach position with flaps in the most unfavourable approach position and the landing gear retracted. (See AMC 25.201(a)(2).)

(b) In each condition required by sub-paragraph (a) of this paragraph, it must be possible to meet the applicable requirements of CS 25.203 with –

(1) Flaps, landing gear and deceleration devices in any likely combination of positions approved for operation; (See AMC 25.201(b)(1).)

(1) Flaps, landing gear and deceleration devices in the most unfavourable combinations, and, when necessary, intermediate steps of positions approved for operation;

(2) Representative weights within the range for which certification is requested;

(3) The most adverse centre of gravity for recovery; and

(4) The aeroplane trimmed for straight flight at the speed prescribed in CS 25.103(b)(6).

[…]

4.1.1.7 CS 25.207 Stall warning

(a) Stall warning with sufficient margin to prevent inadvertent stalling with the flaps and landing gear in any normal position with the flaps at least in the extreme positions (preferably with intermediate steps) and landing gear in any normal position must be clear and distinctive to the pilot in straight and turning flight.

(b) The warning must be furnished either through the inherent aerodynamic qualities of the aeroplane or by a device that will give clearly distinguishable indications under expected conditions of flight. However, a visual stall warning device that requires the attention of the crew within the cockpit is not acceptable by itself. If a warning device is used, it must provide a warning in each of the aeroplane configurations prescribed in sub-paragraph (a) of this paragraph at the speed prescribed in sub-paragraphs (c) and (d) of this paragraph. Except for the stall warning prescribed in subparagraph (h)(3)(ii) of this paragraph, the stall warning for flight in icing conditions must be provided by the same means as the stall warning for flight in non-icing conditions. (See AMC 25.207(b).)

(c) When the speed is reduced at rates not exceeding 0.5 m/s^2 (one knot per second), stall warning must begin, in each normal configuration, at a speed, V_{SW}, exceeding the speed at which the stall is identified in accordance with CS 25.201(d) by not less than 9.3 km/h (five knots) or five percent CAS, whichever is greater. Once initiated, stall warning must continue until the angle of attack is reduced to approximately that at which stall warning began. (See AMC 25.207(c) and (d)).

(d) In addition to the requirement of subparagraph(c) of this paragraph, when the speed is reduced at rates not exceeding 0.5 m/s^2 (one knot per second), in straight flight with engines idling and at the centre-of-gravity position specified in CS 25.103(b)(5), V_{SW}, in each normal configuration, must exceed V_{SR} by not less than 5.6 km/h (three knots) or three percent CAS, whichever is greater. (See AMC 25.207(c) and (d)).

(e) In icing conditions, the stall warning margin in straight and turning flight must be sufficient to allow the pilot to prevent stalling (as defined in CS 25.201(d)) when the pilot starts a recovery manoeuvre not less than three seconds after the onset of stall warning. When demonstrating compliance with this paragraph, the pilot must perform the recovery manoeuvre in the same way as for the airplane in non-icing conditions. Compliance with this requirement must be demonstrated in flight with the speed reduced at rates not exceeding 0.5 m/sec^2 (one knot per second), with –

(1) The most critical of the take-off ice and final take-off ice accretions defined in Appendices C and O, as applicable, in accordance with CS 25.21(g), for each configuration used in the take-off phase of flight;

(2) The most critical of the en route ice accretion(s) defined in Appendices C and O, as applicable, in accordance with CS 25.21(g), for the en route configuration;

(3) The most critical of the holding ice accretion(s) defined in Appendices C and O, as applicable, in accordance with CS 25.21(g), for the holding configuration(s);

(4) The most critical of the approach ice accretion(s) defined in Appendices C and O, as applicable, in accordance with CS 25.21(g), for the approach configuration(s); and

(5) The most critical of the landing ice accretion(s) defined in Appendices C and O, as applicable, in accordance with CS 25.21(g), for the landing and go-around configuration(s).

(f) The stall warning margin must be sufficient in both non-icing and icing conditions to allow the pilot to prevent stalling when the pilot starts a recovery manoeuvre not less than one second after the onset of stall warning in slowdown turns with at least 1.5g load factor normal to the flight path and airspeed deceleration rates of at least 1 m/sec^2 (2 knots per second), When demonstrating compliance with this paragraph for icing conditions, the pilot must perform the recovery manoeuvre in the same way as for the airplane in non-icing conditions. Compliance with this requirement must be demonstrated in flight with –

(1) The flaps and landing gear in any normal position;

(1) The most critical flap positions and landing gear in any normal position;

(2) The aeroplane trimmed for straight flight at a speed of 1.3 VSR; and

(3) The power or thrust necessary to maintain level flight at 1.3 VSR.

(g) Stall warning must also be provided in each abnormal configuration of the high lift devices any critical configuration of the high lift devices that is likely to be used in flight following system failures (including all configurations covered by Aeroplane Flight Manual procedures).

(h) The following stall warning margin is required for flight in icing conditions before the ice protection system has been activated and is performing its intended function. Compliance must be shown using the most critical of the ice accretion(s) defined in Appendix C, part II(e), and Appendix O, part II(d), as applicable, in accordance with CS 25.21(g). The stall warning margin in straight and turning flight must be sufficient to allow the pilot to prevent stalling without encountering any adverse flight characteristics when:

(1) The speed is reduced at rates not exceeding 0.5 m/sec^2 (one knot per second);

(2) The pilot performs the recovery manoeuvre in the same way as for flight in non-icing conditions; and

(3) The recovery manoeuvre is started no earlier than:

(i) One second after the onset of stall warning if stall warning is provided by the same means as for flight in non-icing conditions; or

(ii) Three seconds after the onset of stall warning if stall warning is provided by a different means than for flight in non-icing conditions.

(i) In showing compliance with subparagraph (h) of this paragraph, if stall warning is provided by a different means in icing conditions than for non-icing conditions, compliance with CS 25.203 must be shown using the accretion defined in appendix C, part II(e). Compliance with this requirement must be shown using the demonstration prescribed by CS 25.201, except that the deceleration rates of CS 25.201(c)(2) need not be demonstrated.

4.1.2 AMCs

4.1.2.1 AMC 25.143(b)(1) Control Following Engine Failure

1 An acceptable means of showing compliance with CS 25.143(b)(1) is to demonstrate that it is possible to regain full control of the aeroplane without attaining a dangerous flight condition in the event of a sudden and complete failure of the critical engine in the following conditions:

a. At each take-off flap setting at the lowest speed recommended for initial steady climb with all engines operating after take-off, with –

a. At the most critical take-off flap settings at the lowest speed recommended for initial steady climb with all engines operating after take-off, with –

i. All engines, prior to the critical engine becoming inoperative, at maximum take-off power or thrust;
ii. All propeller controls in the take-off position;
iii. The landing gear retracted;
iv. The aeroplane in trim in the prescribed initial conditions; and

[…]

4.1.2.2 AMC 25.147(f) Lateral control: All engines operating

An acceptable method of demonstrating that roll response and peak roll rates are adequate for compliance with CS 25.147(f) is as follows:
It should be possible in the conditions specified below to roll the aeroplane from a steady 30° banked turn through an angle of 60° so as to reverse the direction of the turn in not more than 7 seconds. In these demonstrations the rudder may be used to the extent necessary to minimise sideslip. The demonstrations should be made rolling the aeroplane in either direction, and the manoeuvres may be unchecked.

Conditions:

(a) En-route: Airspeed. All speeds between the minimum value of the scheduled all-engines-operating climb speed and V_{MO}/M_{MO}.

Wing-flaps. En-route position(s).

Wing-flaps. In the most unfavourable en-route position(s).

Air Brakes. All permitted settings from Retracted to Extended.

Landing Gear. Retracted.

Power. All engines operating at all powers from flight idle up to maximum continuous power.

Trim. The aeroplane should be in trim from straight flight in these conditions, and the trimming controls should not be moved during the manoeuvre.

(b) Approach: Airspeed. Either the speed maintained down to the 15 m (50 ft) height in compliance with CS 25.125(a)(2), or the target threshold speed determined in accordance with CS 25.125(c)(2)(i) as appropriate to the method of landing distance determination used.

Wing-flaps. In each landing position.

Wing-flaps. In the most unfavourable landing positions.

Air Brakes. In the maximum permitted extended setting.

Landing Gear. Extended.

Power. All engines operating at the power required to give a gradient of descent of 5·0%.

Trim. The aeroplane should be in trim for straight flight in these conditions, and the trimming controls should not be moved during the manoeuvre.

4.1.2.3 AMC 25.149(f) Minimum Control Speed during Approach and Landing

(a) CS 25.149(f) is intended to ensure that the aeroplane is safely controllable following an engine failure during an all-engines-operating approach and landing. From a controllability standpoint, the most critical case usually consists of an engine failing after the power or thrust has been increased to perform a go-around from an all-engines-operating approach.

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(b) To determine V_{MCL}, the flap and trim settings should be appropriate to the approach and landing configurations the flap and trim settings should be appropriate to the most unfavourable approach and landing configurations, the power or thrust on the operating engine(s) should be set to the go-around power or thrust setting, and compliance with all the V_{MCL} requirements of CS 25.149(f) and (h) must be demonstrated.

(c) At the option of the applicant, a one-engine-inoperative landing minimum control speed, $V_{MCL (1 out)}$, may be determined in the conditions appropriate to an approach and landing with one engine having failed before the start of the approach. In this case, only those configurations recommended for use during an approach and landing with one engine inoperative need be considered. The propeller of the inoperative engine, if applicable, may be feathered throughout.

The resulting value of $V_{MCL (1 out)}$ may be used in determining the recommended procedures and speeds for a one-engine-inoperative approach and landing.

4.1.2.4 AMC 25.149(g) Minimum Control Speed with two Inoperative Engines during Approach and Landing

(a) For aeroplanes with three or more engines, V_{MCL-2} is the minimum speed for maintaining safe control during the power or thrust changes that are likely to be made following the failure of a second critical engine during an approach initiated with one engine inoperative.

(b) In accordance with CS 25.149(g)(5) for propeller-driven aeroplanes, the propeller of the engine that is inoperative at the beginning of the approach may be in the feathered position. The propeller of the more critical engine must be in the position it automatically assumes following an engine failure.

(c) Tests should be conducted using either the most critical approved one-engine-inoperative approach or landing configuration (usually the minimum flap deflection), or at the option of the applicant, each of the approved one-engine-inoperative approach and landing configurations. Tests should be conducted using either the most critical approved one-engine-inoperative approach or landing configuration (usually the minimum flap deflection), or at the option of the applicant, the most critical approved one-engine-inoperative approach and landing configurations and intermediate steps. The following demonstrations should be conducted to determine V_{MCL-2}:

(1) With the power or thrust on the operating engines set to maintain a -3 ° glideslope with one critical engine inoperative, the second critical engine is made inoperative and the remaining operating engine(s) are advanced to the go-around power or thrust setting. The V_{MCL-2} speed is established with the flap and trim settings appropriate to the approach and landing configurations with the flap and trim settings appropriate to the most unfavourable approach and landing configurations, the power or thrust on the operating engine(s) set to the go-around power or thrust setting, and compliance with all the V_{MCL-2} requirements of CS 25.149(g) and (h) must be demonstrated.

(2) With the power or thrust on the operating engines set to maintain a -3° glideslope, with one critical engine inoperative:

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(i) Set the airspeed at the value determined in paragraph (c)(1) above and, with a zero bank angle, maintain a constant heading using trim to reduce the control force to zero. If full trim is insufficient to reduce the control force to zero, full trim should be used, plus control deflection as required; and

(ii) Make the second critical engine inoperative and retard the remaining operating engine(s) to minimum available power or thrust without changing the directional trim. The V_{MCL-2} determined in paragraph (c)(1) is acceptable if a constant heading can be maintained without exceeding a 5° bank angle and the limiting conditions of CS 25.149(h).

(iii) Starting from a steady straight flight condition, demonstrate that sufficient lateral control is available at V_{MCL-2} to roll the aeroplane through an angle of 20° in the direction necessary to initiate a turn away from the inoperative engines in not more than five seconds. This manoeuvre may be flown in a bank-to-bank roll through a wings-level attitude.

(d) At the option of the applicant, a two-engine-inoperative landing minimum control speed, $V_{MCL-2\ (2\ out)}$ may be determined in the conditions appropriate to an approach and landing with two engines having failed before the start of the approach. In this case, only those configurations recommended for use during an approach and landing with two engines inoperative need be considered. The propellers of the inoperative engines, if applicable, may be feathered throughout.

The values of V_{MCL-2} or $V_{MCL-2\ (2\ out)}$ should be used as guidance in determining the recommended procedures and speeds for a two-engine inoperative approach and landing.

4.1.2.5 AMC 25.177(d) Full Rudder Sideslips

1.1 At sideslip angles greater than those appropriate for normal operation of the aeroplane, up to the sideslip angle at which full rudder control is used or a rudder control force of 801 N (180 lbf) is obtained, CS 25.177(d) requires that the rudder control forces may not reverse and increased rudder deflection must be needed for increased angles of sideslip. The goals of this higher-than-normal sideslip angle test are to show that at full rudder, or at maximum expected pilot effort: (1) the rudder control force does not reverse, and (2) increased rudder deflection must be needed for increased angles of sideslip, thus demonstrating freedom from rudder lock or fin stall, and adequate directional stability for manoeuvres involving large rudder inputs.

1.2 Compliance with this requirement should be shown using straight, steady sideslips. However, if full lateral control input is reached before full rudder control travel or a rudder control force of 801 N (180 lbf) is reached, the manoeuvre may be continued in a non-steady heading (i.e., rolling and yawing) manoeuvre. Care should be taken to prevent excessive bank angles that may occur during this manoeuvre.

1.3 CS 25.177(d) states that the criteria listed in paragraph 1.1 must be met at all approved landing gear and flap positions for the range of operating speeds and power conditions appropriate to each landing gear and flap position with all engines operating. The range of operating speeds and power conditions appropriate to each landing gear and flap position with all engines operating should be consistent with the following:

CS 25.177(d) states that the criteria listed in paragraph 1.1 must be met at all approved landing gear positions and wing-flaps in the range of flap positions for the range of operating speeds and power conditions appropriate to each landing gear position and in the range of flap positions with all engines operating. The range of operating speeds and power conditions appropriate to each landing gear position and wing-flaps in the range of flap positions with all engines operating should be consistent with the following:

a. For take-off configurations, speeds from V_{2+xx} (airspeed approved for all-engines-operating initial climb) to V_{FE} or V_{LE}, as appropriate, and take-off power/thrust;

b. For flaps up configurations, speeds from 1.23 V_{SR} to V_{LE} or V_{MO}/M_{MO}, as appropriate, and power from idle to maximum continuous power/thrust;

c. For approach configurations, speeds from 1.23 V_{SR} to V_{FE} or V_{LE}, as appropriate, and power from idle to go-around power/thrust; and

d. For landing configurations, speeds from V_{REF}-9.3 km/h (5 knots) to V_{FE} or V_{LE}, as appropriate, with power from idle to go-around power/thrust at speeds from VREF to V_{FE}/V_{LE}, and idle power at V_{REF}-9.3 km/h (5 knots) (to cover the landing flare).

[…]

4.1.2.6 AMC 25.201(a)(2) Stall demonstration

The power for all power-on stall demonstrations is that power necessary to maintain level flight at a speed of 1·5 V_{SR1} at maximum landing weight, with flaps in the approach position with flaps in the most unfavourable approach position and landing gear retracted, where V_{SR1} is the reference stall speed in the same conditions (except power). The flap position to be used to determine this power setting is that position in which the reference stall speed does not exceed 110% of the reference stall speed with the flaps in the most extended landing position.

4.1.2.7 AMC 25.201(b)(1) Stall demonstration

Stall demonstrations for compliance with CS 25.201 should include demonstrations with deceleration devices deployed for all flap positions unless limitations against use of the devices with particular flap positions are imposed all critical flap positions and sufficient intermediate steps unless limitations against use of the devices with particular flap positions are imposed. 'Deceleration devices' include spoilers when used as air brakes, and thrust reversers when use in flight is permitted. Stall demonstrations with deceleration devices deployed should normally be carried out with power off, except where deployment of the deceleration devices while power is applied is likely to occur in normal operations (e.g. use of extended air brakes during landing approach).

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4.2 Subpart C – Structure

4.2.1 Certification Specifications

4.2.1.1 CS 25.335 Design airspeeds

[...]

(e) *Design wing-flap speeds, V_F.* For V_F, the following apply:

(1) The design wing-flap speed for each wing-flap position for useful ranges of wing-flap positions (established in accordance with CS 25.697(a)) must be sufficiently greater than the operating speed recommended for the corresponding stage of flight (including balked landings) to allow for probable variations in control of airspeed and for transition from one wing-flap position to another for transition of wing-flaps.

(2) If an automatic wing-flap positioning or load limiting device is used, the speeds and corresponding wing-flap positions programmed or allowed by the device may be used.

(3) V_F may not be less than –

(i) 1·6 V_{S1} with the wing-flaps in take-off position at maximum take-off weight;

(ii) 1·8 V_{S1} with the wing-flaps in approach position at maximum landing weight; and

(iii) 1·8 V_{S0} with the wing-flaps in landing position at maximum landing weight.

[...]

4.2.1.2 CS 25.345 High lift devices

(a) If wing-flaps are to be used during take-off, approach, or landing, at the design flap speeds established for these stages of flight under CS 25.335(e) and with the wing-flaps in the corresponding positions at the design flap speeds established for these stages of flight under CS 25.335(e) and with the wing-flaps in the corresponding range of positions, the aeroplane is assumed to be subjected to symmetrical manoeuvres and gusts. The resulting limit loads must correspond to the conditions determined as follows:

(1) Manoeuvring to a positive limit load factor of 2·0; and

(2) Positive and negative gusts of 7.62 m/sec (25 ft/sec) EAS acting normal to the flight path in level flight. Gust loads resulting on each part of the structure must be determined by rational analysis. The analysis must take into account the unsteady aerodynamic characteristics and rigid body motions of the aircraft. (See AMC 25.345(a).) The shape of the gust must be as described in CS 25.341(a)(2) except that –

Uds = 7.62 m/sec (25 ft/sec) EAS;

H = 12.5 c; and

c = mean geometric chord of the wing (metres (feet)).

(b) The aeroplane must be designed for the conditions prescribed in sub-paragraph (a) of this paragraph except that the aeroplane load factor need not exceed 1·0, taking into account, as separate conditions, the effects of –

(1) Propeller slipstream corresponding to maximum continuous power at the design flap speeds V_F, and with take-off power at not less than 1·4 times the stalling speed for the particular flap position and associated maximum weight; and

(2) A head-on gust of 7.62m/sec (25 fps) velocity (EAS).

(c) If flaps or other high lift devices are to be used in en-route conditions, and with flaps in the appropriate position at speeds up to the flap design speed chosen for these conditions If flaps or other high lift devices are to be used in en-route conditions, and with flaps in the appropriate range of positions at speeds up to the flap design speed chosen for these conditions, the aeroplane is assumed to be subjected to symmetrical manoeuvres and gusts within the range determined by –

(1) Manoeuvring to a positive limit load factor as prescribed in CS 25.337(b) ; and

(2) The vertical gust and turbulence conditions prescribed in CS 25.341. (See AMC 25.345(c).)

(d) The aeroplane must be designed for a manoeuvring load factor of 1.5 g at the maximum take-off weight with the wing-flaps and similar high lift devices in the landing configurations.

4.2.1.3 CS 25.373 Speed control devices

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 at the speeds and corresponding range of device positions that the mechanism allows.

4.2.1.4 CS 25.457 Wing-flaps

Wing flaps, their operating mechanisms, and their supporting structures must be designed for critical loads occurring in the conditions prescribed in CS 25.345, accounting for the loads occurring during transition from one wing-flap position and airspeed to another the loads occurring during the movement of the wing-flap in the valid ranges and changes of the airspeed.

4.3 Subpart D – Design and Construction

4.3.1 Certification Specifications

4.3.1.1 CS 25.697 Lift and drag devices, controls

(a) Each lift device control must be designed so that the pilots can place the device in any takeoff, en-route, approach, or landing position established under CS 25.101(d). Lift and drag devices must maintain the selected positions, except for movement produced by an automatic positioning or load limiting device, without further attention by the pilots.

(a) Each lift device control must be designed so that the pilots can place the device to any desired position established under CS 25.101(d). Lift and drag devices must maintain the selected position,

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except for movement produced by an automatic positioning or load limiting device, without further attention by the pilots.

[…]

4.3.1.2 CS 25.699 Lift and drag device indicator

(a) There must be means to indicate to the pilots the position of each lift or drag device having a separate control in the cockpit to adjust its position. In addition, an indication of unsymmetrical operation or other malfunction in the lift or drag device systems must be provided when such indication is necessary to enable the pilots to prevent or counteract an unsafe flight or ground condition, considering the effects on flight characteristics and performance.

(b) There must be means to indicate to the pilots the take-off, en-route, approach, and landing lift device positions.

(b) There must be means to indicate to the pilots the recommended lift device settings for take-off, en-route, approach, and landing, or a range of suitable settings.

(c) If any extension of the lift and drag device beyond the landing position the maximum landing position is possible, the control must be clearly marked to identify this range of extension.

4.4 Subpart G – Operating Limitations and Information

4.4.1 Certification Specifications

4.4.1.1 CS 25.1511 Flap extended speed

The established flap extended speed V_{FE} must be established so that it does not exceed the design flap speed V_F chosen under CS 25.335(e) and 25.345, for the corresponding wing-flap positions and engine powers.

The established flap extended speed V_{FE} must be established as a function of flap deflection angle so that it does not exceed the design flap speed V_F chosen under CS 25.335(e) and 25.345, for the corresponding wing-flap positions and engine powers.

4.4.1.2 CS 25.1563 Airspeed placard

A placard showing the maximum airspeeds for wingflap extension for the take-off, approach, and landing positions must be installed in clear view of each pilot.

A placard showing the maximum airspeeds for wingflap extension as a function of flap position for various flight phases (e.g. take-off, approach, and landing) must be installed in clear view of each pilot.

4.4.1.3 CS 25.1583 Operating Limitations

(a) *Airspeed limitations.* The following airspeed limitations and any other airspeed limitations necessary for safe operation must be furnished.

(1) The maximum operating limit speed V_{MO}/M_{MO} and a statement that this speed limit may not be deliberately exceeded in any regime of flight (climb, cruise, or descent) unless a higher speed is authorised for flight test or pilot training.

(2) If an airspeed limitation is based upon compressibility effects, a statement to this effect and information as to any symptoms, the probable behaviour of the aeroplane, and the recommended recovery procedures.

(3) The manoeuvring speed established under CS 25.1507 and statements, as applicable to the particular design, explaining that:

(i) full application of pitch, roll, or yaw controls should be confined to speeds below the manoeuvring speed; and

(ii) rapid and large alternating control inputs, especially in combination with large changes in pitch, roll, or yaw, and full control inputs in more than one axis at the same time, should be avoided as they may result in structural failures at any speed, including below the manoeuvring speed.

(4) The flap extended speeds V_{FE} and the pertinent wing-flap positions and engine powers.

(4) The flap extended speeds V_{FE} and the pertinent ranges of wing-flap positions and engine powers.

(5) The landing gear operating speed or speeds, and a statement explaining the speeds as defined in CS 25.1515(a).

(6) The landing gear extended speed V_{LE}, if greater than V_{LO}, and a statement that this is the maximum speed at which the aeroplane can be safely flown with the landing gear extended.

[…]

4.4.1.4 CS 25.1587 Performance information

(a) Each aeroplane Flight Manual must contain information to permit conversion of the indicated temperature to free air temperature if other than a free air temperature indicator is used to comply with the requirements of CS 25.1303(a)(1).

(b) Each aeroplane Flight Manual must contain the performance information computed under the applicable provisions of this CS-25 (including CS 25.115, 25.123 and 25.125 for the weights, altitudes, temperatures, wind components, and runway gradients, as applicable) within the operational limits of the aeroplane, and must contain the following:

(1) In each case, the conditions of power, configuration, and speeds, and the procedures for handling the aeroplane and any system having a significant effect on the performance information.

(2) V_{SR} determined in accordance with CS 25.103.

(3) The following performance information (determined by extrapolation and computed for the range of weights between the maximum landing weight and the maximum takeoff weight):

(i) Climb in the landing configuration.

(i) Climb in the most unfavourable landing configuration.

(ii) Climb in the approach configuration.

(ii) Climb in the most unfavourable approach configuration.

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(iii) Landing distance.
(4) Procedures established under CS 25.101(f) and (g) that are related to the limitations and information required by CS 25.1533 and by this paragraph in the form of guidance material including any relevant limitation or information.
(5) An explanation of significant or unusual flight or ground handling characteristics of the aeroplane.
(6) Corrections to indicated values of airspeed, altitude and outside air temperature.
(7) An explanation of operational landing runway length factors included in the presentation of the landing distance, if appropriate.

c) Each aeroplane flight manual (AFM) must contain the performance information associated with abnormal landing configurations (see AMC 25.1587(c)).

4.4.2 AMCs

4.4.2.1 AMC25.1581 Aeroplane flight manual

[...]

(7) Airspeed and Mach Number Limitations. All airspeed limitations should be in terms of indicated airspeed and in units of knots or Mach number, where applicable and should be consistent with cockpit indication. If airspeed or Mach number limitations vary with altitude or loading conditions, such variation must be shown. Limitations data must be included for at least the following:

(i) Maximum operating limit speed, V_{MO}/M_{MO}, together with a statement that this speed limit may not be deliberately exceeded in any regime of flight (climb, cruise or descent), unless a higher speed is authorised for flight test or pilot training. The last phrase (unless a higher speed is authorised for flight test or pilot training) may be omitted at the option of the applicant.
(ii) Manoeuvring speed (established under CS 25.1507) together with statements, as applicable to the particular design, explaining that:
(a) full application of pitch, roll, or yaw controls should be confined to speeds below the manoeuvring speed; and
(b) rapid and large alternating control inputs, especially in combination with large changes in pitch, roll, or yaw, and full control inputs in more than one axis at the same time, should be avoided as they may result in structural failures at any speed, including below the manoeuvring speed.
(iii) Flap-extended speed, V_{FE}, for each approved flap and high lift device position.
(iii) Flap-extended speed, V_{FE}, for ranges of flap and high lift device positions.
(iv) Landing gear operating speed, V_{LO}, together with a statement that this is the maximum speed at which it is safe to extend or retract the landing gear. If different speeds are established for extension and retraction, each speed should be listed and defined.
(v) Landing gear extended speed, V_{LE}, together with a statement that this is the maximum speed at which the aeroplane can be safely flown with the landing gear extended and locked.

(vi) Any other limiting speeds for extendable devices other than the landing gear, should be included as applicable (e.g. spoilers, thrust reversers, landing lights, ram air turbine (RAT), windows that may be opened in flight, etc.).

[...]

5 Conclusion

This report examines the feasibility of a stepless flap concept in relation to certification specifications, specifically the CS-25. The current certification specifications are designed for conventional aircraft designs featuring flaps with predefined positions. However, flaps that can move without fixed positions, similar to primary control surfaces such as ailerons, elevators, and rudders need an examination of the regulations and an alternative approach to demonstrate compliancy where necessary.

The relevant paragraphs within the CS-25 that are crucial to consider during the design phase of a stepless flap concept are identified and highlighted. These requirements are located in Subpart B, Subpart C, Subpart D, Subpart F, and Subpart G of the CS-25. The analysis not only focuses on requirements directly related to control surfaces but also looks at the broader system design. This includes pointing out necessary requirements for, e.g., the Human-Machine Interface (HMI), ensuring that the implementation of stepless flaps does not compromise safety.

In a subsequent step, requirements that specifically address certain flap settings must be adapted to enable the implementation of stepless flaps. These adaptations involve adjusting existing requirements with suggestions on how the concept of stepless flaps can be integrated while maintaining the same safety standards as conventional flap designs. However, adaptations to certification specifications would need to undergo a rulemaking process and should be only considered if sufficiently justified. In case of a single type, which cannot demonstrate compliancy with all requirements, an Equivalent Safety Finding could be requested, considering alternative requirements.

Finally, combining the certification specifications with alternative approaches to demonstrate compliancy provides a strategy for future aircraft designs implementing stepless flaps. This approach ensures that flap designs can be safely integrated into aircraft without compromising regulatory compliance or safety performance. The analysis provides a possibility for more flexible and potentially efficient aircraft designs that can use the benefits of stepless flap technology while maintaining safety standards.