The Process and Measures of Reliability Data Management for Civil Products

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Abstract. Based on the characteristics of the entire lifecycle of civil aircraft products and the requirements of airworthiness authorities in recent years for the review of reliability data used in safety analysis, this article discusses the management of reliability data throughout the entire lifecycle of civil aircraft. By describing the reliability data that should be emphasized in the development process of civil aircraft, this paper introduces the management process and measures of reliability data generated in various aspects of civil aircraft products.

Keywords: airworthiness; Security analysis; Reliability data; data management

1 Introduction

Safety is the lifeline of civil aircraft, and the quality of safety is the primary consideration for the success of passenger aircraft. When conducting quantitative and qualitative safety analysis, fault tree analysis is usually used to prove that the probability of hazardous events occurring is within an acceptable range. The data at the bottom of the fault tree comes from reliability analysis processes such as FMEA and reliability prediction. Therefore, in the development process of civil aircraft, the reliability data of products is particularly important.

In recent years, with the deployment of C919 aircraft and the development of domestic civil aviation, airworthiness authorities have focused on the reliability of domestic products and required research and development units to provide data analysis or testing methods to demonstrate the airworthiness compliance of reliability data to verify whether the quantitative analysis results of safety meet airworthiness requirements. After completing the above process, it is necessary to consider how to retain the data and use it in the subsequent development process. Therefore, it is necessary to identify which reliable data needs attention and develop an effective set of data management measures to carry out data management work.

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2 Requirements for Data Validity and Current Status and Significance of Reliability Management in Aircraft Development Process

2.1 Requirements for Data Validity During Aircraft Development Process

At present, airworthiness authorities have put forward requirements for the validity of various data in the process of civil aircraft safety analysis, including data source requirements, data validity confirmation methods, etc. [1]. When demonstrating the compliance of security analysis, it is necessary to analyze the effectiveness of various data, and the data types that usually need to be considered are as follows:

1) Manual standard data, including NPRD, NSWC and other manual standard data;

2) Reliability test data, including reliability enhancement, reliability identification, and other tests;

3) Historical usage data, including reliability data during test flights and operational phases.

According to the data validity analysis requirements of airworthiness compliance verification, it is important to identify the above types of reliability data for review and control during reliability data management.

2.2 Current Status of Reliability Data

The reliability data analysis work abroad began to be reflected as early as 1949 on the X-8 sounding rocket in the United States. This type of rocket was developed based on the analysis of over 10000 reliability data, saving a lot of manpower and financial resources [2]. Boeing and Airbus, two aircraft manufacturers, have been conducting research on the reliability of aircraft usage for a long time and have established complete procedures and standards for collecting and processing relevant reliability data [3]. A large amount of data has been accumulated abroad to form reliable databases such as NPRD and NSWC [4]. The collection and management of reliability data in China started relatively late, especially in the development of civil aircraft products, where there is a lack of relevant experience, historical data, and reliability data analysis to support product design. Electronic products can refer to GJB/Z 299C for fault rate data, while other products still need to refer to foreign standards for design analysis in actual engineering development.

2.3 Significance of Reliability Data Management

The data analysis work carried out according to airworthiness requirements takes up a lot of time in model design, and the requirements for data validity analysis involve a lot of work. Many analysis methods are still unclear, and the required data span time is long, there are many branches, and the data volume is large, requiring high traceability. The analysis of data validity itself has certain exploratory and uncertain aspects in actual engineering development. For example, reliability testing methods are used for data

validity analysis, and there are significant differences in reliability testing for different types of products. Even if the experiments are the same, there is a high possibility of data bias due to various factors in the actual operation process, which to some extent increases the difficulty of analyzing data validity and managing reliable data.

Given the current focus on the reliability of domestic products and the requirements for reliability data in airworthiness, after completing data validity analysis and passing airworthiness compliance verification, it is necessary to focus on how to utilize and manage these data.

3 Reliability Data Management Process

3.1 Reliability Data Management Process

To carry out reliability data management work, the first step is to identify which data is related to product reliability from a large number of data sources and identify them. Secondly, the identified data will be subjected to data validity analysis to demonstrate that the analyzed data reflects the true level of the current product. Finally, the data from the data validity analysis will be used for airworthiness review, and the completed review data will be collected to provide support for future product design. Each research and development unit should identify key reliability data based on actual work and manage and control the data. In the data management process, it should ensure the integrity, reliability, effectiveness, and traceability of the data, and provide support for future product design. The specific data management process is shown in Figure 1.

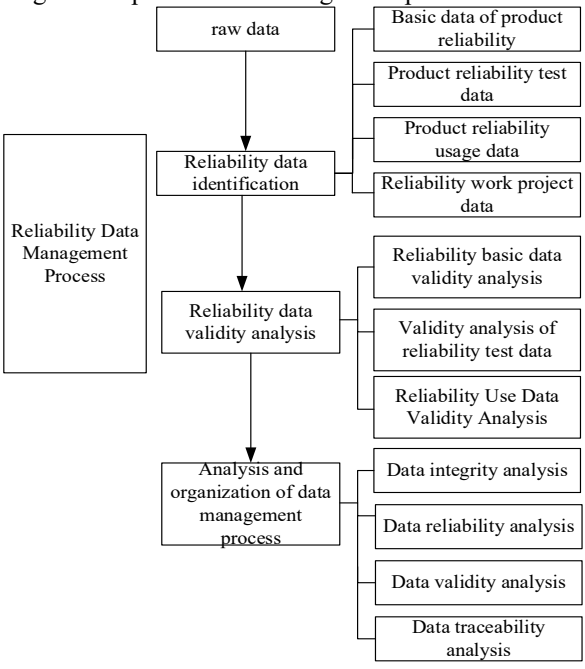

Fig. 1. Reliability Data Management Process

3.2 Reliability Data Identification

The first step in carrying out reliability data management work is to clarify which data is of concern in the reliability design process and needs to be accumulated and managed.

The scope and content of commonly identified reliability data should at least include: (1) basic data on product reliability; (2) Product reliability test data; (3) Product reliability usage data; (4) Reliability work project data, etc. [5].

According to the product stage, it can be divided into design stage reliability data and operation stage reliability data. The reliability data in the design phase is divided into basic reliability data and product reliability test data, including reliability prediction, failure rate data used in FMEA, failure rate data determined by various reliability tests of the product, and product failure modes. The reliability data during the operation phase includes product reliability usage data and reliability work project data, including statistical product failure rates during product test flights and operation phases, as well as failure modes during product test flights and operation phases, and analysis.

3.3 Reliability Data Validity Analysis

Reliability Basic Data Validity Analysis

The basic data of product reliability usually includes component failure rate, reliability diagram, product stress environment, and product failure mode. These data are typically used for reliability prediction and FMEA analysis. At present, domestic prediction and FMEA work usually uses NPRD and NSWC for fault rate analysis. When searching for fault rate data using manual standards, it is necessary to analyze the consistency of fault modes and quality level similarity of the data used and incorporate the effectiveness analysis data into the data management process. The specific process is shown in Figure 2.

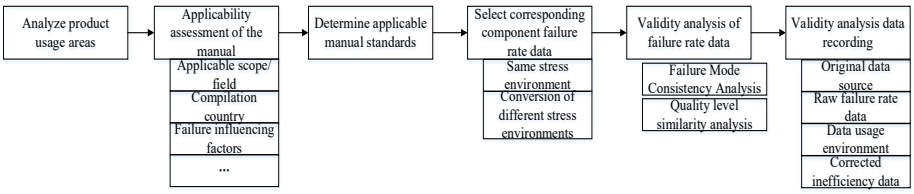

Fig. 2. Reliability Basic Data Validity Analysis

Validity Analysis of Reliability Test Data

In the early stages of product development, various tests are required to verify product performance. It is a reflection of the level of product reliability, which can be processed to obtain product reliability data and provide a basis for formulating product reliability growth test plans [6].

When conducting reliability tests to obtain failure rate data and failure mode data of components, electronic components, or related equipment, it is necessary to analyze the consistency of the test piece and the effectiveness and completeness of the test. Before

conducting reliability tests, the consistency of the test pieces should be analyzed first, and similarity analysis should be conducted for inconsistent test pieces. During the experiment, it is necessary to analyze the effectiveness and completeness of the experiment. There are certain differences in the analysis factors that need to be completed for different types of experiments. For example, in reliability tests under normal stress loading, the following factors need to be analyzed, including: determining the test sample; Determine the testing time; Determine environmental stress; Fault handling; Analyze whether the fault is consistent with the target failure mode. Accelerated life testing requires analysis of the following factors, including: failure mode mechanism analysis; Determine the test sample; Determine the calculation expression for failure rate; Determine the test stress level; Determine the testing time; Analyze the effectiveness of data processing methods and determine the acceleration coefficient; Analyze whether the fault is consistent with the target fault mode. The specific process is shown in Figure 3.

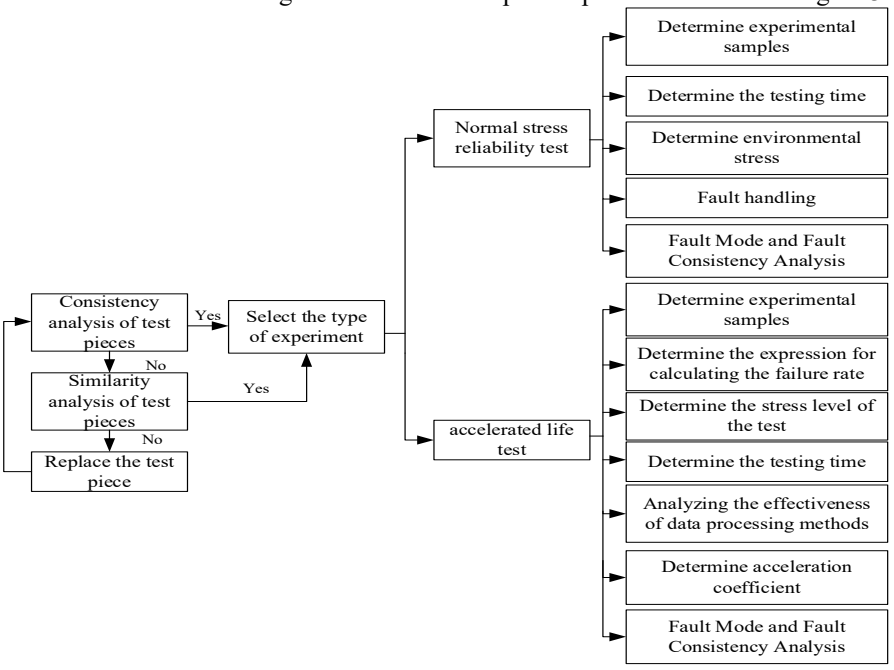

Fig. 3. Reliability Test Data Validity Analysis

Reliability Data Validity Analysis During

Flight Test and Operation Phase. The reliability data at this stage mainly includes product fault information, including fault location, working time, number of faults, fault mode, fault impact, fault mode frequency, fault cause, etc. [5]. After collecting relevant information at this stage, the following work is required to demonstrate the effectiveness of failure rate and failure mode:

1) Clarify the data source;

2) Conduct similarity analysis between statistical components and manufacturing components, including design and manufacturing similarity analysis, functional similarity analysis, and durability similarity analysis;

3) Explanation of the effectiveness analysis of fault data, including the methods and effectiveness analysis of the statistical accumulation mechanism of fault data, as well as the analysis of the consistency of fault modes.

The specific process is shown in Figure 4.

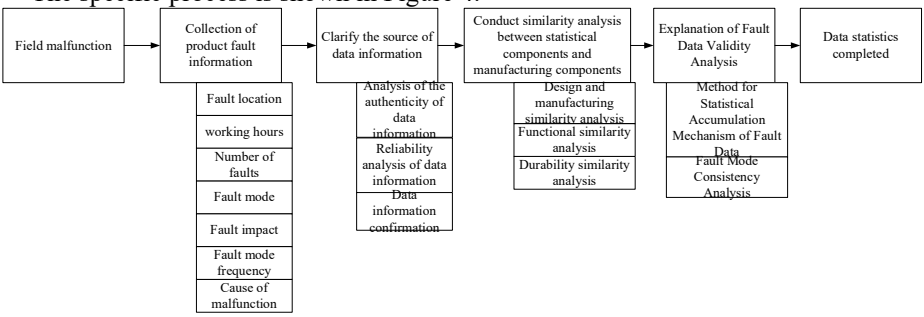

Fig. 4. Reliability Data Validity Analysis during Flight Test and Operation Phase

Reliability Data Management

After completing the reliability data validity analysis, it is necessary to evaluate the completeness, reliability, effectiveness, and traceability of the analysis process[7]. Confirm that the analysis process is complete and in compliance with standard specifications, the analysis process is reliable and effective, and the analyzed data can be utilized. The analysis data is traceable and can be used to search for information such as data sources. Finally, indicate to the reviewing unit that the data and process meet the review requirements. After the host or bureau completes the review, the obtained product failure rate data and failure mode information will be controlled and recorded on the data platform, ultimately forming a product failure rate database and product failure mode database.

4 Reliability Data Management Measures

4.1 Standard Formulation

Throughout the entire stage of data collection, supporting standard specifications should be established to guide relevant personnel in conducting data collection, data validity analysis, and data control work. Standardize the types of data collection, collection methods, and analysis processes to ensure the accuracy of the final data recording.

4.2 Personnel Management

In the face of a large number of data sources, professional personnel should be equipped for data collection and analysis work, and personnel should be trained on data collection requirements and data analysis skills in accordance with supporting standard requirements, to strengthen their understanding of the importance of reliable data. The recorded data should be analyzed for its traceability, clarity, synchronization, originality, and accuracy.[8]

4.3 Platform Management

Establish a comprehensive reliability data management platform, control data through the data platform, and facilitate designers to search and update. And establish corresponding configuration management processes, standardize data change processes and methods.

5 Conclusion

With the development of the domestic aviation industry, a large number of domestically produced products are applied in the development process of aircraft. Currently, there is an urgent need for relevant data to prove the reliability level of the products and provide a basis for reliability improvement work. Taking advantage of the delivery of C919 aircraft and the development of domestic aviation products, conducting reliability data management can provide data support for improving product reliability, reduce costs, and enhance product competitiveness based on highly reliable data sources.

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