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Research on Airworthiness Management Technology for Type Design Changes of Transport Aircraft

Fang Zhao [1, a], Xiaohu Xi [1], and Haiming Liu [1]

[1]COMAC Shanghai Aircraft Flight Test Co., Ltd, China;

[a] zf15251761613@163.com

Abstract. According to the CAAC airworthiness regulations, type design changes are categorized into major and minor design changes; substantive, significant, and insignificant changes; acoustical and non-acoustical changes; as well as emission and non-emission changes. This paper investigates the airworthiness management technology for type design changes of transport aircraft in accordance with CAAC regulations. It categorizes design changes into major and minor, and further into substantive, significant, and insignificant changes based on their impact on aircraft characteristics. The study explores the approval process for design changes, including the establishment of approval basis, formulation of approval plans, determination of conformity methods, and implementation of manufacturing compliance inspections. It also examines different approval methods such as applying for a new Type Certificate, Supplemental Type Certificate (STC), Modification Design Approval (MDA), and Amended Type Certificate. A case study of a design change for plateau envelope expansion is presented to illustrate the airworthiness management process. The research aims to provide a reference for the airworthiness management of transport aircraft design optimization.

Keywords: Design Changes; Major Design Changes; Minor Design Changes; Airworthiness Management.

1. Introduction

After obtaining a type certificate, a transport aircraft enters the post-certification design optimization stage. In this phase, it continuously undergoes improvements to produce more optimized, safer, and more reliable designs, so as to meet the requirements of authorities, customer demands, or market needs.

The Chinese Civil Aviation Regulations "Certification Regulations for Civil Aviation Products and Components" (CCAR-21)[1] provide overall requirements for the classification, approval methods, and determination of applicable regulations for type design changes. “Aircraft Type Certification Procedure” (AP-21-AA-2022-11) [2] specifies the approval process for design changes in accordance with the requirements of CCAR-21. “Determination Method for Design Change Approval Basis of Aviation Products” (AC-21-AA-2014-36) [3] is based on the requirements of CCAR-21 to determine the certification basis for design changes made to products that have already completed type certification.

In China, an analysis has been carried out regarding the disparities in airworthiness management for design changes among CCAR, FAR, and CS provisions. Through comparison and analysis, it has been found that both FAA and EASA have adopted "top - down" airworthiness requirements for post - certification design changes. Moreover, there are no differences in the provisions of CCAR 21, FAR 21, and CS 21. Yan Yi et al. [5] proposed the classified management of design change reasons. Qiao Yu et al. [6] combined with domestic and foreign regulations and studied the classification of civil transport aircraft type design changes, clarified the classification standards and guidelines of design changes, and provided examples. Guo Ben et al. [7] conducted research on the design changes of civil aviation engines in the continuous airworthiness stage. Huang Xuecong [8] combined with the certification experience of a certain helicopter and conducted research on the determination of the helicopter design change approval Basis.

Based on the existing research, this article analyzed the relevant regulations of civil aviation in China, further studied the classification methods and approval methods of design changes, clarified

the airworthiness management work process of changing the existing type certificate after a certain type aircraft obtained the TC (type certificate), and provided references for the subsequent development of airworthiness management work of civil transport aircraft type design changes.

2. Classification of type design changes

According to the "Certification Regulations for Civil Aviation Products and Components"（CCAR-21）[1]and the "Aircraft Type Certification Procedure"（AP-21-AA-2022-11）[2], type design changes are divided into minor changes and major changes. “Minor changes "refer to those changes that have no significant impact on the weight, balance, structural strength, reliability, usage characteristics, and airworthiness of civil aviation products. "Major changes" refer to any changes other than minor ones.

According to "Certification Regulations for Civil Aviation Products and Components"(CCAR-21-R4) and "Method for Determining the Certification Basis of Aviation Product Design Changes" [3] (AC-21-AA-2014-36), In order to facilitate the determination of the Certification basis for design changes, major design changes are divided into substantive changes, significant changes and other major design changes. The classification of design changes is shown in Table 1.

A substantial change in a civil aviation product pertains to alterations in its design, power, thrust, or weight to such an extent that a substantial and comprehensive review of the product's conformity with applicable regulations is required, and a new TC (Type Certificate) must be applied for. Examples of such changes include modifying the number or position of engines, changing the configuration from an upper single wing to a single wing, shifting from an all - metal aircraft to having the main structure (fuselage, wings, tail) made entirely of composite materials, and transitioning from subsonic to supersonic flight, etc.

A significant change does not amount to a substantial change. It refers to the change in the overall configuration of the aircraft product class, construction principles or assumptions used for conformity determination. Examples include reducing the number of flight crews, changing the type and number of emergency exits, extending the operating envelope, and lengthening or shortening the fuselage.

Non-significant changes are design changes apart from substantial and significant changes. For example, the floor structure is redesigned, the cabin interior is rearranged, and the brake material is changed to carbon-based brake material.

Table 1. The classification of design changes

<table>
<tr><td colspan="4">design changes</td></tr>
<tr><td colspan="3">Major design changes</td><td rowspan="2">minor design changes</td></tr>
<tr><td rowspan="2">Substantial changes</td><td rowspan="2">significant changes</td><td>other major design changes</td></tr>
<tr><td colspan="2">Non-significant changes</td></tr>
</table>

For the purpose of complying with the “ Aircraft type and airworthiness certification noise regulations” (CCAR-36) [9], type design changes can be classified into two categories: "acoustical changes" and "non acoustical changes". Acoustical changes are defined as voluntary changes in aircraft type design that may lead to an increase in aircraft noise levels.

For the purpose of complying with the” Turbine Engine Aircraft Fuel Discharge and Exhaust Effluent Regulations” (CCAR-34) [10], type design changes can be classified into two categories: "emission changes" and "non-emission changes". "Emission changes" are defined as type design changes in an aircraft or engine design that may lead to an increase in fuel discharge or gas emissions.

In summary, the classification of design changes can be summarized as shown in Figure 1:

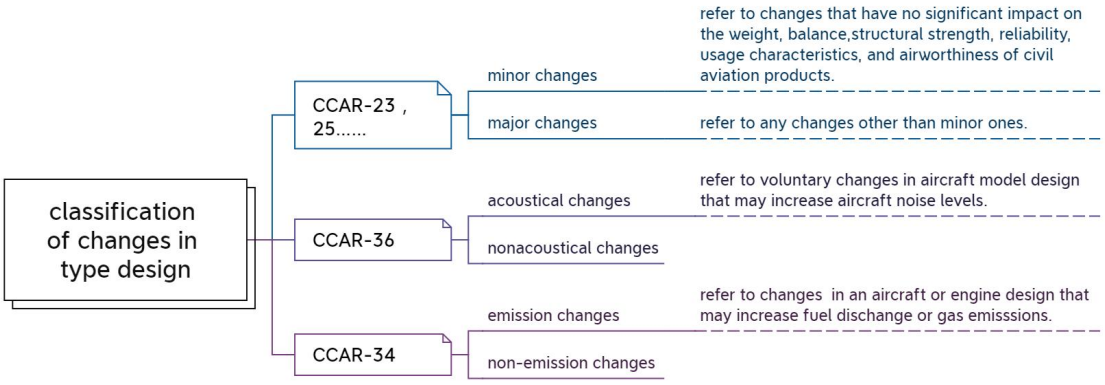

Figure 1. Classification of changes in type design

3. Overall requirements for design changes.

3.1 Overall process of design changes

The overall process of design changes consists of the following steps: design change project approval, establishment of modification item (MI), confirmation of airworthiness classification, development of an approval plan and completion of verification activities, upgrading of MI and its incorporation into batch production drawings, and downstream implementation. Among these steps, the confirmation of airworthiness classification, development of an approval plan, and completion of verification activities are closely related to airworthiness management. The overall process is illustrated in Figure 2.

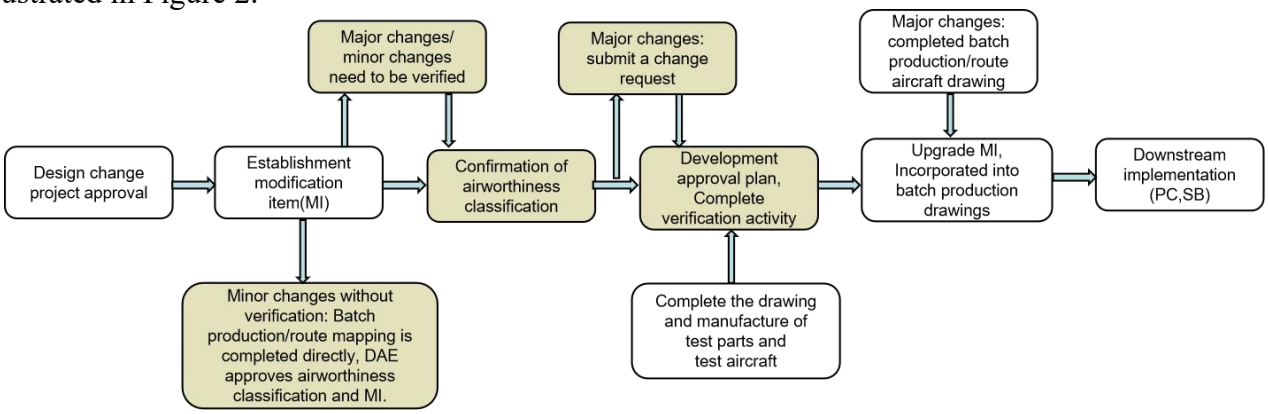

Figure 2. Overall process of design changes

3.2 Requirements of airworthiness regulations

According to section 21.95 of the “Certification Regulations for Civil Aviation Products and Components ”(CCAR-21-R4), "minor changes in type design can be approved in a manner acceptable to the authority prior to providing the verification or explanatory data to the authority."

According to section 21.97 of the “Certification Regulations for Civil Aviation Products and Components” (CCAR-21-R4), "the applicant for approval of a major change in type design shall comply with the following requirements: (1) submit verification materials and necessary explanatory materials to the authority; (2) indicate that the change and the affected area comply with the applicable requirements of relevant regulations, and submit a method of demonstrating compliance to the authority; (3) submit a statement declaring that the applicant has met the applicable requirements.

According to section 21.101 of the “Certification Regulations for Civil Aviation Products and Components” (CCAR-21-R4), "(1)except for paragraphs (2) and (3) of this article, the applicant for a change in the type certificate or type approval certificate shall demonstrate that the changed civil

aviation product meets the airworthiness requirements in effect on the date of the change application, and complies with the requirements of the “Turbine Engine Aircraft Fuel Discharge and Exhaust Effluent Regulations(CCAR-34) [10] and the Noise Regulations for Aircraft Type and Airworthiness Certification (CCAR-36) [9].

3.3 Airworthiness approval for design changes

3.3.1 Approval method for design changes

From the perspective of airworthiness certification, after obtaining the type certificate (TC), the type certificate holder mainly uses the following four methods to complete design changes for airworthiness approval.

(1) Apply for A New Type Certificate
(2) Supplemental Type Certificate (STC)
(3) Modification Design Approval (MDA)
(4) Amended Type Certificate

Applying for a new Type Certificate is required when there is a substantive change in the design, energy, thrust, or weight of a type. Such a change demands a comprehensive review of compliance with applicable airworthiness regulations. Therefore, a new Type Certificate application is necessary.

Supplemental Type Certificate (STC) is an approval granted by regulatory authorities for major design changes to aviation products that have already received a Type Certificate (TC). Through referring to relevant TCs, STC approves not only the changes but also the influence of these changes on the original design (i.e., Type Design Baseline).

The Modification Design Approval can be used to approve minor design modifications for aviation products which have already been granted a Type Certificate (TC).

The Amended Type Certificate involves approval for both minor and major design changes. For minor design changes following the Type Certificate (TC), they can be approved in a manner acceptable to the authority prior to the submission of verification or explanatory materials, and generally, authorization approval is required. As for major design changes after TC, it is necessary to prove compliance with applicable airworthiness provisions and complete the submission and approval of relevant materials as per the authority's requirements.

Generally, for non-type certificate holders who want to make design changes to civil aviation products, there are two approval forms: STC (Supplemental Type Certificate) and MDA (Minor Design Approval). They can apply for STC for major modifications and MDA for minor modifications.

3.3.2 Approval requirements for design changes

At present, in accordance with the scope of approval authorization for minor design changes listed in the approved design assurance manual, minor design changes can be approved by authorized personnel.

The applicant is required to identify and evaluate the category of design changes, define the affected areas, and consider all relevant design changes and applicable regulations before making major changes in type design. According to the principles of CCAR - 21 section 21.101, the applicant shall submit a design change application to the authority. Then, the authority should conduct a review in line with the relevant requirements of "Type Certification Process" and "Type Design Changes" in the "Aircraft Type Certification Procedure". After confirming that the aircraft with major design changes meets the determined approval basis, the authority shall approve the design changes.

4. Design Change Airworthiness Management

After a certain type aircraft obtains the TC (Type Certificate), the holder of the type certificate makes design changes to the aircraft to better meet customer and market requirements. In such case, post-certification design changes are mostly carried out in the way of changing the existing type certificate. The airworthiness engineer, according to the design change classification (major design change or minor design change), coordinates and confirms the certification basis and certification plan of the design change, clarifies the compliance method and the manufacturing compliance inspection requirements, and organizes and conducts the compliance verification work.

4.1 Determination of Type Design Change Approval Basis

To determine the approval basis for type design changes, the following steps are necessary. First, identify and evaluate the scope of the impact of the design change, and define the affected area. Second, consider all design changes and applicable regulations related to it before the change, and explain the associated changes of the change. These contents need to be included in the technical documents of the design change plan to support the determination of the approval basis. Based on the principles of section 21.101 of CCAR-21-R4 "Certification Regulations for Civil Aviation Products and Components", a recommended approval basis should be proposed, including the regulations and versions used, as well as specific applicable provisions. The principles for determining the basis for type design change approval are as follows:

(1) For minor changes, the approval basis can be used to carry out airworthiness verification and approval based on the original approval basis;

(2) For significant changes, the approval basis is a combination of the latest, earlier, and existing regulations;

(3) For non-significant changes, the approval basis can continue to be the original one, unless the original approval basis fails to fully verify the design change.

4.2 Determination of Type Design Change Approval Plan

The design change approval plan is used for the following purposes in future design change projects: determining the approval basis with the authority, specifying the required compliance verification methods, clarifying the required compliance evidence documents, making clear the authority's involvement in the review activities, and formulating a detailed review activity plan.Normally, a design change project corresponds to an approval plan. For comprehensive design change projects at the aircraft level, multiple approval plans can be prepared as per the requirements of different specialties or topics.

For major changes in type design, the approval plan needs to be approved by personnel from the authority. As for minor changes in type design that require supplementary compliance verification work, the approval plan shall be approved by authorized personnel of the design assurance system in accordance with the approved design assurance manual. However, minor changes in type design that have negligible impact on airworthiness neither require additional compliance verification work nor the preparation of an approval plan.

4.3 Criteria for determining compliance methods for type design changes

The airworthiness engineer shall jointly determine the compliance method for type design changes in coordination with the design and development personnel, and describe it in the certification plan. After airworthiness verification, major changes need to be submitted to the authority for approval. For minor design changes that require supplementary compliance verification, they shall be approved by the authorized personnel of the design assurance system. The main principles for selecting compliance methods include:

a) When both analysis calculation and testing can demonstrate compliance, priority should be given to analysis calculation;

b) When compliance verification can be conducted through laboratory tests, ground tests, and flight tests, laboratory tests or ground tests are preferred;

c) When multiple testing methods are available for compliance verification, it is crucial to correctly select the compliance method accepted by the authorities. This method should be time-saving, labor-saving, and cost-effective while ensuring compliance demonstration.

In addition, when selecting compliance methods for design change projects, it is necessary to consider fully utilizing mature methods that have been previously recognized by the authorities, as well as using the obtained compliance data to improve airworthiness review efficiency while ensuring compliance is demonstrated.

4.4 Conformity inspection for type design changes

The applicant recommends conformity inspection items for design changes based on factors such as quality management level, production facilities and equipment capabilities, product complexity, impact on flight safety and test results, and whether new materials, structures, processes, technologies, etc. have been adopted.

For major design changes, the items recommended for conformity inspection of the design changes shall be submitted to the authority for final determination. Then the authority shall carry out the conformity inspection.

According to the design assurance system manual, for minor design changes that require supplementary compliance verification, the authorized personnel of the design assurance system shall ultimately determine the recommended items for conformity inspection of design changes. And the conformity verification should be carried out in accordance with the authorized scope of the design assurance system.

4.5 Implementation of compliance verification activity for type design changes

In accordance with the type design major change review plan, various compliance verification activities for major design changes should be strictly implemented in line with the type development plan. Also, the preparation and review of various compliance documents for major design changes should be carried out according to the type development plan.

For minor design changes that require to supplement compliance verification, in accordance with minor design change review plan, various compliance verification activities for minor design changes should be carried out in accordance with the type development plan. Moreover, according to the approved design assurance manual, these activities should be witnessed by the authorized personnel of the design assurance system.

5. A Case of design changes for a certain type of aircraft

After obtaining the TC (Type Certificate) for a certain type of aircraft, a design change for Plateau envelope expansion is required to expand the operating altitude limit. This design change for plateau expansion does not affect the aircraft's weight, aerodynamic shape, and structural strength. However, it alters the airworthiness and usage restrictions. Consequently, based on the classification criteria for design changes, this change is considered a major design change.

Based on the content of the design change, the applicant is required to identify the affected scope, applicable airworthiness regulations, and plan compliance verification activities. Then, the applicant needs to submit a design change application to the authority in the form of a corresponding report. Once the authority accepts the application, the applicant shall carry out design change verification in accordance with the planned compliance verification activities. Meanwhile, the authority shall review the type until the approval of the type design change is completed.

6. Summary

This article mainly studies the airworthiness management technology of design changes in combination with CAAC airworthiness regulations. By combining with the classification method of design changes, it explores the approval methods and requirements for design changes. Moreover, it offers the determination methods of the approval basis, approval plan, compliance method, conformity inspection, and compliance activity implementation for design changes. In combination with a typical case of a certain aircraft, it elaborates on the main process of airworthiness management for design changes, providing a reference for subsequent type design change work.

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