# Optimization Study of civil Aircraft System Maintenance Task Interval Based on Reliability Data

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**Abstract.** The optimization of maintenance intervals of civil aircraft involves the reliability, maintainability, and operating costs of onboard equipment, and it is also an important research direction that is of common interest to the airline companies, the main research units, suppliers, and so on. By collecting basic reliability data and operational reliability data of aircraft equipment and analyzing them statistically, the Weibull life distribution model of the equipment is derived. Based on this model, the average life of the equipment is statistically derived, and the inspection interval of the equipment is determined and optimized through comparative analysis.

**Keywords:** life distribution model; maintenance interval; reliability data

## 1 Introduction

The current situation at home and abroad is that maintenance interval optimization is mainly determined by the engineering experience of conducting MSG-3. This study focuses on collecting basic reliability data and operational reliability data of aircraft equipment and analyzing them statistically to obtain the Weibull life distribution model of the equipment [1]. The Weibull life distribution model can statistically determine the average life of the equipment. Based on the equipment's failure impact category, existing maintenance intervals, and average life expectancy, combined with the maintenance decision model, the optimization results of maintenance and inspection intervals can be determined after comparative analysis.

## 2 Workflow for Maintenance Interval Optimization

The workflow for maintenance interval optimization based on operational reliability data is shown below.

- Collection of equipment base and operational reliability data [2][3].
- Confirmation of equipment failure samples. The equipment failure samples are determined based on the base and operational reliability data of the equipment in

accordance with the requirements of the equipment life distribution model analysis [4].

- Statistical analysis of equipment life distribution. According to the Weibull distribution model and the Weibull distribution fitting method, based on the failure samples of the equipment, the statistical analysis gives the life distribution of the equipment [5].
- Maintenance decision modeling determination. Based on the results of the aircraft's MSG-3 analysis, the MPD of the Maintenance Outline MRBR report, and the Maintenance Outline MRBR Development Policies and Procedures Handbook (PPH), the equipment's failure impact category, pre-existing equipment maintenance intervals, and the aircraft's Maintenance Task Alphabet Inspection Interval (MTAI) policy are determined.
- A maintenance inspection interval optimization conclusion is given. According to the life distribution of the equipment given the average life of the stable period, combined with the maintenance decision-making model, after a comparative analysis, the optimization of the maintenance and inspection interval conclusion is given [6].

The specific workflow is shown in Figure 1.

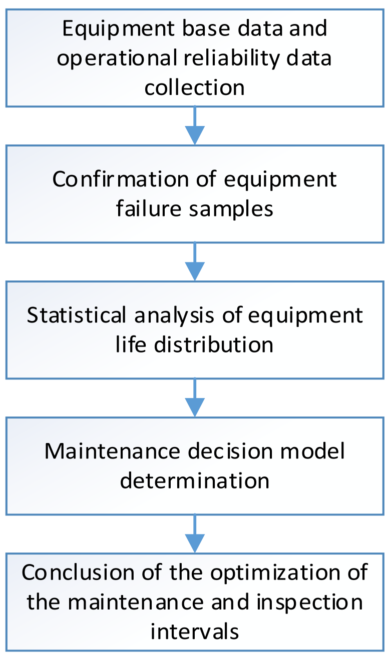


**Fig. 1.** Workflow for maintenance interval optimization.

# 3 Experimental Cases

## 3.1 Reliability Data

**Basic Reliability Data.** Basic reliability data mainly includes system equipment composition, number of equipment, and equipment reliability level. The basic reliability data for the gas system equipment is shown in Table 1.

**Table 1.** List of equipment for the gas supply system.

| Serial Number | Equipment Name | Quantities | MTBF |
|---|---|---|---|
| 1 | Intermediate Pressure Check Valve | 2 | Analyzing and summarizing based on route operation data |
| 2 | High-Pressure Valve | 2 | |
| 3 | Bleed Monitoring Pressure Sensor | 2 | |
| 4 | Pressure Regulating and Shut-Off Valve | 2 | |
| 5 | Fan Air Valve | 2 | |
| 6 | Pre-cooler | 2 | |
| 7 | APU Check Valve | 1 | |
| 8 | Cross Bleed Valve | 1 | |
| 9 | High-Pressure Ground Connection | 1 | |
| 10 | Bleed Temperature Sensor | 2 | |
| 11 | Bleed Pressure Sensor | 2 | |
| 12 | High-Pressure Conduit system | 1 | |
| 13 | Pre-cooler cold side header | 2 | |

**Operational Reliability Data.** Operational reliability data mainly includes three parts: aircraft fleet equipment removal and replacement record data, daily flight data, and aircraft fleet data.

## 3.2 Confirmation of equipment Failure Samples

In the experimental example, sample data on failures of intermediate pressure check valves (IPCVs) are used.

## 3.3 Statistical Analysis of Equipment Life Distribution

IPCV is a mechanical part. The failure of mechanical products satisfies the Weibull distribution law. So the life distribution of IPCV adopts weibull distribution.

Through the statistical analysis, the life distribution of IPCV obeys the Weibull distribution, and the statistical results of the life distribution are β=1.71, η=68881.6, as shown in the following Figure 2.

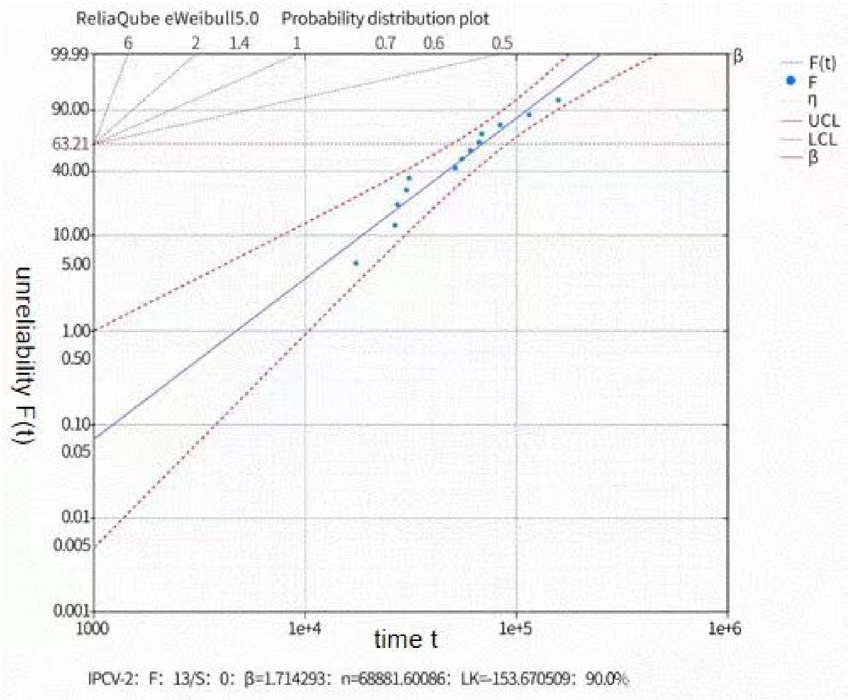


**Fig. 2.** Field statistical life distribution of medium-pressure unidirectional flapper IPCVs.

### 3.4 Maintenance Decision Modeling Determination

**Analysis of the Gas Supply System MSG-3.** The MSG-3 analysis report for the gas system is shown in Table 2.

**Table 2.** MSG-3 analysis of the air supply system.

| SYSTEM&POWERPLANT ANALYSIS-MSG-3 ANALYSIS | |
|---|---|
| | Task Interval Selection |
| | Task Sequence No.:36-10-00-01 |
| Analysis Result | 25000FH |
| Similar Aircraft | Airbus A320 72 MO/8000FC/12000 FH. |
| | Removing Intermediate Pressure Bleed Check Value for Detailed Inspection. |
| | Airbus A350 24000 FH. |
| | Removing IPCV for Detailed Inspection. |

| | |
|---|---|
| System Engineer Judgement | Reliability calculation: The MTBF of IPCV is 288143 FH if the Weibull distribution is used to model the failure characteristics of components, the relationship between task interval t and reliability R(t) is: $t=\eta.\left[-\ln R\ (t)\right]^{\frac{1}{\beta}}$, where η is the characteristics of life, and β is the shape parameter. Additionally, the relationship between MTBF and shape parameter is $MTBF=\eta.\Gamma\left(\frac{1+\beta}{\beta}\right)$. If the reliability R(t)=80%, $\beta$ =1.5, then the characteristics life $\eta$ =319185 and task interval t=91452 FH. Considering the Weibull distribution calculation results, the final interval is 25000 FH. |
| Others | |

**MRBR Report on an Aircraft Maintenance Syllabus.** An aircraft maintenance outline MRBR report is shown in Table 3.

**Table 3.** MRBR report for an aircraft maintenance syllabus.

| Revision Status (Computing) | MRB Task No. | Failure Impact Category | Task Type | Threshold | Interval | Applicability | Task Description | Source |
|---|---|---|---|---|---|---|---|---|
| | 36-10-00-01-01 | 6 | DET | 25000 FH | 25000 FH | ALL | Detailed inspection of IPCV Approach: Open the fan shroud | MSI |

**MPD for an Aircraft Maintenance Program Document.** The MPD for an aircraft maintenance program document is shown in Table 4.

**Table 4.** MPD for an aircraft maintenance program document

| MPD Task No. | Failure Impact Category | Task Type | Area | Task Description | Inspection Threshold | Repeat Check Interval | Man-Hour | Applicability |
|---|---|---|---|---|---|---|---|---|
| 36-10-00-01-01 | 6 | DET | 410/420 | Detailed inspection of IPCV Approach: Open the fan shroud | 25000 FH | 25000 FH | 0.05 H | ALL |

**Fault Impact Categories and their Reliability Requirements.** The data for the failure impact categories and their reliability requirements are derived from the requirements in MIDOT used in the Boeing MRBR development process, as shown in Table 5.

**Table 5.** Fault impact categories and their reliability requirements.

| Failure Impact Category | Required Reliability |
|---|---|
| Obvious Safety Impact (Category 5) | 0.9 |
| Obvious Usability Impact (Category 6) | 0.8 |
| Obvious Economic Impact (Category 7) | 0.7 |
| Hidden Safety Impacts (Category 8) | 0.9 |
| Concealed Non-Safety Impacts (Category 9) | 0.7 |

### 3.5 Maintenance Decision Model Determination

Based on the results of the MRBR, MPD, and MSG-3 analyses of the air source system and reliability prediction reports for a particular type of aircraft:

- Life distribution of medium-pressure unidirectional valves in the gas supply system: $\beta$=1.71, $\eta$=68881.6;
- The inspection interval policy is: inspection interval > 4000 FH, then the interval increment is 500 FH;
- Failure impact category of the medium pressure one-way valve of the gas supply system: obvious serviceability impact (Category 6);
- When the reliability is 80%, according to the life distribution of the medium-pressure one-way valve IPCV (shape parameter $\beta$ = 1.71, scale parameter $\eta$ = 68881.6), the interval of the medium-pressure one-way valve IPCV is 28715 FH.

### 3.6 Maintenance and Inspection Interval Optimization Summary

According to a certain model of aircraft maintenance outline, MRBR gives the air source system in the pressure one-way valve inspection interval 25000 FH, through a certain model of aircraft operation process reliability data statistical analysis of the air source system, the maintenance interval of the pressure one-way valve is 28715 FH.

Considering the incidental damage (weather effects, passenger activities, ground support equipment tools, etc.) and environmental degradation damage (temperature, humidity, contaminants, etc.) included in the IPCV, and combining the results of the PPH, MRBR, and MSG-3 analyses, it is recommended that: the maintenance interval for the pressure check valves in the air supply system of a certain type of aircraft should be adjusted from 25,000 FH to 28,000 FH.

Longer intervals between scheduled maintenance can save the airline aircraft operating costs. The formula for calculating the cost of planned maintenance is:

$$DMC = \sum R \times MH_{ONi} \times (T_{Ri})^{-1} \quad (1)$$

In the formula:

$DMC$ -- Direct maintenance costs for planned maintenance (dollars/flight hour).

$R$ -- Maintenance labor hour rate (dollars/hour).

$MH_{ON\,i}$ -- Maintenance labor hours for planned maintenance task i (hours).

$T_{R\,i}$ -- Maintenance interval for planned maintenance task i (flight hours).

The IPCV maintenance labor rate is \$55. Usually, maintenance labor time is 2 hours. The direct maintenance cost before optimization is 0.0044 dollars. The direct maintenance cost after completing the optimization is 0.0039 dollars. IPCV optimization saves 0.0005 dollars per driver repair. Airlines pay a lot of attention to the optimization of maintenance intervals. The content of this study is important for airline companies.

## 4 Conclusion

The methodology and case study of civil aircraft maintenance task interval optimization based on the Weibull distribution of reliability data used in this paper demonstrates its feasibility. Based on the reliability data of aircraft operations, a Weibull distribution model is used for equipment life analysis. After that, a comparative analysis is carried out by combining the failure impact of the equipment and the existing equipment maintenance intervals, etc., to obtain the optimized value of the equipment's scheduled inspection intervals. The method has an obvious advancing effect on the optimization of maintenance task intervals of civil aircraft.

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