Research on Civil Aircraft Dispatch Reliability Parameter System and Analysis Method

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Keywords: Civil aircraft, Dispatch reliability, Parameter system, Analysis method.

Abstract. Dispatch reliability is a top parameter of civil aircraft, therefore how to build its parameter system and allocate it to system and subsystem from top to bottom and evaluate it contrarily is important for civil aircraft development and operation. This paper innovatively proposed conceptions of inherent dispatch reliability and operational dispatch reliability and their parameter system. Based on the conceptions, it put forward corresponding analysis process including allocation, prediction, and especially data fusion from suppliers to evaluate MTBF and simulation method considering the whole dispatch process. Finally computing results in a civil aircraft dispatch reliability design and analysis platform turn out that the studies above are useful and will be helpful for civil aircraft dispatch reliability management.

Introduction

Dispatch reliability (DR) is a significant top parameter of civil aircraft to ensure operation economically. Civil aircraft dispatch reliability is not only associated with manufacturer, but also more relevant to operation of airlines, accordingly it should be consider all the factors in development phase that affect dispatch reliability from design and operation two aspects in order to improve it through corresponding management and control. This paper analyzes factors that affect dispatch reliability and presents conception of inherent dispatch reliability and operation dispatch reliability with their analysis method and flow.

Dispatch Reliability

Characteristic

Dispatch reliability can be used as a design parameter or an operational parameter. As a design parameter, it is mainly allocated to lower level, that is to say, allocating aircraft dispatch reliability to system and subsystem level, and then it is validated by prediction model; as a operational parameter, it is evaluated through actual operational data during the operational phase of the flight test and after the aircraft is delivered to the airline, and is refined by increasing the spare parts fulfillment rate and reducing logistical time.

Classification

Due to the technical and non-technical factors affect aircraft dispatch reliability, it can be divided into inherent dispatch reliability and operational dispatch reliability. Inherent dispatch reliability is only related to the aircraft's own technology factors (failure, etc.), but operational dispatch reliability is directly related to operational environment and management level of airlines. Civil aircraft manufacturers are more concerned about the inherent dispatch reliability, while the airlines emphasis on operational dispatching reliability.

Inherent Dispatch Reliability

Parameter System

Inherent dispatch reliability is defined as the percentage of departures from the station without delays
due to technical reasons for the failure of the aircraft system or cancellation of the flight. Technical delays refer to delays in the final departure of an aircraft due to inspection and necessary repairs due to an on-board equipment and component malfunction. If a predetermined departure time is exceeded for a period of time (usually 15 minutes), a technical delay is assumed.

Inherent dispatch reliability is calculated as follows:

\[ \text{Inherent dispatch reliability} = 1 - \frac{\text{technical delayed and cancelled flights}}{\text{Operating flights}}. \]  

(1)

Inherent dispatch reliability could not be directly used for product design which needs to be converted into dispatch interrupt rate (DIR).

\[ \text{inherentDIR} = 1 - \text{inherentDR} . \]  

(2)

The technical factors that affect the reliability of civil aircraft dispatch reliability include the MMEL status, fault condition, fault detection, fault repair, etc. The corresponding parameters are as follows:

![Figure 1. Inherent dispatch reliability parameter system.](image1)

**Analysis Process**

Dispatch reliability could be determined according to a similar aircraft in the initial development stage of civil aircraft. According to the parameter system of this paper, the main manufacturer allocates DIR to system and sub-system supplier from top to bottom, then it is predicted and evaluated with fault data from suppliers through supplier management. V-type design and analysis process of inherent DIR of civil aircraft is shown in the figure.

![Figure 2. Inherent dispatch reliability analysis process.](image2)

Allocation formula [1,2] of DIR is calculated as follows:
\[ DIR_{\text{System}} = DIR_{\text{Aircraft}} \times \frac{N_{\text{System}}}{\sum_{i=1} N_{\text{System}}} \quad (3) \]

\( N_{\text{System}} \): Number of failure states of \( i \)th system in ATA chapter by Functional Failure Analysis (FFA).

Prediction formula of Subsystem (above) DIR is calculated as follows:

\[ DIR_{\text{Subsystem}} = \sum_{i=1}^{N} DIR_{\text{Device i}} \quad (4) \]

DIR of device is related to a number of factors which is calculated [3] as follows:

\[ DIR_{\text{Device}} = f(MTBF, \text{fault detection}, \text{MMEL}, \text{repairparameters}, \text{etc.}) \quad (5) \]

MTBF of device is related to data of the shelf products from suppliers, similar products data, failure data from test and reliability data in design phase. For most shelf products and the modified products with little change, MTBF is evaluated with shelf products data or similar products data. For new research products, there is a reliability comprehensive evaluation method based on the evidence theory.

\[ MTBF = f(\text{shelf products data}, \text{similar products data}, \text{failure data}, \text{reliability data etc.}) \quad (6) \]

If the evaluated and predicted results do not meet the allocation goals, they will be analyzed and iterated until the predicted results meet.

**Operational Dispatch Reliability**

**Parameter System**

Operational dispatch reliability is a parameter to characterize the ability of airplanes to dispatch, which mainly reflects the influence of operational factors on dispatch reliability. In an airline, operational dispatch reliability is expressed as flight normal rate.

\[ \text{Operational dispatch reliability} = 1 - \frac{\text{delayed and cancelled flights}}{\text{Operating flights}}. \quad (7) \]

The non-technical factors that affect flight normal rate have many features such as unpredictability, high correlation and so on. They need to be considered in terms of management level, meteorological conditions and operating environment. Therefore, the operational dispatch reliability parameter system should focus on factors affecting flight dispatch and management of airlines such as maintenance and support. So the parameter system is as follows:
Airlines could carry out dispatch reliability design and analysis according to the above mentioned parameters and the following method to improve operational management.

**Analysis Method**

Due to randomness of the non-technical factors influencing the operational dispatch reliability, it could not be calculated by analytical method. In this case, Monte Carlo simulation method is proposed in order to make the analysis results more accurate. This method prefers to operational dispatch reliability considering the whole dispatch process which is concerned by airlines than other works[4,5].

In the simulation model, factors that affect dispatch is regarded as input which is set to random event, then it is decided whether or not to dispatch through a set of judgment from dispatch release process. Finally operational dispatch reliability is output by calculating successful dispatch times after simulation for given times.

If operational dispatch reliability does not meet the requirements, the airline needs to adjust corresponding spare parts and logistics management, and recalculate until the requirements are met.

**Example**

According to the above parameter system and analysis process, dispatch reliability analysis and design platform of civil aircraft has been developed.

1) **Analysis Process of Inherent DR**

   (1) In the early stages of development, value of civil aircraft inherent DR could be calculated through similarity analysis by expert system. In this example, it is calculated as 0.98 compared to 0.97 of a similar aircraft that is acquired through operation by airlines.

   (2) The value is allocated to system and subsystem.


Table 1. Allocating result.

<table>
<thead>
<tr>
<th>System</th>
<th>Subsystem</th>
<th>DR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flight Controls</td>
<td></td>
<td>0.9983723</td>
</tr>
<tr>
<td>Fuel</td>
<td></td>
<td>0.999229</td>
</tr>
<tr>
<td>Landing Gear</td>
<td></td>
<td>0.996659</td>
</tr>
<tr>
<td>Wheel brake system</td>
<td></td>
<td>0.998715</td>
</tr>
</tbody>
</table>

(3) MTBF of device is evaluated by fault data fusion which is more accurate than single data, then DIR of device is predicted. When DIR of all devices in a subsystem are finished, DIR of the subsystem is predicted. Compare to allocating result (0.998715), the predicted DR (0.999888) of “Wheel Brake system” is satisfied.

2) Simulation of Operational DR

Set up random events and distributions and give simulation times to 3000, then run the simulation.

As a result, the number of successful dispatch is 2954 and dispatch reliability is 0.9847. So the assumed operational conditions with environment conditions meet the target requirement (0.98).

Summary

Based on the factors that affect civil aircraft dispatch reliability, the concept of inherent dispatch reliability and operational dispatch reliability is put forward. Inherent dispatch reliability is mainly applied to the civil aircraft manufacturers, providing reference on reliability parameter system in development phase of civil aircraft for manufacturers and further providing a basis for civil aircraft inherent dispatch reliability distribution, evaluation, prediction and validation; Operational dispatch...
reliability is mainly applied to airlines, which provides a method for airlines to improve reliability and management.

References


