INVESTIGATION OF AIRBORNE PRODUCT EXPENDING DYNAMIC CALIBRATION LIFE METHODS

Sun Jianying
Chinese Flight Test Establishment
Sunjianying101@yahoo.com.cn

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Abstract

Extending the calendar life of airborne products is an urgent problem for aviation maintenance engineering since there are not sophisticated theories and methods. This paper analyzes the existing problems in life control system of airborne products. Based on the reliability-centered maintenance (RCM) theory and flight test, then a new method called "Comprehensive Analysis and Decision-making Method for Life Extension" is presented. At last, flight test results are given to illustrate the correctness and effectiveness of the methods. The method makes great contribution to the integrated logistic supportability of the aircraft.

1 Summary

For aircraft and airborne products, besides advanced performance indexes, they should have an appropriate life control system to decide whether the aircraft can be brought into service efficiently. Nowadays, there are still a good many of disadvantages in the practice of establishing calendar life for airborne products. When carrying out calendar life extension by means of traditional methods, all effecting factors on the calendar life could not be comprehensively considered. Thereby, developing effective engineering methods for extending calendar life for airborne products is very much needed.

This paper mainly studies the life extension of airborne products in the first overhaul stage, based on the RCM theory and flight test. And a new method called "Comprehensive Analysis and Decision-making Method of Life Extension" is further proposed and applied to the decision-making practice of the calendar life extension for airborne products.

The method has been used in Chinese Flight Test Establishment (CFTE) for many years. In consequence, the calendar lives of hundreds airborne products have been extended, obtaining significant cost saving.

Here the hydraulic solenoid valve YDF-A (YDF-A for short) and hydraulic sensor YCG-B (YCG-B for short) are taken as an example to present the method of extending the calendar life of the airborne products.

2 Test Aircraft

The test aircraft presented here which has just finished its type certification is the one used for the aeronautic scientific research and new technology verification [1].

2.1 Chinese Flight Test Establishment

Founded in 1959, CFTE is the unique national facility for the research and testing of aircraft. During the past 53 years, CFTE has accomplished all the flight test tasks assigned by the state and made great contribution to the development of Chinese aviation industry.

The symbol and air fleet of Chinese Flight Test Establishment see Fig. 1 and Fig. 2.

Fig. 1 CFTE Logo

Fig. 2 CFTE Air Fleet

2.2 Flight Test

Flight test is to carry out the scientific research and products test in the real flight. It is an important way in the aeronautic and astronautic technology development. Flight test is a necessary process in the aviation products research and evaluation, and also is an effective way for engineers to do research and accumulate experience.

3 Life of Airborne Products

3.1 Life of Airborne Products

The life of airborne products, generally including the first overhaul, spaced overhaul, total service life, service life limit, storage time limit, is a concept used to describe the five life concepts listed above with a calendar time period [2].

3.2 Problems in Controlling the Calendar Life of Airborne Products

For many years, the bath-tub curve guided the airborne products calendar life management. The traditional reliability theory shows that the failure rate of the general products form the bath-tub curve as time goes by. As shown in Fig. 3. Because of different failures of the products, the failure rate can be divided into three stages: Stage Ⅰ - Early service failure; stage Ⅱ - occasional failure; stage Ⅲ- loss failure. In the product failure bath-tub curve, the length (Ⅰ + Ⅱ) of the bath-tub bottom shows the durability of the product. And this can be used as a reference value for the first overhaul of the product, the service time limit and the time between overhauls.

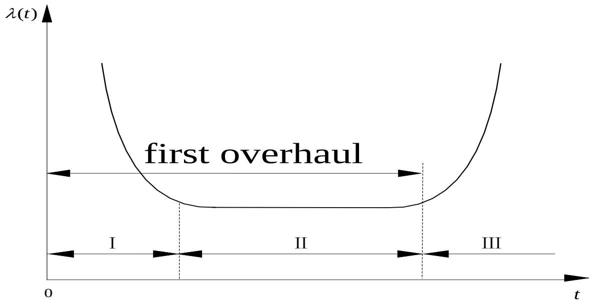

Fig. 3 Bath-tub Curve

According to the bath-tub theory, time limits for discarding and overhaul are ruled for the airborne products, and once the time limit is reached, the products will be out of service or sent back to their manufacturer for overhaul. This is an easy way, but we also decide inapplicable service lives for some products. Managing the product maintenance and overhaul with this theory not only increases the workload, but also affects the integrated logistic support work of the aircraft.

4 Investigation of the Methods Used to Extend the Calendar Life of Airborne Products

Main technical routes for products research are shown as follows. (See Fig. 4)

4.1 Selection of Airborne Products Needing Life Extension

We judge and determine the product whose life need to be extended with the three methods described below.

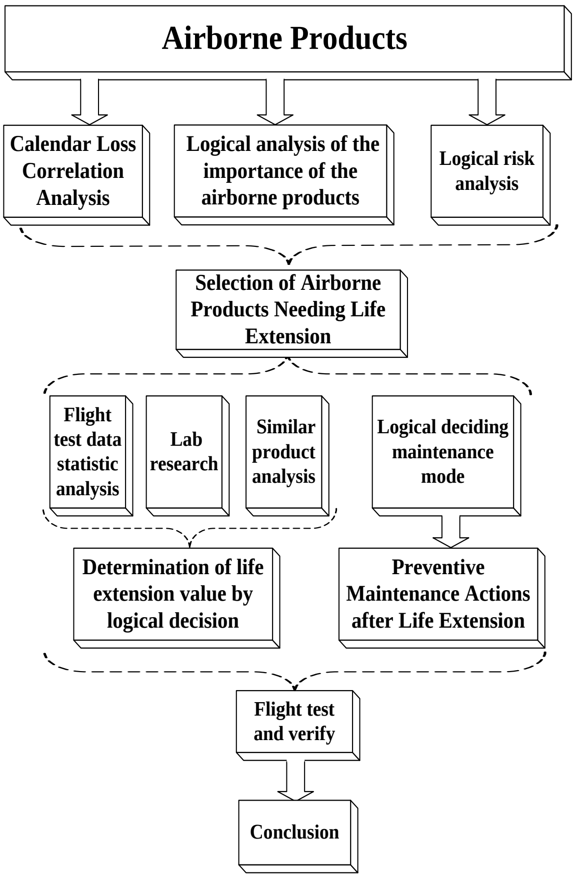

Fig. 4 Technical Routes for Products Research

4.1.1 Calendar Loss Correlation Analysis of Products

Study the structure and functions of products and analyze the main failure modes and causes. According to the failure mode and effect analysis (FMEA) results, it can be decided whether the failure mode is related to calendar loss. If the failure mode is irrelevant to loss, it will be maintained together with the aircraft overhaul. If the failure mode is related to the calendar loss, its service life should be extended.

4.1.2 Logical Analysis of The Importance of the Airborne Products

The importance of the airborne products can be mainly classified as the following three classes.

1. Key product (Class A): Failure of the product will affect the flight safety directly.
2. Important product (Class B): Failure of the product cannot have direct influence on the flight safety, but the mission result can be directly affected.
3. Ordinary product (Class C): Failure of the product cannot affect the flight safety and the mission result.

We use the logic decision method from the RCM theory to analyze the importance of the airborne products. For Class A and B products, the service life indexes should be determined individually. If the product is classified as Class C, it will be maintained at the same time the first overhaul of the aircraft is conducted.

4.1.3 Logical Risk Analysis

According to RCM theory, the original reliability of the products should be kept after the product life extension, which can lower the risk of life extending.
Risk factor R is used to evaluate the level of possible risk after the airborne products life extension. The risk factor jointly considers the effects of serious level (S) and the level of difficulty to check the failure (D) as shown in formula 1. Life extension process cannot be carried on the products with high risk factor.

$$R = S \times D \qquad (1)$$

The failure serious level (S) is to scale the serious level when a failure happens. We rank the serious level from 1 to 5, as shown in Table 1.

Table 1 Failure Serious Level

	Remark	Factor
Dangerous	Failure may influence flight safety, and an accident may happen easily.	5
High	Failure affects the main function and mission.	4
Medium	Failure affects parts of the system function	3
Low	Failure has a little influence on the system function, and results in slight performance degradation.	2
Slight	The effect of the failure can be neglected.	1

Difficulty degree (D) is the comment on whether the product failure is hard to be founded out in current maintenance circumstances. We also rank this effect into 5 classes, see Table 2.

Table 2 Standard of Check Difficulty Degree

Check difficulty degree	Possibility to find out	Factor
Very hard to check	The failure is very hard to check on the ground.	5
Hard to check	The failure is hard to check on ground.	4
Medium	No warning information in flight, but the failure can be checked on ground.	3
Easy to check	Warning information in flight, and the failure can be checked on ground.	2
Obvious	The failure is obviously to be found out.	1

4.2 Estimating the calendar life extension of airborne products.

In the course of the airborne products life extension research, the calendar life extension period is estimated with the methods of flight test data statistics, laboratory research and similar products.

4.2.1 Flight Test Data Statistics Analysis

The method of estimating the life of airborne products based on zero-failure data is studied. By collecting the service time and the failure information, a bi-parameter Wei-bull distribution model is established. Secondly the life distribution curve and characteristic life value (life intervals of confidence level) are estimated on the basis of the zero-failure data. And then the results are transformed to the life value with "year" as the unit for easy application.

Given the product life according to bi-parameter Wei-bull distribution, equation 2 is used as the product accumulation distribution function.

$$F(t) = 1 - \exp\left[-\left(\frac{t}{\eta}\right)^m\right] \qquad (2)$$

Where,

m stands for Fig. factor, m>0;

η stands for characteristic life, η >0.

We developed a service life estimating system for airborne products on the basis of Wei-bull distribution (See Fig. 5).

Fig. 5 Airborne Products Life Extension System

We used Wei-bull distribution to estimate the service life of the products in the example. The results are shown in Chart 3.

Chart 3 System Assessment Results

	Characteristic life (Hour)	Estimated Life (Year)
YDF-A	8889.7506	26.27
YCG-B	9499.1142	23.33

4.2.2 Lab Research

To evaluate the airborne product life extending through certain lab tests is another frequently-used method. This method is very persuasive and of low risk because it has test data as the evidence.

Fig. 6 YCG-B under Performance Test

Fig. 7 YCG-B under Breakdown Check

Performance test and breakdown check of the products are carried out in the test. The Fig. 6 and Fig. 7 show the tests of YCG-B performance test and the breakdown check, and the research discovers that the product has an amazing potential for life extension.

4.2.3 Similar Product Analysis

There are obvious similarities on aircraft series. Generally the airborne products should have a same or similar function. The module may vary, but they have similarities after carefully analyzing the structure, material, service environment and load capability. Therefore, we can estimate the airborne products life of new aircraft through comparing with that of similar products on the previous type aircraft.

4. 3 Determination of Life Extension Value by Logical Decision

Since these three methods are based on different theories, different databases, we use the three methods together can avoid the limitation of each method and achieve a more believable result. And the life extension of the airborne products can be determined by logical decision ultimately.

According to the research above, we decide to give the estimated product life as shown Chart 4.

Chart 4 Example

Name of the product	Assigned Life	Life after life extension
YDF-A	3 year(time to first overhaul)	10 year (time to first overhaul)
YCG-B	3 year (time to first overhaul)	10 year (time to first overhaul)

4.4 Establishment of Preventive Maintenance Actions after Life Extension

Function and failure analysis were carried out after the product life extension, so as to make the failure result clear. With the specified logical decision procedure, the preventive actions were made to prevent the failure modes. With the methods such as field failure data collection and expert evaluation, we optimized the service-life extending products maintenance strategy and minimized the aircraft ground time loss and the maintenance material consume. New maintenance programs and new maintenance task cards were formulated to finish this work easily.

4.5 Flight Test and Verification

The flight test of the life-extended products was carried out together with scientific research flight test.

With the prevention maintenance actions, a great number of life-extended products have served several aircrafts for thousands of flight hours.

The correctness and effectiveness of Comprehensive Analysis and Decision-making Method to extend the life was proven by flight tests.

5 Conclusions

Comprehensive Analysis and Decision-making Method of Life Extension formed on the basis of RCM theory can determine the life of the airborne products correctly, and has made a great contribution to the test aircraft life extension in CFTE. The experience and data we accumulated during the test aircraft life extension could be a valuable resource with great benefit for the aviation industry to estimate reasonable service lives for the airborne products. This method plays an important role in improving the aircraft complex maintenance.

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