Notice of Proposed Amendment 2013-21

YAWING CONDITIONS (ROTORCRAFT)

RMT.0119 (27&29.003) — 04/11/2013

EXECUTIVE SUMMARY

This Notice of Proposed Amendment (NPA) addresses a safety and regulatory coordination issue.

The specific objective of RMT.0119 has been to review the rationale and application of FAR/CS-VLR/27/29.351, and associated AC/AMC, in meeting the high safety standards envisaged and in its consistent application to the certification of products.

This NPA proposes an amendment to AMC to CS-VLR, CS-27 and CS-29 (including FAA AC).

The proposed changes are expected to maintain a high level of safety and ensure consistency across product certification. However, the rulemaking group developing these proposals were unable to reach consensus on some significant issues within the timeframe allotted. Therefore, full harmonisation has not been achieved and some differences will remain between the Agency and FAA/TCCA.

Applicability		Process map	
Affected regulations and decisions:	CS-VLR, CS-27, CS-29	Concept Paper:	No
		Terms of Reference (Issue 2):	21/10/2008
		Rulemaking group:	Yes
Affected stakeholders:	Rotorcraft TC/RTC/STC applicants	RIA type:	Light
		Technical consultation during NPA drafting:	No
Driver/origin:	Level playing field	Duration of NPA consultation:	2 months
Reference:	N/A	Review group:	TBD
		Focussed consultation:	TBD
		Publication date of the Decision:	2015/01

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1. Procedural information

1.1. The rule development procedure

The European Aviation Safety Agency (hereinafter referred to as the 'Agency') developed this Notice of Proposed Amendment (NPA) in line with Regulation (EC) No 216/2008[1] (hereinafter referred to as the 'Basic Regulation') and the Rulemaking Procedure[2].

This rulemaking activity is included in the Agency's Rulemaking Programme 2013-2016 under RMT.0119 (former task number 27&29.003)

(http://www.easa.eu.int/rulemaking/annual-programme-and-planning.php).

The text of this NPA has been developed by the Agency based on the input of Rulemaking Group RMT.0119. It is hereby submitted for consultation of all interested parties[3].

The process map on the title page contains the major milestones of this rulemaking activity to date and provides an outlook of the timescale of the next steps.

1.2. The structure of this NPA and related documents

Chapter 1 of this NPA contains the procedural information related to this task. Chapter 2 (Explanatory Note) explains the core technical content. Chapter 3 contains the proposed text for the new requirements. Chapter 4 contains the Regulatory Impact Assessment showing which options were considered and what impacts were identified, thereby providing the detailed justification for this NPA.

1.3. How to comment on this NPA

Please submit your comments using the automated **Comment-Response Tool (CRT)** available at **http://hub.easa.europa.eu/crt/**[4].

The deadline for submission of comments is **6 January 2014.**

1.4. The next steps in the procedure

Following the closing of the NPA public consultation period, the Agency will review all comments.

The outcome of the NPA public consultation will be reflected in the respective Comment-Response Document (CRD).

The Agency will publish the CRD with the Decision.

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[1] Regulation (EC) No 216/2008 of the European Parliament and the Council of 20 February 2008 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC (OJ L 79, 19.3.2008, p. 1), as last amended by Commission Regulation (EU) No 6/2013 of 8 January 2013 (OJ L 4, 9.1.2013, p. 34).

[2] The Agency is bound to follow a structured rulemaking process as required by Article 52(1) of the Basic Regulation. Such process has been adopted by the Agency's Management Board and is referred to as the 'Rulemaking Procedure'. See Management Board Decision concerning the procedure to be applied by the Agency for the issuing of Opinions, Certification Specifications and Guidance Material (Rulemaking Procedure), EASA MB Decision No 01-2012 of 13 March 2012.

[3] In accordance with Article 52 of the Basic Regulation and Articles 5(3) and 6 of the Rulemaking Procedure.

[4] In case of technical problems, please contact the CRT webmaster (crt@easa.europa.eu).

2. Explanatory Note

FAR/CS-VLR/27/29.351 'Yawing Conditions' (hereafter referred to as xx.351) is a prime criterion used in determining structural loads and will typically influence the design of the tailboom, fin, rear fuselage, doors, fairings, etc.

The origin of the rule can be traced to FAA CAR 7 (prior to 1956) and was adopted into the original issue of FAA 14 CFR Part 29 (effective 1965). In its original form, the rule stipulated a very conservative approach with loads being determined from applying and maintaining full pedal input at forward speeds up to V_{NE} or V_H, whichever is less, and required a rational analysis to be performed to determine the maximum sideslip angles attainable. The rule was subsequently amended (Amendment 29-30, 1990) to provide a limited sideslip envelope more in line with operational needs and at the same time extended to cover Part 27 rotorcraft (Amendment 27-26), which until that time had no such requirement. The amended rule was adopted by JAA in the 1st issue of JAR-27 (September 1993), JAR-29 (November 1993) and JAR-VLR (September 2003) and subsequently into EASA certification specifications CS-VLR, CS-27 and CS-29 in November 2003.

Since the introduction of the revised rules, manufacturers and authorities have interpreted the yaw manoeuvre structural design requirements prescribed under xx.351, in very different ways, and this has been intensified by the lack of adequate guidance on how to perform the compliance manoeuvre. Certification experience has shown that such variations can have important repercussions on the structural loads established for new designs.

To address these concerns, in 2000 the JAA created a specialists group under the auspices of the JAA Rotorcraft Steering Group, to provide clarification and consistent interpretation. Although clarification was achieved in certain areas, the limited scope of the activity prevented full resolution of the issues, and the group completed its task with majority and minority views expressed. Areas of contention included: interpretation of the term 'resulting sideslip angle'; the scope of structure to which the loading conditions should apply; the environmental conditions applicable; and the use of yaw limiters. The Working Group reported in 2002 and additional AC material was published by the FAA in AC 27-1B Chg 2 and AC 29-2C Chg 2 in April 2006 and formally adoped by the Agency in CS-VLR Amdt 1 and CS-27&29 Amdt 2 (November 2008).

The Agency, however, remains concerned that some interpretations of xx.351 may not provide adequate structural substantiation when applied to modern rotorcraft designs that have a greater yawing capability than was envisaged when the limited sideslip envelope rule was developed. Although the Agency has found no evidence of catastrophic structural failure due directly to loads arising from yawing conditions, there have been several in-service incidents where large sideslip angles, well above those stipulated in the limited sideslip envelope, have been attained, and that structural failure may only have been avoided through past compliance with more stringent certification standards (e.g. FAA rules prior to Amdt 27-26/29-30, or military requirements). It is the Agency's view that the method of compliance given in the latest revision of the FAA ACs does not provide an adequate margin of safety and does not retain the standard previously applied by the Agency through the CRI system. Furthermore, it is the Agency's view that, based on the current trends in modern rotorcraft of providing high power tail rotors with a large yawing capability and in developing rotorcraft specifically for the civil market, there is a potential for future structural safety concerns to arise.

To address the Agency's concerns, the Agency initiated rulemaking task RMT.0119 (27&29.003) in 2006, and formed a rulemaking group consisting of authority and industry representation, with the aim of developing additional regulatory material.

Furthermore, as a temporary stop-gap measure to address the Agency's concerns, the Agency developed AMC to CS-VLR/27/29.351 to supplement FAA AC 27-1B Chg 2 and AC 29-2C Chg 2 when adopting FAA AC into Book 2 of CS-VLR/27/29 (November 2008). Each additional AMC represents an interpretation of the rule acceptable to the Agency and its development was influenced by the on-going discussions within the rulemaking group, where these same areas of concern had been recognised.

The rulemaking group met 6 times during the period 2006-2010. The task was then postponed for 2 years due to changed priorities. This NPA is the outcome of this activity.

2.1. Overview of the issues to be addressed

The primary issues to be addressed relate to the rationale and acceptability of xx.351 and associated AC/AMC, and are detailed in the task ToR. If the certification specifications or associated AMCs were judged to be insufficient or inappropriate, then the group was tasked to identify options to enhance the rules and perform a Regulatory Impact Assessment (RIA) to identify the implications of these options.

The following summaries the outcome of each task assigned to the rulemaking group and the Agency's opinion.

2.1.1 Identify in-service experience of occurrences involving flight at high sideslip angles and determine the loads likely to have been generated in such flight conditions, including those resulting from pilot action.

A review of reported in-service occurences identified 29 occurences between 1982 – 2006 involving large and sudden yaw movements. Causal factors that initiated the large yaw movement were sub-categorised between: rotor drive system failure (8), engine failure/loss of power (6), tail rotor control failure (6), environmental (2), pilot mishandling (6), and birdstrike (1).

There was an opinion within the rulemaking group that the causal factors resulting from a failure condition (20/29) were outside the scope of xx.351 as the requirement was not intended to address failure conditions. Furthermore, the fact that following a tail rotor/drive failure the tail rotor is incapable of generating a restoring moment, precludes the possibility of recovery action through yaw control and therefore cannot lead to excessive tailboom loads. Similarly for engine failure, pilot recovery action will result in a reduction of tail rotor thrust and hence a reduction in loads. Incidents resulting from environmental effects are extremely rare and are outside the assumed gust loads.

Agency's View: Situations can arise where uncommanded/uncontrolled spins or large sideslip angles develop at high speeds. These occurrences, otherwise recoverable, may potentially turn into catastrophic events if there was a structural failure of the tailboom or other components. The Agency therefore retains the opinion that a sound structural design/certification criteria is needed to protect the structure.

2.1.2 Review rotorcraft designs to establish current directional control capabilities

This was not completed by the group.

Agency's View: The Agency's experience shows that the limited sideslip angle proposed under xx.351 can be easily exceeded by modern rotorcraft. In many cases CRIs were raised to highlight and resolve the issue on a case-by-case basis.

Furthermore, several in-service occurences have been identified where helicopters have achieved high sideslip angles, well above the 15 degrees assumed, at high speeds close to V_H. In these examples the helicopters had sufficient control capability to permit recovery from such conditions or to perform safe emergency landings/ditchings. However, it should be noted that in all cases the helicopter designs comply with more stringent yawing condition requirements (FAR 29 pre Amendment 29-30, or UK-CAA BCAR Section G, or military requirements MIL-S-8698, DEF STAN 00-970).

2.1.3 Review previously accepted design/certification practice and the validity of assumptions used.

A review of industry practice relating to performance of the yawing manoeuvre of xx.351 confirmed that the various approaches adopted by several manufacturers were inconsistent, with varying interpretations of the rule. One manufacturer had used in the past the full rotorcraft yaw capability and different types of strategies for the return phase depending on the helicopter model under consideration; in some cases the return phase was initiated at the maximum sideslip angle while in other cases from the steady state angle or, after the introduction of Amdt. 27-26/29-30, by initiating the return phase such as to not exceed the maximum sideslip envelope prescribed by the line. Another manufacturer performs a full rational analysis by applying maximum pedal and holding until the rotorcraft attains maximum transient sideslip, followed by the steady-state sideslip. Recovery is then initiated by returning the pedals to their original trimmed position. All portions of the manoeuvre are considered. Another manufacturer applies a similar practice but only that portion of the manoeuver that is within the line is kept for loads processing.

It was confirmed that the critical loading conditions is either the initial kick-in phase or the return phase.

All manufacturers represented in the rulemaking group confirmed that the primary intent of xx.351 was to establish the design case for those helicopter structural components that are subjected to the critical combination of tail rotor thrust, inertial and aerodynamic forces due to yawed flight. Where structural components are predominantly subjected to aerodynamic loads only (e.g. vertical empennage, cowlings, tail rotor fairing, doors, etc.), the maximum loads generated will be affected by the most critical sideslip angle, and each manufacture had developed internal conservative structural design criteria for the most critical yawing conditions that may be encountered in service. The rulemaking group therefore acknowledged that the current interpretation of xx.351 and the limited yawing envelope may not adequately address those airframe components designed to aerodynamic loads only. Furthermore, there is a risk that these components may not be adequately addressed if no suitable design criteria is developed by or made available to the manufacturer.

The Rulemaking Group has identified a gap in the regulations regarding aerodynamic design loads and has recommended development of a new rule, separate from xx.351, and not limited to yaw motion.

Agency's View: The Agency concurs with the rulemaking group's recommendation. However, until such time as the aerodynamics rule is in place, the Agency should maintain AMC xx.351 to ensure that all structural loads are fully accounted for.

2.1.4 Determine the acceptability of the manoeuvre specified in xx.351 and its associated AC/AMC, and its relevance to actual in-service experience.

As currently written, AC xx.351 is not in line with the current text of the rule, in that:

a) The AC allows the rotorcraft to be stabilised at the maximum steady state sideslip angle whereas the rule specifies that the rotorcraft attain a resulting sideslip angle, which (consistent with the definition given in other certification specifications and previously agreed by JAA), is the maximum transient angle or the limiting angle specified by the rule. There is no mention in the rule of a need to stabilise the rotorcraft at maximum steady state sideslip angle;

b) The AC allows the pilot to reduce the pedal displacement prior to achieving the maximum sideslip angle. There is no mention in the rule that the pilot is allowed to change the position of the directional control from the initial maximum deflection in xx.351(b)(1) and (c)(1). The directional control is allowed to be returned to neutral only upon reaching the resulting sideslip angle.

With this interpretation, industry cannot show compliance to the rule for helicopters with high tail rotor thrust that exceed the 'line' (see definition in Para 3.1 Draft AMC/GM a.Definitions (3)).

At 0.6 V_{NE}, the rule requires full pedal input (to the stops or limited by pilot forces), attain the resulting sideslip angle or 90 degrees, whichever is less, and return the pedals to neutral. The intent of the rule is to place the highest aerodynamic/inertial forces on the tailboom, anything greater than 90 degrees reduces the loading. For helicopters that do not have tail rotor thrust sufficient to go beyond 90 degrees, the rule is adequate. However, for those with excess power that can achieve yaw angles beyond 90 degrees, the pedal position must be trimmed to attain 90 degrees. Thus, they are no longer in compliance with the rule (full pedal deflection). This problem also occurs at V_H/V_{NE}, where the pedal is again fully deflected and the helicopter attains the resulting sideslip angle or 15 degrees, whichever is less. The primary difference between these stipulated endpoints is that the loads do not go down after reaching the 15-degree limit, but rather continue to increase.

The rulemaking group overcame this ambiguity by differentiating between the resulting side slip angle, which is now defined as the stabilised sideslip angle that results from a sustained maximum cockpit directional control deflection or as limited by pilot effort, and the maximum transient sideslip angle. With full cockpit directional control applied, the rotorcraft will therefore yaw to the maximum transient sideslip angle before reaching the resulting (stabilised) sideslip angle. Where the resulting sideslip angle is above the 'line', then the simulation can be re-trimmed to the line using the initial entry airspeed. This clarification is provided in the proposed changes to FAA AC xx.351.

Agency's view: The Agency supports the changes made to FAA AC xx.351 to clarify the intent of the rule.

2.1.4.1 Yaw manoeuvre simulation

As part of the rulemaking group activity, manufacturers performed simulations of the xx.351 manoeuvre using the alternative interpretations of the rule identified earlier and for various rotorcraft types.

The outcome of these simulations were generally consistent across all manufacturers.

Starting the return phase at the instant the simulation crosses the sideslip envelope line invariably produces the highest loads (bending moment and shears) on the tailboom due to the critical combination of tail rotor thrust, inertial and aerodynamic forces. These loads were in excess of the loads generated when the return phase is initiated at the instant when the simulation reached the maximum transient sideslip angle (overswing angle), as determined by its full yaw capability.

However, it has also been shown that the critical design condition occurrs not at V_H but at a lower speed on the line where the helicopter is trimmed using its full control capability (See AC xx.351 Figure 1 – point 'A'). The loads associated to this lower speed than V_H were of the same order of magnitude as the loads derived from the full rational manoeuvre. This was principly attributed to the entry speed at which the control reversal is initiated. When a full rational manoeuvre is simulated to determine the 'natural' steady sideslip angle, the return phase of the manoeuvre is generally initiated at an airspeed much lower than the initial entry speed due to the aerodynamic drag. Conversely, when the return phase is initiated from the reduced angle of 'the line', the initial entry airspeed is artificially restored, producing a comparable load combination of tail rotor thrust and vertical fin force.

It was therefore concluded that there is evidence that the limited sideslip envelope provides a conservative approach to structure that is subject to a combination of thrust, aerodynamic and inertia loads.

Agency's view: On the basis of these results, the Agency accepts that for structure that is subject to a combination of thrust, aerodynamic and inertia loads, the limited yawing envelope provides an acceptable and conservative approach.

2.1.4.2 Scope of structure to which the loading conditions of xx.351 applies.

The rulemaking group agreed that xx.351 should be applicable to rotorcraft structure that is subject to a combination of thrust, aerodynamic and inertia loads. In addition, the group identified a gap in the regulations, determining that an additional rule applicable to structures subject to high aerodynamic loading from flight at large sideslip angles should be developed separate from xx.351 and not limited to yaw motion.

Agency's View: The Agency concurs with the rulemaking group. The group's ToR was extended in November 2008 to formally include development of the new aerodynamics rule as a rulemaking group deliverable.

2.1.4.3 Environmental conditions applicable

Previous discussions on this issue had focused on the use of Sea Level ISA conditions in compliance with xx.351. In cold weather operations, the tail rotor can develop higher thrust due to the increased air density, potentially leading to an underestimation of the loads.

The previous JAA working group was split on this issue. Some members believed that the use of ISA SL was not a conservative assumption and the margin between the maximum operational loads and the design condition should be maintained when operating at low temperatures. It was also noted that there are an increasing number of applications that involve operations at temperatures as low as −50°C (winterisation kit). It was proposed that the lowest operational temperature declared in the RFM be used as the basis for loads substantiation or, as an alternative, to use the minimum temperature for temperate climate operations (ISA −20°C) to give a more appropriate ambient temperature.

Other members of the JAA working group considered that the use of ISA S/L density was adequate for design points, as the environmental conditions are considered under xx.307 'Proof of Structure'. The issue is not only limited to xx.351, as the use of lower density altitudes can impact other loading conditions in Subpart C where dynamic pressure is involved. Current industry design practice has been to design to the ISA SL condition, with some noticeable exceptions. The rotorcraft structure must be substantiated for all approved flight manoeuvres under all approved conditions, this includes the higher density associated with lower temperatures. Applicants specifically requesting certification at low temperature must comply with additional requirements, including xx.351. This was not the understanding of the previous JAA working group.

As part of this rulemaking task, industry members performed additional analysis to identify the change in loads at low operating temperatures. The conclusions from this analysis can be summarised as follows:

- Generally speaking, the selection of critical control strategy depends on the individual configuration of empennage, vertical surfaces, and Tail Rotor/Fenestron.
- Among the control strategies considered, however, the difference in the amount of load (i.e. resultant tailboom bending moment) is not significantly high (e.g. <5% for the worst case conditions).
- A lower temperature would, assuming an identical V_H TAS, imply a slight load increase. This assumption, however, must be balanced against the fact that in higher density air the power requirements increase with the consequences of a reduction of V_H TAS.

The results presented to the rulemaking group indicated that operational loads will not increase substantially with lower temperatures. This is based on the knowledge that operational speeds are less than design speeds and design loads are conservatively assessed at S/L conditions.

In conclusion, the rulemaking group were satisfied that the S/L ISA condition represented a sufficiently conservative assumption for the yawing condition rule.

Agency's view: On the basis of these results, the Agency accepts that S/L ISA can be used for normal compliance with xx.351.

2.1.4.4 Validation of Computer simulation tools

The issue was whether some specific text should be introduced in the AC in order to give guidance on the level of validation necessary for the analytical tools used for the simulation of the rational manoeuvre.

Validation of computer models was not specific to xx.351. Validation of analytical tools (e.g. NASTRAN) was generally undertaken on first application and then limited to the validation of inputs (e.g. aerodynamic coefficients) for specific helicopter configurations. The model was then applicable to all the loading condition where a manoeuvre simulation was requested.

Based on these considerations, the group concluded that as model validation was common practice there was no need to add any specific guidance in AC/AMC xx.351.

Agency's view: The Agency concurs with the rulemaking group.

2.1.4.5 Use of yaw limiters.

The rule does not state whether a yaw limiter or yaw damper may be used to show compliance with the rule. The use of such a system can significantly reduce structural loads and the issue then arises as to how to handle system failure cases. The group was split as to the inclusion of guidance on control system limiting devices in AC xx.351.

Within the rulemaking group, one view held the opinion that the yawing manoeuvre prescribed by xx.351 is a design case and should not address failures. Since the 'yaw kick' is not an approved manoeuvre, the failure of the device coupled with the unapproved manoeuvre was essentially a second order failure. System reliability was already addressed in the requirements (e.g. 1309, 1329) and had to meet the reliability levels consistent with its potential failure categorisation. Furthermore, determining quantitatively the probability of failure of mechanical systems was inherently problematic and system/ structural interface issues were not specific to xx.351. This opinion therefore considered the systems/structures interface guidance already contained in FAA AC xx.351 as rulemaking by AC and proposed its removal pending re-introduction in a more appropriately place, possibly as a new rule similar to CS 25.302 introduced into CS-25 for Large Aeroplanes.

Another view recommended retention of the text in xx.351, noting that there is a need to establish a methodology to evaluate design ultimate load conditions when a rotorcraft has installed a system and/or device intended to protect the helicopter from exceeding critical loads in flight. This need is urgent for compliance with xx.351 as some rotorcraft already incorporate such devices that will protect the helicopter airframe from exceeding critical loads due to yawing conditions. xx.1309 does not address the effects of system failures on the structural design loads determined under Subpart C; that was the reason why CS 25.302 had been introduced into CS-25.

Agency's View

The Agency supports the view that a new rule for rotorcraft similar to CS 25.302 would be the long-term solution. However, if a device is necessary to show compliance to the rule, then compensating features must be employed if the device fails, and the flight time spent in a failed condition must be taken into account. Without such an approach, it is conceivable that the ultimate loads generated with a yaw limiting device fitted and operating may be less than the limit loads generated with the device in the failed condition. The Agency therefore aims to retain this aspect of AMC xx.351.

2.1.5 Develop draft regulatory text relating to aerodynamic loads. This may be separate from xx.351 and not limited to yaw motion.

The rulemaking group's aim was to create a new design goal to address the aerodynamic loading on vertical surfaces, doors, windows and their surrounding structure and attachments.

Options addressed included:

(i) Consider re-introducing a form of xx.413, which had been removed from the rules in 1990;

(ii) Extend xx.351 to address aerodynamic surfaces;

(iii) Introduce the lateral gust requirement of CS 29.341 into CS-27;

(iv) Extend existing AMC/AC to existing rules (xx.775 – windshields and windows, xx.783 – Doors, xx.427 – Unsymmetrical loads);

(v) Create a new rule (i.e. xx.352 Aerodynamic loads);

(vi) C_{lmax} at $V_{NE.}$

In evaluating the options, the rulemaking group were of the opinion that aerodynamics needed to be treated separately from the yawing condition and other axes included. The overall strategy agreed was therefore to accept Opinon (v) and to develop a dedicated aerodynamics rule. Various criteria were proposed and evaluated, including a rational analysis, or V_D (1.11 V_{NE}) at 15deg yaw. V_D was selected due to the potential to generate high aerodynamic loads and the consequence of failures (including consequential damage) on the rotorcraft's stability and control.

Within the timeframe of the rulemaking group, it was not feasible to fully validate the proposed methodology due to lack of flight test or wind tunnel data at these extreme conditions. Furthermore, some members of the rulemaking group, subsequently questioned the need for such a rule for secondary structure, which had the potential to significantly increase loads, costs and the effort required for substantiation, without any safety justification.

Agency's View: The Agency is of the opinion that a potential safety risk may exist if the methodologies used to substantiate structure (including secondary structure) are not conservative. Until such time as a new rule is developed, the Agency intends to retain the acceptable means of compliance for aerodynamics loads contained in AMC xx.351. This requires the applicant to develop suitable design criteria acceptable to the Agency. One acceptable approach would be the determination of loads through a rational analysis using the simulation of the yaw manoeuvre of xx.351.

2.2. Objectives

The overall objectives of the EASA system are defined in Article 2 of the Basic Regulation. This proposal will contribute to the achievement of the overall objectives by addressing the issues outlined in Chapter 2 of this NPA.

The specific objective of RMT.0119 has been to review the rationale and application of xx.351, and associated AMC, in meeting the high safety standards envisaged and in its consistent application to the certification of products. This NPA proposes an amendment to AMC to CS-VLR, CS-27 and CS-29 (including FAA AC), that aims to meet these objectives.

2.3. Summary of the Regulatory Impact Assessment (RIA)

The proposed changes identified in this NPA are intended to provide a clear and unambiguous means of compliance to further enhance rotorcraft structural substantiation and provide a consistent and conservative approach. The additional AC/AMC will enable applicants to predetermine the Agency's expectations and so avoid unnecessary cost and time delays during a certification project.

2.4. Overview of the proposed amendments

2.4.1. The envisaged changes to FAA AC and to Decision 2003/17/RM, 2003/15/RM and 2003/16/RM are:

- Amendment to FAA AC 27-1B AC 27.351 Yawing Conditions
- Amendment to FAA AC 29-2C AC 29.351B Yawing Conditions
- Amendment of AMC VLR.351: Yaw Manoeuvre Conditions
- Amendment of AMC 27.351: Yaw Manoeuvre Conditions
- Amendment of AMC 29.351: Yaw Manoeuvre Conditions

2.4.2. Summary of the main changes proposed in this NPA.

Amendment to FAA AC 27&29.351:

- The 'zero yaw' definition is clarified by redefining it as 'Initial Trim Condition'. The rulemaking group considered that either zero bank or zero sideslip were acceptable initial trim conditions and that differences in resulting maximum loads arising from application of the manoeuvre of xx.351 were not significant.
- The 'Line' is clearly defined to aid understanding in applying this AC.
- Experience has shown that 'resulting sideslip angle' has been interpreted in different ways in previous certification/validation programmes. The introduction of this definition clearly defines the resulting sideslip angle as the steady state condition reached following sustained pedal application from the initial trimmed condition.
- The scope of structural components applicable are those that are primarily designed to the critical combinations of tail rotor thrust, inertial and aerodynamic forces. The applicable structure will therefore be dependent on the rotorcraft

configuration (e.g. the vertical stabilizer may be included if it supports the tail rotor).

- The failure of a control system limiting device is no longer included.
- Clarification is provided that the simulated manoeuvre should be conducted at the initial level flight power condition and that the initial sustained pedal input should be maintained to allow the rotorcraft to reach a maximum transient sideslip angle before reaching the steady state resulting sideslip angle. The return phase of the manoeuvre should not begin until the resulting sideslip angle has been obtained. Initiation of the return phase should not begin at the instant the rotorcraft crosses the line, or the pedal input reduced to avoid exceeding the line. The loads associated with the manoeuvre are then calculated based on the maximum transient sideslip angle, if the maximum angle obtained is less than the line, or the angle defined by the line.
- If the sideslip is limited to the line, the simulation should be adjusted to use less than maximum cockpit directional control. As airspeed will decay during the simulated manoeuvre due to increased drag, clarification is given that entry (initial) airspeed should be used in comparing the resulting sideslip angle with the line.
- The AC confirms that a rational analysis using a full dynamic simulation of the manoeuvre is an alternative acceptable method of compliance.

<u>Amendment to AMC VLR/27/29.351:</u>

- AMC VLR/27/29.351 is retained largely intact with minor editorial changes.

3. Proposed amendments

The text of the amendment is arranged to show deleted text, new or amended text as shown below:

(a) deleted text is marked with ~~strikethrough~~;

(b) new or amended text is highlighted in grey;

(c) an ellipsis (…) indicates that the remaining text is unchanged in front of or following the reflected amendment.

3.1. Draft Acceptable Means of Compliance and Guidance Material (Draft EASA Decision)

Proposal 1: Amend FAA AC 27.351 and FAA AC 29.351 as follows:

(*Note: The text of AC 27.351 is identical to that of § 29.351B and is not reproduced here.*)

AC 29.351B § 29.351 (Amendment 29-XX) YAWING CONDITIONS

a. Definitions

(1) Suddenly. For the purpose of this section, 'suddenly' is defined as an interval not to exceed 0.2 seconds for a complete control input. A rational analysis may be used to substantiate an alternative value.

(2) Initial Trim Condition~~Zero Yaw~~. Steady~~Normal~~, 1-g, level flight condition with zero bank angle or zero sideslip.

(3) 'Line'. The rotorcraft sideslip envelope, defined by the rule, between 90° at $0.6V_{NE}$ and 15° at V_{NE} or V_H, whichever is less. (See Figure 1).

(4) Resulting Sideslip Angle. The rotorcraft stabilized sideslip angle that results from a sustained maximum cockpit directional control deflection or as limited by pilot effort, in the initial level flight power conditions.

b. Explanation. The rule requires a rotorcraft "structural" yaw or sideslip design envelope~~. This sideslip envelope~~ that must cover minimum forward speed, or hover, to V_{NE} or V_H, whichever is less. ~~The rotorcraft must be structurally safe for the thrust capability of the directional control system.~~The scope of the rule is intended to cover structural components that are primarily designed to the critical combinations of tail rotor thrust, inertial and aerodynamic forces. This may include, but is not limited to; fuselage, tailboom and attachments, vertical control surfaces, tail rotor and tail rotor support structure.

(1) The rotorcraft structure must be designed to withstand the loads for the specified yawing conditions. The standard does not require a structural flight demonstration. It is a structural design standard.

(2) The standard applies only to power-on conditions. Autorotations need not be considered.

(3) This standard requires the maximum allowable rotor RPM consistent with each~~the~~ flight condition~~s, including special operational rotor settings~~ for which certification is requested.

(4) For the purpose of this section, the analysis may be performed at international standard atmosphere (ISA) sea level conditions.

~~(5) The rotorcraft structure must be designed to withstand the loads for the specified sideslip conditions. This includes, but is not limited to:~~

~~(i) Main cabin, tailboom, and vertical control surfaces.~~

~~(ii) Tail rotor structures, including the fitting attachments to the frame.~~

~~(iii) Windows, doors, and other transparencies.~~

~~(iv) Landing gear and retracting mechanism.~~

~~(v) Fairings and cowlings.~~

(5~~6~~) Maximum displacement of the directional control, except as limited by pilot effort (§ 29.397(a)), is required for the conditions cited in the rule. ~~Control system limiting devices may be used, however the probability of failure or malfunction of these system(s) should be considered (see Figure AC 29.351B-2). This evaluation may include Flight Manual Limitations, if failure of the system is reliably indicated to the crew~~A control system limiting device may be used.

(6~~7~~) Both right and left yaw conditions should be evaluated.

(7~~8~~)~~For vertical stabilizers,~~ The airloads on the vertical stabilizers may be assumed independent of the tail rotor thrust~~ (superpositioning)~~.

(8~~9~~) Loads associated with sideslip angles exceeding the values of the "line" defined in Figure 1 do not need to be considered. The corresponding points of the maneuver may be deleted.

c. Procedure. The design loads should be evaluated within the limits of Figure 1 or the maximum yaw capability of the rotorcraft, whichever is less; at speeds from zero to V_H or V_{NE}, whichever is less, for the following phases of the maneuver (See Note 1):

(1) With the rotorcraft at an Initial Trim Condition ~~(1g level flight and zero yaw)~~, the cockpit directional control is suddenly displaced to the maximum deflection limited by the control stops or by the maximum pilot force specified in § 29.397(a). This is intended to generate a high tail rotor thrust.

(2) While maintaining maximum cockpit directional control deflection, within the limitation specified in c(1) of this AC paragraph, allow the rotorcraft to yaw to the maximum transient sideslip angle ~~or to the value defined in Figure 1, whichever is less~~. This is intended to generate high aerodynamic loads that are determined based on the maximum transient sideslip angle or the value defined by the "line" in Figure 1, whichever is less. (See Note 1)

(3) Allow the rotorcraft ~~to stabalize at the maximum steady-state sideslip angle~~ to attain the resulting sideslip angle. In the event that the ~~maximum steady-state angle~~resulting sideslip angle is greater than the value defined by the "line" in Figure 1, the rotorcraft should be trimmed to that value of the angle using less than maximum cockpit directional control deflection using the entry airspeed of the maneuver. (See Note 2)

(4) With the rotorcraft yawed to the ~~static equilibrium~~ resulting sideslip angle specified in c (3) of this AC paragraph, the cockpit control is suddenly returned to its initial trim position. This is intended to combine a high tail rotor thrust and high aerodynamic restoring forces.

d. Another method of compliance may be used with a rational analysis (dynamic simulation), acceptable to the Agency/Authority, performed up to V_H or V_{NE}, whichever is less, to the maximum yaw capability of the rotorcraft with recovery initiated at the Resulting Sideslip Angle at its associated airspeed. Loads should be considered for all portions of the maneuver.

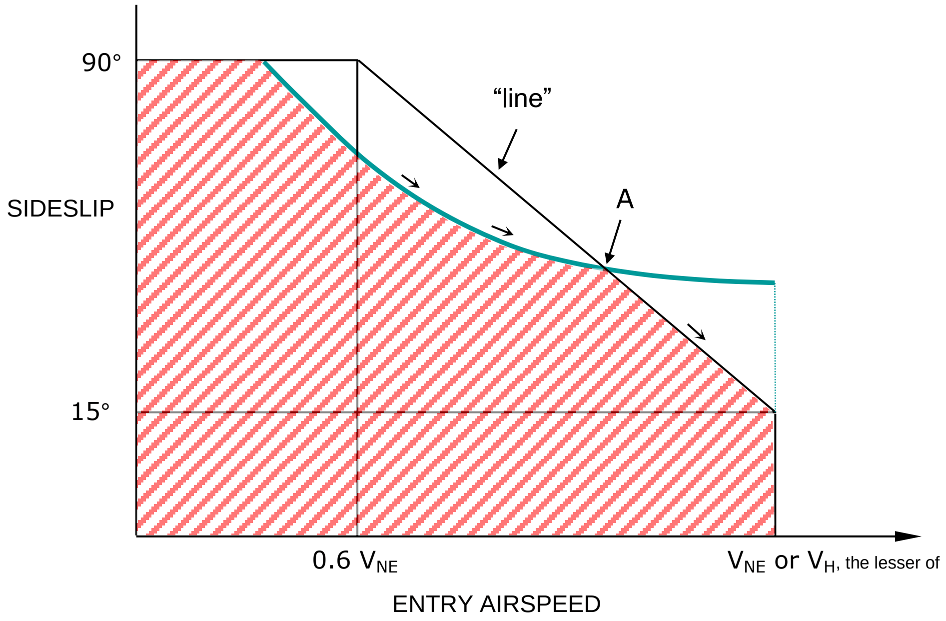


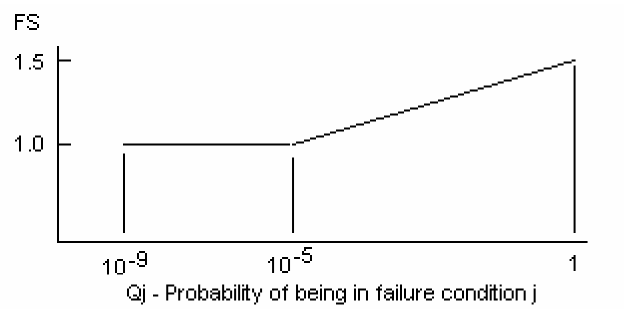
Figure 1 – YAW/ FORWARD SPEED DIAGRAM

NOTE:

(1) When comparing the rotorcraft sideslip angle against the "line" of Figure 1, the entry airspeed of the maneuver should be used.

(2) When evaluating the yawing condition against the "line" of Figure 1, sufficient points should be investigated in order to determine the critical design conditions. This investigation should include the loads that result from the maneuver initiated specifically at the intermediate airspeed which is coincident with the intersection of the "line" and the resultant sideslip angle (point "A" in Figure 1).

- ~~For static strength substantiation, each part of the structure should be able to withstand without failure, the loads generated by the maneuver described in the rule multiplied by a factor of safety depending on the probability of being in this failure state. The factor of safety is defined in the figure below:~~



~~Qj = (Tj)(Pj)~~
~~where:~~

~~Tj = Average flight time spent with a failed control limiting system j (in hours)~~

~~Pj = Probability of occurrence of failure of the control limiting system j (per hour)~~

~~Note: If Pj is greater than 10^{-3} per flight hour then a 1.5 factor of safety should be applied to all limit load conditions specified in this standard.~~

~~FIGURE AC 29.351B-2~~

~~Safety Factors for Probability of Failure~~

Proposal 2: Amend AMC 27.351 and AMC 29.351 as follows:
(Note: The text of AMC 27.351 is identical to that of AMC 29.351 and is not reproduced here.)

AMC 29.351
Yaw manoeuvre conditions

1. Introduction

This AMC provides further guidance and acceptable means of compliance to supplement FAA AC[5] ~~29-2C Change 2 (AC 29.351b. § 29.351 (Amendment 29-40) YAWING CONDITIONS),~~ to meet the Agency's interpretation of CS 29.351. As such it should be used in conjunction with the FAA AC but take precedence over it, where stipulated, in the showing of compliance.

Specifically, this AMC addresses two areas where the FAA AC has been deemed by the Agency as being unclear or at variance to the Agency’s interpretation. These areas are as follows:

a. Aerodynamic Loads

The certification specification CS 29.351 provides a minimum safety standard for the design of rotorcraft structural components that are subjected in flight to critical loads combinations of anti-torque system thrust (e.g. tail rotor), inertia and aerodynamics. A typical example of these structural components is the tailboom.

However, compliance with this standard according to FAA AC ~~29-2C Change 2~~ may not necessarily be adequate for the design of rotorcraft structural components that are principally subjected in flight to significant aerodynamic loads (e.g. vertical empennage, fins, cowlings and doors).

For these components and their supporting structure, suitable design criteria should be developed by the Applicant and agreed with the Agency.

In lieu of acceptable design criteria developed by the applicant, a suitable combination of sideslip angle and airspeed for the design of rotorcraft components subjected to aerodynamic loads may be obtained from a simulation of the yaw manoeuvre of CS 29.351, starting from the initial directional control input specified in CS 29.351(b)(1) and (c)(1), until the rotorcraft reaches the maximum transient ~~overswing~~ sideslip angle (overswing) resulting from its motion around the yaw axis.

b. Interaction of System and Structure

Maximum displacement of the directional control, except as limited by pilot effort (CS 29.397(a)), is required for the conditions cited in the certification specification. In the load evaluation, credit may be taken for consideration of the effects of control system limiting devices.

However, the probability of failure or malfunction of these system(s) should also be considered and if it is shown not to be extremely improbable, then further load

[5] See Reference in AMC 29 General.

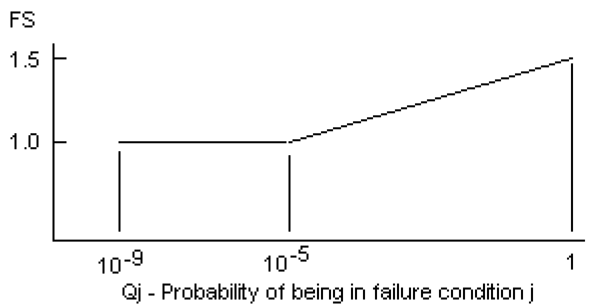
conditions with the system in the failed state should be evaluated. This evaluation may include Flight Manual Limitations, if failure of the system is reliably indicated to the crew.

A yaw limiting device is a typical example of a system whose failed condition should be investigated in the assessment of the loads requested by CS 29.351.

An acceptable methodology to investigate the effects of all system failures not shown to be extremely improbable on the loading conditions of CS 29.351 is as follows:

i) With the system in the failed state and considering any appropriate reconfiguration and flight limitations, it should be shown that the rotorcraft structure can withstand without failure the loading conditions of CS 29.351, when the manoeuvre is performed in accordance with the provisions of this AMC.

ii) The factor of safety to apply to the above specified loading conditions to comply with CS 29.305 is defined in the figure below.



Qj = (Tj)(Pj)

where:

Tj = Average flight time spent with a failed limiting system j (in hours)

Pj = Probability of occurrence of failure of control limiting system j (per hour)

Note: If Pj is greater than 1×10^{-3} per flight hour, then a 1.5 factor of safety should be applied to all limit load conditions evaluated for the system failure under consideration.

Proposal 3: Amend AMC VLR.351 as follows:

AMC VLR.351

Yaw manoeuvre conditions

1. Introduction

This AMC provides further guidance and acceptable means of compliance to supplement FAA[6] ~~AC 27-1B Change 2 (AC 27.351. § 27.351 (Amendment 27-26) YAWING CONDITIONS),~~ to meet the Agency's interpretation of CS VLR.351. As such it should be used in conjunction with the FAA AC but take precedence over it, where stipulated, in the showing of compliance.

Specifically, this AMC addresses an area where the FAA AC has been deemed by the Agency as being at variance to the Agency’s interpretation. This area is as follows:

[6] See Reference in AMC VLR General.

a. Aerodynamic Loads

The certification specification CS VLR.351 provides a minimum safety standard for the design of rotorcraft structural components that are subjected in flight to critical loads combinations of anti-torque system thrust (e.g. tail rotor), inertia and aerodynamics. A typical example of these structural components is the tailboom.

However, compliance with this standard according to FAA AC ~~27-1B Change 2~~ may not necessarily be adequate for the design of rotorcraft structural components that are principally subjected in flight to significant aerodynamic loads (e.g. vertical empennage, fins, cowlings and doors).

For these components and their supporting structure, suitable design criteria should be developed by the applicant and agreed with the Agency.

In lieu of acceptable design criteria developed by the applicant, a suitable combination of sideslip angle and airspeed for the design of rotorcraft components subjected to aerodynamic loads may be obtained from a simulation of the yaw manoeuvre of CS VLR.351, starting from the initial directional control input specified in CS VLR.351(b)(1) and (c)(1), until the rotorcraft reaches the maximum transient ~~overswing~~ sideslip angle (overswing) resulting from its motion around the yaw axis.

4. Regulatory Impact Assessment (RIA)

4.1. Issues to be addressed

The Agency is concerned that some interpretations of CS-VLR/27/29.351 and associated AMC do not provide an adequate margin of safety or sufficient structural substantiation when applied to modern rotorcraft designs that have a greater yawing capability than was envisaged when the limited sideslip envelope rule was developed. EASA product certification experience shows that limit sideslip angle proposed under xx.351 can be easily exceeded by modern rotorcraft designs.

The Agency had already developed additional AMC to xx.351 to extend the method of compliance given in the latest revision of the FAA ACs (AC 27-1B Chg 3/AC 29-2C Chg 3), to improve clarity and avoid misleading statements, with the objective of retaining the standard previously applied by the Agency through the CRI system. However, further development of the rules and AC/AMC is required to ensure structural requirements and acceptable means of compliance are appropriate, meet the identified safety risks and harmonised to the maximum extent possible.

4.1.1. Safety risk assessment

Although the Agency has found no evidence of catastrophic structural failure due directly to loads arising from yawing conditions, there have been several in-service incidents where large sideslip angles, well above those stipulated in the rule, have been attained at high speed, and that structural failure may only have been avoided through past compliance with more stringent certification standards (e.g. military requirements). The cause of these large sideslip angles can be the result of pilot command, environmental effects, or as a consequence of a failure e.g. engine/tail rotor failure.

4.1.2. Who is affected?

Rotorcraft design organisations.

4.1.3. How could the issue/problem evolve?

Modern rotorcraft are being designed and developed specifically for the civil market and may no longer be subjected to the more stringent military requirements. Furthermore, based on current trends of installing high power tail rotor systems to enhance rotorcraft yawing capability, this could result in future structural safety concerns arising.

The issue is common to all rotorcraft and is likely to remain controversial for all future certification/validation activities until finally resolved.

4.2. Objectives

The specific objective of this proposal is to propose an amendment to AMC to CS-VLR, CS-27 and CS-29 (including FAA AC), that clarifies compliance with the yawing condition of xx.351, and that will ensure a high and consistent level of safety is both attained and maintained.

4.3. Policy options

As the intent of this task is to clarify the application of existing rules, only 1 option is identified.

Table 1: Selected policy options

Option No	*Short title*	**Description**
0		Baseline option (no change in rules; risks remain as outlined in the issue analysis).
1		Further clarify the regulatory intent by amending CS-VLR/27/29 and associated AMC.

4.4. Analysis of impacts

4.4.1. Safety impact

There is no consistent interpretation of xx.351. This was illustrated in the rulemaking group's activities with 4 leading helicopter manufacturers presenting their existing compliance methodologies, with each having a unique interpretation. Unless best practice is adhered to, there is a potential to reduce or negate the envisaged safety margins embedded in the certification codes to the extent that structural strength of the rotorcraft is not assured.

Option 0

Option 0 will not alleviate these concerns or improve safety standards.

Option 1

Option 1 proposes changes to FAA AC xx.351 to clarify the means of compliance and avoid ambiguities. This will ensure that best practice is applied and that derived loads are conservative.

Two further safety-related issues were identified by the group: structural loads on those components subject primarily to aerodynamic forces only; failure of control system limiting devices. As the rulemaking group were unable to reach consensus on these issues, the Agency aims to retain AMC xx.351.

4.4.2. Environmental impact

None identified.

4.4.3. Social impact

None identified.

4.4.4. Economic impact

Option 0

As no consistent interpretation of xx.351 exists, the likelihood of encountering issues during product certification is high, resulting in the need to raise a CRI with its consequential impact on project costs and timescales.

Any in-service incidents resulting in the need to redesign and re-certificate structural elements is likely to lead to considerable costs.

Option 1

Following extensive investigation by the group, it has been determined that the limited sideslip envelope provided under xx.351 remains valid for structures that are primarily designed to the critical combinations of tail rotor thrust, inertial and aerodynamic forces.

The only regulatory change necessary is therefore to add clarity in AC material to ensure that consistent and standardised means of compliance are used. For some manufacturers, this will mean a change in compliance methodology and associated tools and procedures. However, the cost of such changes is likely to be low.

Retention of Agency AMC xx.351 will not add any additional burden on industry, as compliance must already be shown and most design organisations will already have in-house design criteria that is used for structure subject primarily to aerodynamic loads.

4.4.5. General aviation and proportionality issues

The concept of 'the line' in FAA Amendment 27-26 & 29-30 was introduced as a simple means of compliance in recognition that GA and SMEs may not have the capability or resources to undertake a full dynamic simulation. This proposal retains this option of using 'the line' in the showing of compliance.

4.4.6. Impact on 'Better Regulation' and harmonisation

Option 0

Experience has shown that there are implementation issues associated with xx.351 which have led to inconsistent interpretation by specialists and the need for CRIs to be raised during product certification/validation.

Option 1

The fact that the rulemaking group were unable to reach consensus within the timescale available has resulted in some differences being retained.

On the positive side:

- Proposed amendments to AC 27.351 and AC 29.351 will clarify some issues with regard to simulating the yawing condition manoeuve, and have been jointly agreed. These amendments are expected to be published by the FAA in Change 4 of AC 27-1B and AC 29-2C and will be adopted by the Agency.
- The rulemaking group has identified that there is a gap in the regulation relating to structures primarily subject to aerodynamic loads.

Issues that were not agreed and will remain differences for the foreseeable future include:

- Aerodynamic rule
- Interaction of systems and structures

These difference are highlighted in amendments to Agency specific AMC VLR/27/29.351

4.5. Comparison and conclusion

4.5.1. Comparison of options

Option 0: Do nothing

Differences of opinion will remain between specialists on the interpretation of xx.351 and associated AMC. As a result, safety concerns on those rotorcraft designs with high yawing capability will impact on the certification/validation process, with consequential cost and timescale impacts.

Option 1: Further clarify the regulatory intent by amending AC/AMC xx.351

The proposed changes identified in this NPA are intended to provide a clear and unambiguous means of compliance to further enhance rotorcraft structural substantiation and provide a consistent and conservative approach. The additional AC/AMC will enable applicants to predetermine the Agency's expectations and so avoid unnecessary cost and time delays during a certification project.

4.5.2. Monitoring and ex post evaluation

While the proposals in this AMC are expected to provide greater consistency of approach to compliance with xx.351, areas where the rulemaking group could not agree will remain controversial for the foreseeable future. These issues need to be monitored in the future with a view to identifying acceptable common practice.

5. References

5.1. Affected regulations

N/A

5.2. Affected CS, AMC and GM

Decision No 2003/17/RM of the Executive Director of the Agency of 14.11.2003 on certification specifications for very light rotorcraft (CS-VLR). Decision as last amended by Decision 2008/11/R of the Executive Director of the Agency on 17 November 2008.

Decision No 2003/15/RM of the Executive Director of the Agency of 14.11.2003 on certification specifications for small rotorcraft (CS-27). Decision as last amended by Decision 2012/021/R of the Executive Director of the Agency on 11 December 2012.

Decision No 2003/16/RM of the Executive Director of the Agency of 14.11.2003 on certification specifications for large rotorcraft (CS-29). Decision as last amended by Decision 2012/022/R of the Executive Director of the Agency on 11 December 2012.

5.3. Reference documents

N/A