Proposed Special Condition on Small Jet engine for Sailplane
Applicable to Sailplanes category

Introductory note

The following Special Condition has been classified as an important Special Condition and as such shall be subject to public consultation, in accordance with EASA Management Board decision 02/04 dated 30 March 2004, Article 3 (2.) of which states:

> 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.

Since the Turbine Engine design is not yet covered by CS-22, subpart H, Special conditions are required in accordance with par. 21A.16B(a)(1) to address this design.

Statement of Issue

An applicant has submitted a proposal to establish a safe rotor life for a small jet engine for sailplanes as an alternative means of compliance to justify no Hazardous Engine effect because of potential release of High Energy Debris subsequent to Disc Failure.

History

To cover the turbine engine in CS-22, a set of special conditions have been developed between EASA, CAA-CZ and LBA in order to address the turbine engine design. The introduction of these 18 special conditions specifically addresses the turbine engine design. SC 13 and SC 14 require a containment test to show containment of high energy rotating parts after a hub failure. These Special Conditions[1] are already agreed after public consultation on 22.08.2007.

Discussion

Experience with other small turbine design has shown that because of the design specifics of such single shaft jet engines it may be difficult to achieve a tri-hub burst at the required conditions.
Therefore, it is proposed to establish a safe rotor life as an alternative means of compliance to the Special Conditions 13 and 14.

> ***Special Condition 13***: *Rotor Containment requires the engine to provide containment of the maximum kinetic energy fragments from the hub failure as described in SC14(c)*
>
> ***Special Condition 14***: *Containment*
> *This Special Condition describes the details about the required substantiation of the compliance with SC13.*

[1] Ref: Attachment 1

New Special Conditions:

Special Condition 13 revised

To prevent the release of high energy debris, which is considered a hazardous engine effect, it is required to either provide containment as described in SC14(c) or to establish a rotor approved life as described in SC19.

Special Condition 19

To establish an approved life for a rotor, the following tests must be highly conservative.

Approved Life: The mandatory replacement of a part which is approved by the agency.

A highly conservative way will be achieved by using pre-prepared rotors with an initial crack at the most critical position from a stress point of view. The test engine should be pre-prepared with such a crack at the most critical positions in both compressor and turbine rotors.

The initial anomaly size is at least one of the following:

- 0,381mm x 0.762mm (*0.015 inches x 0.030 inches*) for an assumed (semicircular) surface anomaly.
- 0.381mm x 0.381mm (*0.015 inches x 0.015 inches*) for an assumed (quarter-circular) corner anomaly.

Cycling

(a) The start-stop cycle to be applied should be defined considering the assumed flight cycle of the typical engine installation as well as the related environmental and engine conditions. Because in this case the fatigue life is based on test data obtained from cyclic testing, the test results should be corrected for inherent scatter.

(b) To establish a conservative and acceptable cycle life, the engine test can be performed with a real engine on a bench. The approved life should be very conservative, 1/3 of the cycles shown in the test without burst, or significant crack growth. Only one rotor/shaft assembly can be used for the test (*one set of Compressor, Turbine and Shaft*). If during the test other parts fail (*like bearings*), they can be changed in between.

(c) Cycling Test

- The applicant to define a suitable test with representative start-stop cycles considering the operating envelope and typical flight usage profile of the engine.
- Run the engine for x-cycles
- Inspect => no cracks
- Release 1/3 of x ⇨ y
- y= Approved Life Limit

Rotor Integrity

(a) For each compressor and turbine rotor it must be established by test and analysis that a rotor with the most adverse combination of material properties and dimensional tolerances allowed by its type design will not burst when it is operated in the engine for 5 minutes at the most critical condition.

(b) The following speeds must be evaluated, in conjunction with their associated temperatures and temperature gradients, throughout the engine's operating envelope:

1) **120%** of the max permissible rotor speeds associated with any of the ratings
2) **105%** of the highest rotor speed that would result from either:
   i. The failure of the component that is most critical with respect to over speeding.
   ii. The failure of any component that in combination with the failure of a component or system that would normally not be detected during a routine pre-flight or during normal flight operation that is the most critical with respect to over speeding.
3) **100%** of the highest rotor speed that would result from the Failure of the component or system which in a representative installation of the engine, is the most critical with respect to over speeding when operating at any rating condition.

Growth of the rotor while it is operating at the applicable conditions must not cause the Engine to:

i. Catch fire,
ii. Release high energy debris through the Engine's casing or result in a hazardous Failure of the Engine's casing,
iii. Generate loads greater than those ultimate loads for which the Engine's mountings have been designed in compliance with CS-22.1823, or
iv. Lose the capability of being shut down.

After the applicable period of operation, the rotor must not exhibit conditions such as cracking or distortion which preclude the safe operation of the Engine during any likely continued operation following such an over-speed event in service.

The applicant must develop:

i. An engineering plan, the execution of which establishes and maintains that the combinations of loads, material properties, environmental influences and operating conditions, are sufficiently well known to allow the rotor to be withdrawn from service at the Approved Life before hazardous engine effects can occur. This includes the determination of the most critical location for the artificial cracks induced for the test, and the definition of the spin cycle including the specific test conditions. The Approved Life must be published.

ii. A manufacturing plan, defining the material specifications and traceability, appropriate NDT evidence and acceptable test methods necessary to consistently produce rotors with the attributes required by the engineering plan.

iii. A service management plan which defines in-service processes for maintenance and repair of the rotor which will maintain attributes consistent with those required by the engineering plan. These processes must become part of the instructions for continued airworthiness.

Attachment 1
Agreed Special Conditions, after public consultation on 22.08.2007

Subject : Special Condition - Airworthiness Standard for CS-22H - Turbine Engine to be operated in Powered Sailplanes

Status : closed

Requirement reference : Commission Regulation (EC) No. 1702/2003, 21A.16B(a)(1); CS-22,Subpart H

Statement of issue:

Since the Turbine Engine design is not yet covered by CS-22 Subpart H, a Special condition in accordance with para. 21A.16B(a)(1) is required to address this specific design.

Discussion

Because of the intended use of this engine, i.e. installation in self-sustaining sailplanes only and no usage for take-off operation, it is considered an undue burden for the applicant to base the EASA Certification for this engine on the Certification Specifications of CS-E. Therefore, between EASA, CAA-CZ and LBA a set of Special Conditions has been developed in order to address the turbine engine design. The general approach of this CRI is to change/amend Subpart H of CS-22 by introducing 17 Special Conditions which specifically address the Turbine Engine Design.
Accordingly, the following paragraphs of CS-22 Subpart H have been replaced by individual Special Conditions: CS 22.1801, CS 22.1825, CS 22.1833, CS 22.1835, CS 22.1839, CS 22.1843, CS 22.1845, CS 22.1849, CS 22.1851.
The following paragraphs of Subpart H are retained as being applicable for turbine engines as well:
CS 22.1805, CS 22.1807, CS 22.1808, CS 22.1815, CS 22.1817, CS 22.1819, CS 22.1821, CS 22.1823, CS 22.1853, CS 22.1855, CS 22.1857.

1. EASA Special Conditions :

SC1: Applicability

The Special Conditions SC1...SC17 are applicable to turbine engines for powered sailplanes.
Because of the use of these engines in sailplanes, there are several assumptions, to simplify the requirements for certification.
The assumptions are:

- engines will be used for self-sustaining sailplanes only, not intended for take-off
- no bleed air, no reverse functions
- no flight in icing or hail conditions
- no aerobatic operation
- the turbine engine is not used to drive accessories that are essential for any other means than the turbine engine itself
- the strike and ingestion of foreign matter can be treated as extremely remote, because the engine is started and shut down in flight. Ground operation will only take place for maintenance purpose.

SC2: Functioning

The engine must be free from dangerous surge and instability throughout its operating range of ambient and running conditions within the air intake pressure and temperature conditions declared by the constructor.

SC3: Accessory Attachment

Each accessory drive and mounting attachment must be designed and constructed so that the engine will operate properly with the accessories attached. The design of the engine must allow the examination, adjustment or removal of each engine accessory. The engine shall not provide accessory drives other than used for essential engine equipment which is part of the engine Type Design.

SC4: Engine Control System

(a) Engine Control System Operation. It must be substantiated by tests, analysis or a combination thereof that the Engine Control System performs the intended functions in a manner which –

(1) Enables selected values of relevant control parameters to be maintained and the Engine kept within the approved operating limits over changing atmospheric conditions throughout the declared flight envelope, and

(2) Does not create unacceptable thrust or power oscillations.

b) It must also be demonstrated that the engine is capable of functioning properly in case of exposure to electromagnetic interference. The demonstrated levels have to be included in the Installation Instructions.

SC5: Vibration

The engine must be designed and constructed to function throughout its declared flight envelope of rotational speeds and power/thrust, without inducing excessive stress in any Engine part because of vibration and without imparting excessive vibration forces above the approved aircraft limitations on the structure of the powered sailplane.

SC6: Fuel and induction system

(a) The fuel system of the engine must be designed and constructed to supply the appropriate fuel throughout the complete operating range of the engine under all starting, flight and atmospheric conditions. It should also keep the rotational speed in the range, defined by the manufacturer.

(b) The engine intake shall be designed and constructed to minimise ice accretion.

(c) The type and degree of fuel filtering necessary for protection of the engine fuel system against foreign particles in the fuel must be specified. The applicant must show (e.g. within the 50-hour run prescribed in SC10(a) that foreign particles passing through the prescribed filtering means will not critically impair engine fuel system functioning.

(d) The engine design has to prevent situations in which fuel may accumulate inside the engine while not in use. This applies to all attitudes that the applicant establishes as those the engine can have when the powered sailplane in which it is installed is in the static ground attitude.

SC7: Lubrication system

(a) The design of the oil system must be such as to ensure its proper functioning under all intended flight attitudes, installation, atmospheric and operating conditions, including oil temperature and expansion factors.
(b) If required by the engine design, provisions shall be provided to allow for the installation of means for cooling the lubricant.
(c) The oil system including the oil tank expansion space must be adequately vented.

SC8: Vibration Test

(a) The engine must undergo a vibration survey to establish that the vibration characteristics of those components that may be subject to mechanically or aerodynamically induced vibratory excitations are acceptable throughout the declared flight envelope. The engine surveys and their extent must be based upon an appropriate combination of experience, analysis and component test and must address, as a minimum, blades, vanes, rotor discs, spacers and rotor shafts.

(b) The surveys must cover the ranges of power or thrust and both the physical and corrected rotational speeds for each rotor system, corresponding to operations throughout the range of ambient conditions in the declared flight envelope, from the minimum rotational speed up to 103% of the maximum physical and corrected rotational speed permitted for rating periods of two minutes or longer and up to 100% of all other permitted physical and corrected rotational speeds, including those that are Over-speeds. If there is any indication of a stress peak arising at the highest of those required physical or corrected rotational speeds, the surveys must be extended sufficiently to reveal the maximum stress values present, except that the extension need not cover more than a further two percentage points increase beyond those speeds.

SC9: Calibration Test

In order to identify the engine thrust or power changes that may occur during the endurance test of SC10, thrust or power calibration curves of the test engine must be established either by specific tests accomplished immediately before and after the endurance test or by measurements obtained during the first and final stages of the endurance, up to the highest rated power.

SC 10: Endurance test

(a) The engine must be subjected to an endurance test (with a representative propeller for turbo-prop) that includes a total of 50 hours of operation and consists of the cycles specified below:

Sequence	Duration	Operating Conditions
1	1	Starting idle
2	10	Max Power / Thrust
3	1	Cooling run (idle)
4	5	Maximum Power / Thrust
5	1	Cooling run (idle)
6	30	Max continuous Power / thrust
7	1	Cooling run
8	10	Acceleration and deceleration of 6 cycles from ground idling to maximum power / thrust, maintaining Maximum power/thrust for a period of 30 seconds, the remaining time being at ground idling
9	1-3	Cooling run (idle) and stop

(b) During or following the endurance test the fuel and if applicable oil and gas consumption must be determined.

SC11: Operation test

The operation test shall include the demonstration of characteristics in case of idling, transitional characteristics among operational stages, characteristics of acceleration of design load, characteristics in case of overspeeding as well as any other operational characteristics of the engine.

SC12: Cyclic Endurance Test

Depending on the results of the tests prescribed in SC8, additional endurance testing may be required at one or more particular rotational speed(s) to find out whether the engine may be operated without fatigue failure.

SC 13: Rotor Containment

For each high-energy engine rotor, the engine must be designed to provide containment of the Maximum kinetic energy fragments from the hub failure as specified in SC14(c).

SC 14: Containment

(a) Compliance with SC13 of each high-energy rotor, critical and non-critical[1)], must be substantiated by test, analysis or combination thereof as specified in SC14(a)(1) and (a)(2), under the conditions of SC14(b), (c) and (d).

(1) The critical rotor of each compressor and turbine rotor assembly must be substantiated by engine test.

Analyses and / or component or rig tests may be substituted only if they are validated by engine test.

(2) Non-critical rotors may be substantiated by validated analysis.

(b) Containment must be demonstrated at the following speed and temperature conditions:

(1) The highest speed which would result from either:

(i) Any single failure of the Engine Control System, or

(ii) Any single failure or likely combination of failures not considered to be Extremely Remote.

(2) The temperature of the containing components must not be lower than the temperature during operation of the engine at maximum power/thrust rating.

(c) Containment must be substantiated as hub containment under the following condition: for all types of compressors and turbines, fragments resulting from a failure which produces the maximum translational kinetic energy.

Note: The containment tests have to be performed with the engine fitted to a representative mounting system intended to be used for the typical aircraft installation.

(d) It must be shown that the following specifications were met:

(1) The engine did not experience a sustained external fire

(2) The engine did not release high-energy fragments radially through the engine casings

(3) The engine did not axially release any substantially whole rotors with residual high energy.

(4) If debris were ejected from the engine inlet or exhaust, the approximate reported maximum size, weight, energy and trajectory of the debris must be estimated and provided in the engine instructions for installation.

1) A critical Rotor is a Rotor for which the engine design provides the smallest margin for containment in the defined conditions. The margin for containment addresses the direct containment of the failed part as well as potential secondary effects which could produce an end effect identified under SC17.

SC15: Continued Rotation

If the engines rotating system will continue to rotate after the engine is shutdown for any reason while in flight, and means to prevent that continued rotation are not provided, any continued rotation during the maximum period of flight and in flight conditions expected to occur with that engine inoperative must not result in effects that would be unacceptable under SC17.

SC16: CS22.1823 (c) - (Amendment to CS22.1823):

For Turbine engines, the compliance demonstration to CS 22.1823(b) has to address engine seizure and blade off loads.

SC17: Safety Analysis

An analysis of the engine including its control system must be carried out in order to assess at least those failures that could result in hazardous engine effects such as non-containment of high energy debris, uncontrolled fire, failure of the engine mount system leading to inadvertent engine separation, complete inability to shut the engine down.
It must be shown that Hazardous Engine Effects are predicted to occur at a rate not in excess of that defined as Extremely Remote (probability less than 1E-05 per engine flight hour).

SC18: CS 22.1808 Selection of engine power and/or thrust ratings

(adjustment to the headline for consistency with terminology in this CRI)