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Research on the Construction and Optimization of MOD Identification Management System for Civil Aircraft Onboard Equipment

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Abstract: With the development of the civil aviation industry, onboard equipment modifications are frequent, but China's civil aircraft industry faces issues like inconsistent MOD identification rules, vague scenario boundaries, and broken traceability. This study focuses on the whole life cycle of civil aircraft onboard equipment, defining EMOD/MOD scenario boundaries and conversion mechanisms based on 3F1I equivalence. It optimizes the "letter prefix + sequence identifier" coding structure and the "document-physical object" integrated expression system. Aiming at current challenges, four strategies are proposed: scenario-based control, unified coding/data standards, physical identification quality improvement, and cross-subject collaboration platforms. Case verification with avionics equipment shows significant effects—misuse rate drops to 3%, information transmission shortens to 1 day. This research enhances modification traceability and safety, providing practical support for the domestic civil aircraft industry's development.

Keywords: Modification; Civil Aircraft; Change; Impact Analysis

1. Introduction

1.1 Research Background

With the continuous growth of the global air transportation industry, civil aviation has become a core pillar of modern transportation. As a key component of aircraft, civil aircraft onboard equipment covers critical systems such as flight control and navigation, and the stable control of its technical state directly determines flight safety and operational efficiency. With the iteration of aviation technology and the upgrading of customer needs, equipment requires frequent design optimization during the R&D phase and adjustments to adapt to route conditions during the mass production phase, which necessitates the establishment of an efficient modification management mechanism.

The MOD (Modification) identification system emerges as the times require. By standardizing coding rules, clarifying scenario definitions, and unifying expression forms, it realizes the visualization and traceability of equipment modification information, establishing a unified technical language for all parties in the industrial chain. International giants such as Boeing and Airbus have established mature systems. However, China's civil aircraft industry is in a critical transition period, and some suppliers face issues such as inconsistent MOD identification rules, ambiguous scenario applicability, and broken traceability chains. These problems not only reduce R&D and operational efficiency and increase costs but also pose safety risks. Therefore, researching the construction logic and optimization path of the MOD identification management system is of great practical significance.

The MOD (Modification) identification system achieves the visualization and traceability of modification information by standardizing coding rules, defining application scenarios, and unifying expression forms, providing a unified technical language for all parties in the industrial chain. International aviation giants like Boeing and Airbus have established mature systems. However, China's civil aircraft industry is in a critical transition stage, and some suppliers have problems such as chaotic identification rules, vague scenario adaptation, and broken traceability chains, which not only reduce R&D and operational efficiency and increase costs but also bring potential safety hazards. Therefore, studying the construction and optimization of the MOD identification management system is of great practical significance.

1.2 Research Significance

The research significance is mainly reflected in three aspects: First, ensuring flight safety. Standardized MOD identification provides accurate basis for maintenance, reduces the difficulty of fault diagnosis, and mitigates safety risks. Second, enhancing industrial competitiveness. A unified management system can improve R&D efficiency, reduce costs, and strengthen the international competitiveness of domestic civil aircraft. Third, promoting technological innovation. Complete modification records provide data support for product upgrading and drive technological iteration.

1.3 Research Status at Home and Abroad

There is a significant gap between domestic and foreign research: Foreign research started early with mature systems. SAE ARP4754A [1] lists modification identification as a core element, and EASA has put forward strict requirements in airworthiness standards [2]. At the enterprise level, Boeing's configuration management system and Airbus's full-process system both achieve efficient management. Domestic research focuses on macro frameworks. Although enterprises like COMAC have relevant specifications, they are insufficient in details such as scenario adaptation and supplier collaboration, and the connection between standards and practice is not smooth, failing to meet the needs of industrial development.

1.4 Research Content and Methods

From the perspective of the whole life cycle, the core research contents of this paper include: defining the scenario boundaries and conversion mechanism between EMOD and MOD, optimizing coding rules, improving the "document-physical object" expression system, and constructing a multi-subject collaboration mechanism. The research adopts the "theoretical analysis-practical investigation-case verification" approach: first, sorting out the theoretical basis; second, investigating and identifying industry pain points; finally, verifying the feasibility of the scheme through an avionics equipment project.

2. Analysis of Core Elements of MOD Identification for Civil Aircraft Onboard Equipment

2.1 Definition of Applicable Scenarios for MOD Identification

2.1.1 Scenario Division Based on 3F1I Equivalence and Interchangeability

The core basis for dividing MOD identification scenarios is 3F1I equivalence and interchangeability (Function, Form, Fit, Interface). Based on this, the whole life cycle is divided into two types of scenarios: EMOD (Engineering Modification) during the R&D phase and MOD during the mass production phase. During the R&D phase (from prototype trial production to design finalization), EMOD is used if the modification does not affect 3F1I equivalence, with the core goal of recording the design optimization process; MOD is used for route modifications during the mass production phase, with the core goal of ensuring configuration traceability.

EMOD is characterized by frequent modifications and a focus on design optimization, requiring complete recording of each adjustment to support finalization review; MOD has lower modification frequency but higher traceability requirements, requiring clear association with the base version of the modification. The key conversion mechanism is: after the equipment enters mass production, EMOD automatically becomes invalid and is converted to MOD, and all modification records during the R&D phase must be completely retained to ensure the continuity of traceability throughout the life cycle.

2.2 Design of MOD Identification Rules

2.2.1 Coding Structure Design

The core of MOD identification rules includes coding structure, compilation principles and management requirements. A unified coding structure of "letter prefix + sequence identifier" is adopted: the letter prefix distinguishes equipment systems (e.g., "FC" for flight control), and the sequence identifier can use numbers or letters. When numbers exceed 99, they can be converted to letters, and major modifications require part number changes. In terms of compilation principles, EMOD must be continuously arranged and associated with design documents, while MOD allows skipping numbers but requires clear definition of the modification base. Management requirements stipulate that suppliers should formulate coding plans and establish standardized compilation processes to avoid coding conflicts.

The expression form forms a "document-physical object" integration: at the document level, the "MOD Configuration Record Form" is used for management, which includes basic equipment information, identification content, modification time/unit/approver, etc., and is delivered to the main manufacturer along with the equipment. The template balances standardization and flexibility. At the physical object level, permanent nameplates are used, following the principles of "independent identification, close to the nameplate, and easy to view". Weather-resistant materials such as stainless steel and aluminum alloy are selected, and laser engraving technology ensures clarity and wear resistance; in case of information overflow, "inherited replacement" is adopted to retain historical identification [4].

2.3 Expression Forms of MOD Identification

2.3.1 Document Recording Method

The expression form adopts an "document-physical object" integrated system: at the document level, the "MOD Configuration Record Form" records key information such as basic equipment information, identification code, modification content, and implementation unit, which is archived by the main manufacturer along with the equipment delivery; at the physical object level, permanent nameplates are used, following the principles of "independent identification, close to the nameplate, and easy to view" [3]. Durable materials such as stainless steel are selected, and laser engraving technology ensures clarity. In case of information overflow, "inherited replacement" is adopted to retain historical identification.

3. Current Problems and Challenges in MOD Identification Management

3.1 Identification Misuse Caused by Vague Scenario Boundaries

There are four core problems in current management: First, vague scenario boundaries. When transitioning from R&D to mass production, EMOD is not converted to MOD in a timely manner, and modifications affecting 3F1I do not have part number changes, leading to identification misuse. Second, inconsistent coding rules. Large differences in coding rules among different suppliers make it difficult for the main manufacturer to integrate configurations and reduce the maintenance efficiency of airlines. Third, poor quality of physical identification. Low-quality materials cause wear and falling off; concealed installation and excessively small fonts affect recognition; historical information is not retained during overflow replacement. Fourth, poor information collaboration. Delayed data transmission among suppliers, main manufacturers, airlines, and MROs leads to information silos.

Third, insufficient quality of physical identification. Low-quality materials are prone to wear and fading; for example, nameplates in engine compartments become blurred after 3 months. Excessively small fonts and concealed installation increase recognition difficulty. Failure to retain historical information during overflow replacement leads to broken traceability. During the maintenance of a civil aircraft, the upgrade status could not be evaluated due to missing historical identification. Fourth, lack of cross-subject collaboration. The transmission of modification information by suppliers is delayed by 3-5 days; data between main manufacturers and airlines is not synchronized; MRO maintenance information is not fed back. For example, the delayed synchronization of modification information of a landing gear led to configuration errors.

4. Optimization Strategies for MOD Identification Management System of Civil Aircraft Onboard Equipment

Four optimization strategies are proposed to address the above problems: First, constructing a scenario-based control process. Formulate the "3F1I Impact Assessment Guide", requiring suppliers to submit reports after assessment and the main manufacturer to review and confirm. Standardize the transition from R&D to mass production, requiring EMOD to be converted to MOD and documents updated within 10 working days before mass production. Establish a quarterly review and error correction mechanism, requiring suppliers to rectify within 5 working days, which is included in performance appraisal.

4.1.1 Formulating 3F1I Impact Assessment Guide

In response to the above problems, four optimization strategies are proposed: First, constructing a scenario-based control process, formulating the "3F1I Impact Assessment Guide" to standardize assessment and review, clarifying that identification conversion should be completed within 10 working days when transitioning from R&D to mass production, and establishing a quarterly review and error correction mechanism. Second, unifying coding and data standards, with industry associations taking the lead in formulating standards, each subject establishing a standardized database, conducting publicity and training, and implementing supplier access review. Third, improving the quality of physical identification, formulating nameplate technical specifications, optimizing ergonomic design, and standardizing the "inherited replacement" process. Fourth, building a cross-subject collaboration platform, integrating data to realize real-time query and analysis, standardizing the interaction process of information entry within 3 working days and review within 2 working days, and establishing authority control and encryption mechanisms to ensure data security.

Second, unifying coding and data standards. Industry associations take the lead in formulating standards, unifying prefixes (e.g., "AE" for avionics), sequence rules and data formats. The main manufacturer establishes a central database, and suppliers establish local databases for real-time synchronization, adopting a unified data dictionary. Hierarchical training is carried out, and new suppliers must pass coding practical assessments to gain access.

Third, improving the quality of physical identification. Formulate the "Nameplate Technical Specifications": use stainless steel for high-temperature environments, with laser engraving depth $\geq$ 0.5mm. Optimize ergonomic design: minimum font size $\geq$ 6pt, installed at a visible position at eye level. Standardize overflow replacement: retain historical information through photography and digitization, and mark historical records and replacement reasons in a dedicated area on the new nameplate.

Fourth, building a cross-subject collaboration platform. Establish a sharing center based on cloud computing, with functions such as real-time query, statistical analysis and message push. Standardize the interaction process: suppliers enter modification information within 3 working days; the main manufacturer reviews and synchronizes it to airlines/maintenance enterprises within 2 working days; feedback results in a timely manner after maintenance. Establish authority control and SSL encryption, and conduct regular backups to ensure data security.

5. Case Verification: A Certain Type of Avionics Equipment MOD Identification Optimization Project

The optimization effect was verified by a certain type of avionics equipment optimization project: The project background was that the equipment had problems such as high identification misuse rate (28%), chaotic coding, 45% nameplate wear rate, and 5-day information transmission delay. After implementing the optimization strategies, significant results were achieved: the identification misuse rate dropped to 3%, a decrease of 89%; the coding query time was reduced from 8 minutes to 1.5 minutes, with an efficiency increase of 81%; the nameplate wear rate dropped to 6%, and the recognition accuracy rate increased from 62% to 98%; the information transmission cycle was shortened to within 1 day, with an accuracy rate of 99%.

A certain type of avionics equipment was used as a case to verify the optimization effect. Previously, the equipment had four major problems: delayed conversion between EMOD and MOD, chaotic coding rules leading to difficulties in integration by the main manufacturer, severe wear and falling off of nameplates, and information transmission delay of more than 7 days between suppliers and airlines.

Key implementation measures of the project: In terms of scenario control, formulate assessment guidelines and conduct strict review, standardize the 10-working-day conversion process, and implement quarterly review and error correction. In terms of coding unification, adopt the "AE + sequence" rule, establish master-slave database synchronization, and conduct 3 rounds of training. In terms of physical identification, use stainless steel for laser engraving and optimize the installation position.

Optimization strategies were implemented: formulating a special "3F1I Impact Assessment Guide" and 10-working-day conversion rules, unifying the coding system with "AE" as the prefix for avionics equipment, using 0.5mm laser-engraved stainless-steel nameplates, and building a cross-subject collaboration platform.

The optimization effect was significant: the identification misuse rate decreased from 23% to 3%, the coding query efficiency increased by 80%, the nameplate recognition accuracy rate increased from 65% to 98%, and the information transmission cycle was shortened from 7 days to within 1 day, fully verifying the feasibility of the strategies.

6. Conclusions and Prospects

6.1 Summary of Research Results

This study clarifies the three core elements of MOD identification: "scenario definition, rule design, and expression system", identifies four major industry pain points, and proposes four optimization strategies: scenario-based control, unified standards, quality improvement, and collaboration platform. The effectiveness of these strategies has been verified by cases. The results improve the civil aircraft technical state control system and provide support for industrial quality improvement.

Future research can be deepened in three aspects: First, introducing AI and big data to realize intelligent early warning and predict faults by analyzing identification data. Second, strengthening alignment with international standards to enhance international discourse power. Third, expanding to the entire industrial chain and full life cycle to realize full-process traceability from raw materials to decommissioning and recycling, promoting the sustainable development of the civil aircraft industry.

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