Special Condition C-04 on Interaction of Systems and Structure on helicopters configured with Fly-by-Wire (FBW) Flight Control System (FCS)

This Special Condition is published for public consultation in accordance with the Certification Procedures of the European Aviation Safety Agency (Ref. EASA Management Board Decision No.: 07-2004), Article 3 –applicable requirements, certification specifications, acceptable means of compliance and guidance material, "Deviations from the applicable airworthiness codes, environmental protection certification specifications and/or acceptable means of compliance with Part 21, as well as important special conditions and equivalent safety findings, shall be submitted to the panel of experts and be subject to a public consultation of at least 3 weeks, except if they have been previously agreed and published in the Official Publication of the Agency. The final decision shall be published in the Official Publication of the Agency."

Deadline for comments:	November 08, 2016.
Applicable Manufacturer:	Bell Helicopter Textron
Contact person:	Max Romano, EASA Project Certification Manager
Phone:	+49 (0)22189990 4345
Email:	max.romano@easa.europa.eu

BACKGROUND:

Active flight control systems are capable of providing automatic responses to inputs from sources other than the pilots. Active flight control systems have been expanded in function, effectiveness, and reliability to the point that FBW FCS systems are being installed on new rotorcraft. As a result of these advancements in flight controls technology, the Certification Specifications for Large Rotorcraft CS-29 no longer set an adequate standard to attain an acceptable level of safety for rotorcraft so equipped. Therefore, the certification of these systems requires issuing special conditions under the provisions of Commission Regulation (EU) No 748/2012 Ref.: Annex I (Part 21): Part 21.A.16B.

In the past, traditional rotorcraft flight control system designs have incorporated power-operated systems, stability or control augmentation with limited control authority, and autopilots that were certified partly under CS 29.672 with guidance from Advisory Circular 29-2C, Section AC 29.672. These systems are integrated into the primary flight controls and are given sufficient control authority to manoeuvre the rotorcraft up to its structural design limits in CS-29 Subparts C and D. The FBW FCS advanced technology with its full authority necessitates additional requirements to account for the interaction of control systems and structure.

The regulations defining the loads envelope in CS-29 do not fully account for the effects of systems on structural performance. Automatic systems may affect the structural loads either directly or as a result of a failure or malfunction; for example, they may be inoperative or they may operate in a degraded mode with less than full system authority and associated built-in protection features. Therefore, it is necessary to determine the structural factors of safety and operating margins such that the probability of structural failures due to application of loads during FBW FCS malfunctions is not greater than that found in rotorcraft equipped with traditional flight control systems. To achieve this objective and to ensure an acceptable level of safety, it is necessary to identify the failure conditions with their associated frequency of occurrence.

Traditional flight control systems provide two states, either functioning or inoperative. These states are readily apparent to the flight crew. On the other hand, newer active flight control systems present failure modes that allow the system to function in a degraded mode without full authority and associated built-in protection features. Because these degraded modes are not readily apparent to the flight crew, monitoring systems are required to provide an annunciation of degraded system capability.

EASA Position:

The following special condition is proposed to address the effects of systems on structures.

Interaction of Systems and Structure

For rotorcraft equipped with systems that affect structural performance, either directly or as a result of a failure or malfunction, the influence of these systems and their failure conditions must be taken into account when showing compliance with the requirements of Subparts C and D of CS-29.

The following criteria must be used for showing compliance with these special conditions for rotorcraft equipped with flight control systems, autopilots, stability augmentation systems, load alleviation systems, flutter control systems, fuel management systems, and other systems that affects structural performance either directly or as a result of failure or malfunction. If these special conditions are used for other systems, it may be necessary to adapt the criteria to the specific system.

(a) The criteria defined herein only address the direct structural consequences of the system responses and performance. They cannot be considered in isolation but should be included in the overall safety evaluation of the rotorcraft. These criteria may in some instances duplicate standards already established for this evaluation. These criteria are only applicable to structure whose failure could prevent continued safe flight and landing. Specific criteria that define acceptable limits on handling characteristics or stability requirements when operating in the system degraded or inoperative mode are not provided in this special condition.

(b) Depending upon the specific characteristics of the rotorcraft, additional studies may be required to go beyond the criteria provided in this special condition in order to demonstrate the capability of the rotorcraft to meet other realistic conditions such as alternative gust or manoeuvre descriptions for a rotorcraft equipped with a load alleviation system.

(c) The following definitions are applicable to this special condition.

(1) *Structural performance*: Capability of the rotorcraft to meet the structural requirements of CS 29

(2) *Flight limitations*: Limitations that can be applied to the rotorcraft flight conditions following an in-flight occurrence and that are included in the flight manual (e.g., speed limitations, avoidance of severe weather conditions, etc.).

(3) *Operational limitations*: Limitations, including flight limitations that can be applied to the rotorcraft operating conditions before dispatch (e.g., fuel, payload and Master Minimum Equipment List limitations).

(4) *Probabilistic terms*: The probabilistic terms (probable, improbable, extremely improbable) used in these special conditions are the same as those used in CS 29.1309.

(5) *Failure condition*: The term “failure condition” is the same as that used in CS 29.1309; however, these special conditions apply only to system failure conditions that affect the structural performance of the rotorcraft (e.g. system failure conditions that induce loads, change the response of the rotorcraft to inputs such as gusts or pilot actions, or lower flutter margins).

Effects of Systems on Structure.

(a) General. The following criteria will be used in determining the influence of a system and its failure conditions on the rotorcraft structure.

(b) System fully operative. With the system fully operative, the following apply:

(1) Limit loads must be derived in all normal operating configurations of the system from all the limit conditions specified in Subpart C (or defined by special condition or equivalent level of safety in lieu of those specified in Subpart C), taking into account

any special behaviour of such a system or associated functions or any effect on the structural performance of the rotorcraft that may occur up to the limit loads. In particular, any significant nonlinearity (rate of displacement of control surface, thresholds or any other system nonlinearities) must be accounted for in a realistic or conservative way when deriving limit loads from limit conditions.

(2) The rotorcraft must meet the strength requirements of CS 29 (static strength, residual strength), using the specified factors to derive ultimate loads from the limit loads defined above. The effect of nonlinearities must be investigated beyond limit conditions to ensure the behaviour of the system presents no anomaly compared to the behaviour below limit conditions. However, conditions beyond limit conditions need not be considered when it can be shown that the rotorcraft has design features that will not allow it to exceed those limit conditions.

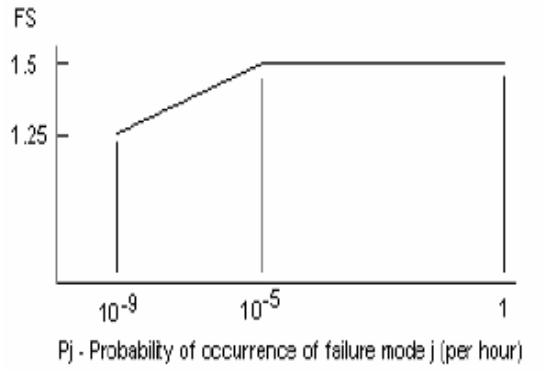
(3) The rotorcraft must meet the flutter and divergence requirements of CS 29.629.

(c) System in the failure condition. For any system failure condition not shown to be extremely improbable, the following apply:

(1) At the time of occurrence. Starting from 1-g level flight conditions, a realistic scenario, including pilot corrective actions, must be established to determine the loads occurring at the time of failure and immediately after the failure.

(i) For static strength substantiation, these loads multiplied by an appropriate factor of safety that is related to the probability of occurrence of the failure are ultimate loads to be considered for design. The factor of safety (FS) is defined in Figure 1.

Figure 1
Factor of safety at the time of occurence



(ii) For residual strength substantiation, the rotorcraft must be able to withstand two thirds of the ultimate loads defined in subparagraph (c)(1)(i) of these special conditions.

(iii) Freedom from flutter and divergence must be shown under any condition of operation including:

(a) Airspeeds up to 1.11 V_{NE} (power on and power off).

(b) Main rotor speeds from 0.95 x the minimum permitted speed up to 1.05 x the maximum permitted speed (power on and power off).

(c) The critical combinations of weight, centre of gravity position, load factor and altitude.

(iv) For failure conditions that result in excursions beyond operating limitations, freedom from flutter and divergence must be shown to increased speeds, so

that the margins intended by (c)(1)(iii) of these special conditions are maintained.

(v) Failures of the system that result in forced structural vibrations (oscillatory failures) must not produce loads that could result in detrimental deformation of primary structure.

(2) For the continuation of the flight. For the rotorcraft in the system failed state, and considering any appropriate reconfiguration and flight limitations, the following apply:

(i) The loads derived from the following conditions (or defined by special conditions or equivalent level of safety in lieu of the following conditions) at speeds up to V_{NE} (power on and power off) (or the speed limitation prescribed for the remainder of the flight) and at the minimum and maximum main rotor speeds, if applicable, must be determined:

(A) the limit symmetrical manoeuvring conditions specified in CS29.337 and in CS29.339.

(B) the limit gust conditions specified in CS29.341.

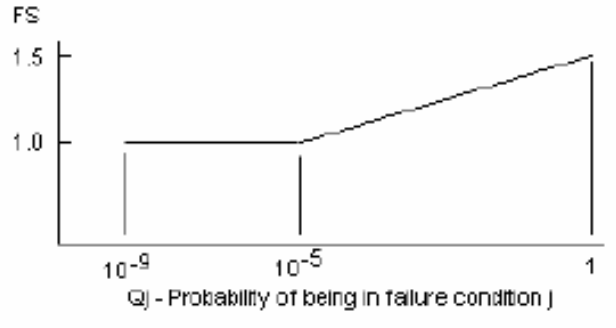
(C) the limit yaw manoeuvring conditions specified in CS29.351.

(D) the limit unsymmetrical conditions specified in CS 29.427

(E) the limit ground loading conditions specified in CS 29.473.

(ii) For static strength substantiation, each part of the structure must be able to withstand the loads in paragraph (c)(2)(i) of these special conditions multiplied by a factor of safety depending on the probability of being in this failure state. The factor of safety is defined in Figure 2.

Figure 2
Factor for safety for continuation of flight



$Q_j = (T_j)(P_j)$ where:

Q_j = Probability of being in failure condition j

T_j = Average time spent in failure condition j (in hours)

P_j = Probability of occurrence of failure mode j (per hour)

Note: If P_j is greater than 10^{-3} per flight hour then a 1.5 factor of safety must be applied to all limit load conditions specified in Subpart C.

(iii) For residual strength substantiation, the rotorcraft must be able to withstand two thirds of the ultimate loads defined in paragraph (c)(2)(ii) of these special conditions.

(iv) If the loads induced by the failure condition have a significant effect on fatigue or damage tolerance, then their effects must be taken into account.

(v) Freedom from flutter and divergence must be shown up to 1.11 V_{NE} (power on and power off).

(vi) Freedom from flutter and divergence must also be shown up to 1.11 V_{NE} (power on and power off), for all probable system failure conditions combined with any damage required or selected for investigation by CS 29.571(g) or CS 29.573(d)(3).

(3) Consideration of certain failure conditions may be required by other sections of CS 29 regardless of calculated system reliability. Where the failure analysis shows the probability of these failure to be less than 10^{-9}, criteria other than those specified in this paragraph may be used for structural substantiation to show continued safe flight and landing.

(d) Failure indications. For system failure detection and indication, the following apply:

(1) The system must be checked for failure conditions, not shown to be extremely improbable, that degrade the structural capability below the level required by CS 29 or that significantly reduce the reliability of the remaining operational portion of the system. As far as reasonably practicable, the flight crew must be aware of these failures before flight. Certain elements of the control system, such as mechanical and hydraulic components, may use special periodic inspections, and electronic components may use daily checks, in lieu of detection and indication systems to achieve the objective of this requirement. These other means of detecting failures before flight will become part of the certification maintenance requirements (CMRs) and must be limited to components that are not readily detectable by normal detection and indication systems, and where service history shows that inspections will provide an adequate level of safety.

(2) The existence of any failure condition, not shown to be extremely improbable, during flight that could significantly affect the structural capability of the rotorcraft and for which the associated reduction in airworthiness can be minimised by suitable flight limitations, must be signalled to the flight crew. For example, failure conditions that result in a factor of safety between the rotorcraft strength and the loads of Subpart C below 1.25, or flutter and divergence margins below 1.11 V_{NE} (power on and power off), must be signalled to the crew during flight.

(e) Dispatch with known failure conditions. If the rotorcraft is to be dispatched in a known system failure condition that affects structural performance, or that affects the reliability of the remaining operational portion of the system to maintain structural performance, then the provisions of these special conditions must be met, including the provisions of paragraph (b) for the dispatched condition and paragraph (c) for subsequent failures. Flight limitations and expected operational limitations may be taken into account in establishing Q_j as the combined probability of being in the dispatched failure condition and the subsequent failure condition for the safety margins in Figure 2 of these special conditions. These limitations must be such that the probability of being in this combined failure state and then subsequently encountering limit load conditions is extremely improbable. No reduction in these safety margins is allowed if the subsequent system failure rate is greater than 10^{-3} per hour.