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The Study of Relationship between Transport Category Aircraft and Aircraft Engine Type Certification

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Abstract

This paper thoroughly studied the relationship between transport category aircraft and aircraft engine type certification. The installation consideration in aircraft engine certification and the use of substantiation data provided by engine manufacture in transport category aircraft certification were discussed. The potential certification principles for domestic civil aircraft certification program were proposed. And finally, the vision of future cooperation and coordination between domestic aircraft and engine certification offices was presented.

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Keywords: Transport Category Aircraft, Aircraft Engine, Type Certification, Compliance Demonstration, Airworthiness, Certification Cooperation and Coordination

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1. Introduction

Issuing aircraft Type Certificate (TC) is a glorious and honorable moment. It represents that the aircraft could enter into service definitely. However, all this glory and honor is based on the whole process of type certification, which starts from the conceptual design of the specific type of aircraft, and goes through the design, manufacturing and verification process. The aircraft manufacturer, also known as aircraft TC applicant, should show compliance for all the systems, equipment and components in both design and manufacturing aspects. Aircraft engine, the “heart” of the aircraft, interfacing with different other aircraft systems, should be certified with the engine TC. This is unique among all the other aircraft systems.

The transport category aircraft airworthiness standard in China Civil Aviation Regulation (CCAR) is Part 25, and the engine airworthiness standard is Part 33. If the domestic developed transport category aircraft installs with engines developed by Chinese company, the aircraft and engine should be certified under CCAR 25 and CCAR 33 separately. However, with the development of engine manufacturers’ business scope, more and more engine manufacturers are capable of designing and manufacturing integrated propulsion systems, consisting of engines, nacelles, and Engine Build-up Units (EBUs). Moreover, since the “airframer + supplier” business model is used by most of aircraft programs nowadays, the engine supplier may locate in different country other than the airframer. As a result, Part 25 and Part 33 will be certified by the authorities of different countries, respectively. In the interest of economics and program schedule, the engine supplier “packages” most parts designed and manufactured by itself and certifies them together with the engine, namely, whoever manufacturer bears the responsibility. However, as there are some corresponding Part 25 requirements for the “packaged” parts other than the engine, it brings difficulties to Part 25 authorities located in a different country for managing the powerplant installation certification, and increases the coordination work between two authorities.

Therefore, adequate communication and coordination between aircraft manufacture, engine manufacture, Part 25/33 certification authorities, and agreement on Part 25/33 certification principles and interfaces in the early stage of the program are deemed necessary. It could avoid redundant certification activities and prevent potential impact on schedule and cost for the applicant and its suppliers. It also optimizes the resources in both applicant and agency sides, and eventually contributes to the success of the program.

2. The Interrelationship Between Part 25 and Part 33 Certification

The value of the aircraft engines could only be realized when they are installed on the aircraft, therefore, one of the objectives for the engine manufacturer in an engine certification program is to show that the certificated engine should be "installable" in a particular aircraft or aircraft type. The installed engines become part of the powerplant system, and should meet all the installation requirements in regulation or other requirements from the aircraft manufacturer. If the particular aircraft has not been defined at the time of engine certification, the engine manufacturer should make reasonable assumptions for installation and operation, evaluate and correct if necessary when the aircraft is defined.

Those components that are part of an engine type design certificated under Parts 33 are considered part of the powerplant installation, any finding of compliance with Part 25 requirements should take maximum advantage of the relevant findings made in support of Part 33 compliance. Doing this is reasonable and the benefit is obvious. The ultimate goal is to ensure compliance integrity of Part 25.

The best practice of FAA is to coordinate the certification tests/analysis content, methods and level of involvement between the Part 25/33 certification offices and aircraft and engine applicants, the Part 25/33 certification offices approve the defined test plans and reports together. As for the engine manufacturer in

other country, the certification cooperation and level of involvement is strongly affected by the bilateral situation.

2.1. Considerations of Powerplant Installation in Part 33 Engine Type Certification

While the possible aircraft installation characteristics are not required for engine certification, the ideal situation is that: the engine applicant introduces the intimately interrelated installation requirements into the engine certification program if the installation characteristics are known in sufficient time, and to meet the installation requirement at the time the engine is certified. As for the new engine developing at the concurrently with the new aircraft program, all applicable installation requirements should be met. Furthermore, in some occasions, the airframer needs the engine applicant's substantiation data for showing compliance for aircraft installation requirements. It is recommended, therefore, that at the initial engine type board meeting, the engine applicant establish the extent to which he plans to provide substantiation data for the installation [1]. Federal Aviation Administration's (FAA) best practice is that such data be submitted with the engine type certificate data, for later coordination among FAA Aircraft Certification Offices [1] (ACO). With more and more international programs coming up, dedicated Part 25 certification documents should be submitted since the Part 25 and Part 33 applicants may be not in the same country.

Comparing the requirements in CCAR 25 and CCAR 33, it is concluded that the regulation items in table 1 are interrelated. It should be noted that table 1 is only the list of items in CCAR 25 which interrelated with CCAR 33, compliance should be shown to all the other applicable powerplant installation requirements in CCAR 25.

Table 1. Comparation of CCAR 25 and CCAR 33 Airworthiness Requirements [2][3]

Airworthiness Requirements	CCAR 25	CCAR 33
Flammable fluid fire protection: minimize the possibility of ignition	25.863	33.17
Powerplant installation: the components installation shall ensure operation safety	25.901	33.91
Thrust reverser test: conduct test per CCAR 33.97	25.934	33.97
Fuel system: operation normally in the specified range of fuel flow and pressure	25.951	33.67
Fuel system: failure of heat exchanger uses fuel as working fluid shall not cause hazards	25.952	33.67
Fuel valves: shall not transfer loads to adjacent lines	25.955	33.67
Fuel filter or fuel strainer: • Easy for draining and cleaning • Have a sediment trap and drain • Its weight is not supported by the connecting lines or by the connections of the strainer or filter itself • Have sufficient capacity	25.997	33.67
Oil lines and fittings • Meet the requirement of 25.993 and 25.1183 • Condensed water vapor cannot accumulate at any point	25.1017	33.71
Oil strainer or filter. • Bypass line could ensure the oil flow at the normal rate • Have sufficient capacity • Have indication of contamination • Contaminates cannot enter bypass oil flow	25.1019	33.71
Oil system drains • Accessible • Have means for positive locking in the closed position	25.1021	33.71
Oil radiator: shall withstand, without failure, any vibration, inertia, and oil pressure load	25.1023	33.71
Induct system components: minimize or eliminate the impact of foreign object damage	25.1091	33.77
Induct system icing protection: no accumulated ice that would adversely affect engine operation or cause a serious loss of power or thrust	25.1093	33.68
Induction system ducts and air duct system: should be fire resistant	25.1103	33.17

Powerplant accessories: meet the engine installation requirements	25.1163	33.91
Flammable fluid-carrying components: shall be fire proof/fire resistant	25.1183	33.17
Function and installation: each item of installed equipment • Be of a kind and design appropriate to its intended function • Be labeled as to its identification, function, or operating limitations • Be installed according to limitations specified • Function properly when installed	25.1301	33.91
Equipment, systems and installations: • Perform their intended functions • Provide Warning information	25.1309	33.91
System Lightning protection	25.1316	33.28
HIRF protection	25.1317	33.28

The items listed in table 1 are noted in both CCAR 33 and 25, however, CCAR 33 focuses more on the engine operation, and CCAR 25 addresses the aircraft level of safety. Some examples are as follow.

Engine induct system icing. CCAR 33.68 (a) requires: "Operate throughout its flight power range (including idling) without the accumulation of ice on the engine components that adversely affects engine operation or that causes a serious loss of power or thrust in continuous maximum and intermittent maximum icing conditions as defined in appendix C of CCAR 25". While CCAR 25.1093(b)(1) requires: "Each turbine engine must operate throughout the flight power range of the engine (including idling), without the accumulation of ice on the engine, inlet system components, or airframe components that would adversely affect engine operation or cause a serious loss of power or thrust—(i) Under the icing conditions specified in appendix C, and (ii) In falling and blowing snow within the limitations established for the airplane for such operation." It is obvious that CCAR 25.1093(b)(1) requires to address not only the ice from engine itself, but also the ice from inlet system components or airframe components. In order to optimize certification resources, the best practice is to define the most sever ice potentially accumulated on engine, inlet system components and airframe components first, and then use the engine ice slab ingestion test to demonstrate that the sufficient margin has been designed. Typically, the aircraft manufacturer will define the size, shape and weight of the ice on radome or other airframe components. And the aircraft manufacturer and its supplier will define the size, shape and weight of the ice on inlet in all conditions (including runback ice, and ice accumulated on inlet cowl and engine surface resulting from a 2-minute delay in actuating the anti-icing system). Then the engine manufacturer will coordinate with aircraft manufacturer to determine the size, shape and weight of the ice slab to be used in the ingestion test. Sufficient margin should be retained. The most critical point on fan blade, ingestion speed and engine power setting will be analyzed for the ice slab ingestion testing. If the potential ice accumulation on inlet system components and airframe components is not adequately discussed before the engine ice slab ingestion test, insufficient engine ingestion capability may result in program delay and cost increase.

Engine Electronic Magnetic Interference (EMI)/High Intensity Radiation Field (HIRF)/Lightning test. This is one of the tests for showing compliance to CCAR 33.28. There is same requirement to powerplant installation in CCAR 25. Testing the Part 25 components separately will cost more time, money and resource. Therefore, the engine manufacturer usually includes all the related components into the part 33 test. And the aircraft manufacturer needs to determine the related components list, and coordinate the test

requirements for the components provided by other suppliers. As for the test level, if the HIRF and lightning test levels for the engine installation on a particular aircraft are not known in engine certification, the engine applicant may use the test levels in RTCA/DO160 or from other acceptable guidance materials. The aircraft applicant should confirm the compatibility of the engine test levels and the lightning transient characterization and HIRF attenuation tests with engines installed prior to aircraft certification. If these assumed test levels used for engine certification are not adequate for a particular aircraft installation, the engine applicant may need to conduct additional engine control system HIRF and lightning tests or analysis [4].

Thrust reverser system test. The thrust reverser could be certified either with Part 33 or Part 25. Typically, It will be certified with Part 33 if provided by engine supplier, otherwise, certified with Part 25, depending on the coordination between aircraft manufacture and its supplier. CCAR 25.934 requires: "Thrust reversers installed on turbojet engines must meet the requirements of CCAR 33.97". Usually, the engine manufacturer will combine the thrust reverser test with other engine tests to save resource and time despite which part it will be certified with.

2.2. The Substantiation Data Provided by Engine Manufacture to be Used in Part 25 Powerplant Installation Certification

During the aircraft type certification, engine installation environment and engine effects on aircraft level safety are the most concern for powerplant installation. All substantiation made in Part 33 certification should adequately show compliance to related requirements of Part 25. Especially for the installation environment related. For instance, the safety analysis in engine certification could not identify and address all the installation issues. Therefore, the Part 33 safety analysis could be used to supplement and feed where applicable into the powerplant installation analysis, not to replace it [4].

Furthermore, the powerplant installation should be compatible with all engine installation instructions and limitations defined by engine manufacturer in achieving Part 33 certification.

And all the other substantiation data, including the tests and analysis done in the Part 33 to show compliance to Part 25, will be used for Part 25 compliance finding.

3. Certification Principles for Part 25 Components Substantiated with Part 33

As above mentioned, those components that are part of an engine type design certificated under Parts 33 are considered part of the powerplant installation, any finding of compliance with Part 25 requirements should take maximum advantage of the relevant findings made in support of Part 33 compliance. It is deemed essential for both the applicant and CAAC to determine the interface between Part 25 and Part 33 certifications and the certification principles for Part 25 parts substantiated with engine TC under Part 33, including the method, content of compliance, and level of involvement, in the early stage of program.

Considering the current domestic aviation industry and airworthiness development situation, the aircraft applicant should propose the components list that will be substantiated with Part 33 certification. And the certification agency should determine the corresponding certification principles as early as possible.

In regard to the Part 25 airworthiness requirements that quote directly to the corresponding Part 33 regulations, the applicant should submit compliance reports. Meanwhile, the applicant should provide all related Part 33 certification documentation for reference. In addition, CAAC Part 25 certification team may select related certification tests as observation items if there are novel or unique design features.

As for the specific Part 25 installation requirements (Part 33 may cover part of the Part 25 requirements, but does not have the installation requirements), all the certification activities to show compliance with Part 25 must be approved and monitored by Part 25 certification team.

As for the airborne software and complex electronic hardware, the applicant shall at least provide the Plan for Software Aspects of Certification (PSAC), Software Configuration Index (SCI) and Software Accomplishment Summary (SAS) of the related software, the Plan for Hardware Aspects of Certification (PHAC), Hardware Verification Plan (HVP), top level drawings and Hardware Accomplishment Summary (HAS) of the related complex electronic hardware to Part 25 certification team. Meanwhile, other life cycle data required by DO-178B and DO-245 shall be accessible to Part 25 certification team or other personnel with delegation per requirements.

In addition, in order to assure Part 25 certification flight tests to be performed smoothly, as one of the conditions to sign and issue Type Inspection Authorization (TIA), the engines installed on the certification flight test aircraft should have obtained Part 33 TC or at least under Part 33 certification configuration control. Moreover, the applicant should coordinate with the engine supplier and the Part 33 authority to assess the effect of any configuration changes on the engine performance and operating characteristics during certification flight testing. And then, based on this, the applicant should provide the assessment of the subsequent effect on the safety and validity of the certification flight tests.

Before issuing the aircraft TC, the type design of engine installed on the aircraft must obtain VTC issued by CAAC. Therefore, it is suggested that the engine supplier to submit VTC application to CAAC at proper time, to ensure obtaining the CAAC VTC prior to issuance of the aircraft TC.

Aircraft type certification is the applicant's responsibility, and is also the authority's holy mission. Therefore, both sides should enhance communication and coordination to determine the related certification principles as early as possible.

4. Vision of Future Domestic Part 25 Part 33 Certification Cooperation

The Chinese commercial aircraft engine for large transport category aircraft is under development. It is believed that the Chinese large civil aircraft will have a "Chinese heart" in the near future. And the airworthiness personnel for both transport category aircraft and aircraft engine need to cooperate as the FAA ACO and Engine Certification Office (ECO) do. Though it will not be as complicated and multi-factor affected as the international program, it is a whole new start. Early study on the cooperation mechanism, communication and coordination principles should be initiated to establish firm basis for Chinese civil aviation products airworthiness certification.

5. Conclusion

This paper thoroughly studied the relationship between transport category aircraft and aircraft engine type certification. Powerplant installation certification is complicated since aircraft engine is the only "component" which has a TC among all the aircraft systems. Therefore, clearly definition of the certification interface and principles between Part 25 and Part 33 is important to the success of the program.

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