Aircraft Fuel System Fuzzy FMEA and FMECA Analysis

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Abstract. Through quantitative analysis,The paper use computer technology and mathematical methods, combined with FMEA and FMECA , the paper organized the failure of an aircraft fuel system parts in recent years ， we set up fault model system to analysis Fuel system of Certain type aircraft , expanding the way of maintenance and support.

1. Introduction

Aircraft system is a multi-component system, and each part run independently, different parts of the system has different affect, so it is necessary to distinguish priority of service. How to efficiently implement maintenance and support, to ensure the complete various tasks successful, it is a brand new topic need to be considered for all levels maintenance engineering and technical staff.

With the growth and enhance troubleshooting capabilities, maintenance staff can not limited only by the available data and resources to diagnose faulty components, and we should focus on anti-failure detection monitoring,from the current priorities and division of labor point of view, basic maintenance staff focus on the discovery and analysis of faults, and isolate the faulty process and methods, maintenance technical management attent to failure time, specific content guidance, management of repair process,equipment office focus on maintenance mode and resources if has a reasonable allocation, industrial production sector is study of macro failure, failure modes and reliability based on basic level maintenance experience.

2. FMEA based on fuzzy theory

The system is based on the component,therefore, system failure is caused mainly by a component failure, study and analyze the fault of the individual components and its failure modes is basic research of system failure, using FMEA risk analysis methods,which can identify system failures mode and effect, reduce the quality risk, eliminate defects, but when analysis a system , there are many complex and uncertain factors inevitably, it is difficult to quantitatively describe the primary and secondary relationship between different failure modes of system components, using fuzzy mathematical method to deal with uncertain information,quantitative analysis of the degree of impact of various risk factors on the system, according to the fuzzy sort of risk priority value of each risk factor, which can control factors of key components fuel systems to reduce the use of risk.

2.1 Traditional FMEA method

Explanation of statistical data as following: Put specific checks and aircraft change season into a class, mechanical day and preparatory maintenance prepare date statistics combined together,due to the current filled card does not regulate,we sort out many similar failures data as one class, such as combined aircraft body and airfoil tank relief valve, combined fuel oil discharge switch and electric switch leakage into one category, combined fuel level control and signal failure of pressure controller while plus pressure into one category, related issues combined statistics. Failure mode of the aircraft fuel systems and impact analysis shown in table 1.

Table 1 Fuel System FMEA table

No.	Component	Symptom	Failure Mode	Cause	Failure affects	Basic maintenance measures
1	Fuselage (wing) fuel tank relief valve	When refueling, "relief vent" does not light	Light does not shine	Internal circuit failure	Local influence	Replacement parts
2	Fuel electric switch	Electric switch indicator rod junction leakage oil	Oil spill	Sealing gasket aging	Affect performance	Replacement parts
3	Fuel gauge indicator	Former group, the total group instruction swing	Swing. Jitter.	oil indicator of Internal Bridge fault	Damage	Replacement parts
4	Switch	Conversion switch set to "left" wing when the indicator is incorrect	Indicating abnormal	Internal mechanical failure	Affect performance	Replacement parts
5	Gas turbine starter	Not turn the engine when starting	Function failure	Starter low efficiency	Function failure	Replacement parts
6	Fuel level controller	lights are not bright When refueling	Light does not shine	Fuel oil controller damage	Local influence	Replacement parts

The traditional method use RPN to sort for the quality risk,through the severity of the failure mode, the probability and detection to assessment risk, which ranges from [1, 10], with quantitative indicators to determine high risk of failure modes and key factors.

Where: RPN = S*O*D

Obviously, three factors given different weights will produce different risk priority number, because factors itself has ambiguity and uncertainty, the traditional expert evaluation method to determine the weight of each factors can not reflect the exact real impact extent of evaluation factors objectively, so we consider obfuscate to the value of three factors.

2.2 Fuzzy risk priority of FMEA based on fuzzy average Weight

Suppose there are n fault mode Fi (I = 1, ..., n), needs assessment, evaluation team has m expert Ej (J = 1, ..., m) . several risk models fuzzy rating of risk factors O, S, D are:

$\tilde{R}_{ij}^{o} = (R_{ijL}^{O}, R_{ijM}^{O}, R_{ijU}^{O})$ $\tilde{R}_{ij}^{S} = (R_{ijL}^{S}, R_{ijM}^{S}, R_{ijU}^{S})$ and $\tilde{R}_{ij}^{D} = (R_{ijL}^{D}, R_{ijM}^{D}, R_{ijU}^{D})$. (L, M, U are risk factor levels)

M ExpertS (EJ) provides fuzzy weight of three risk factors of FMEA:

$$\tilde{w}_{j}^{o} = (w_{jL}^{o}, w_{jM}^{o}, w_{jU}^{o}) \quad \tilde{w}_{j}^{s} = (w_{jL}^{s}, w_{jM}^{s}, w_{jU}^{s}) \quad \tilde{w}_{j}^{D} = (w_{jL}^{D}, w_{jM}^{D}, w_{jU}^{D}) \quad (1)$$

KJ (J = 1, ..., M) is a relatively important weight of the experts, and satisfy

$\sum_{j=1}^{m} kj = 1$, Kj > 0 (J = 1, ..., M).

fuzzy weight of n fuzzy numbers mean:

$$\tilde{y} = f_G(\tilde{x}_1, \ldots, \tilde{x}_n; \tilde{w}_1, \ldots, \tilde{w}_n) = \prod_{i=1}^{n} (\tilde{x}_i)^{\frac{\tilde{w}_i}{\sum_{j=1}^{n} \tilde{w}_j}} , \quad (2)$$

$\tilde{x}i$: N positive fuzzy numbers to be weighted; $\tilde{w}_i$ is respective weights, i = (1 .. n).

based on subjective opinion of experts to calculate overall incidence of the various failure modes, severity, detection of degree level :

$$\tilde{R}_{i}^{O} = \sum_{j=1}^{m} k_j \tilde{R}_{ij}^{O} \quad \tilde{R}_{i}^{s} = \sum_{j=1}^{m} k_j \tilde{R}_{ij}^{s} \quad \tilde{R}_{i}^{D} = \sum_{j=1}^{m} k_j \tilde{R}_{ij}^{D} \quad , I = 1, .., n \ (3)$$

The overall fuzzy weight of O, S, D is:

$$\tilde{w}^O = \sum_{j=1}^{m} k_j \tilde{w}_j^o \quad \tilde{w}^s = \sum_{j=1}^{m} k_j \tilde{w}_j^s \quad \tilde{w}^D = \sum_{j=1}^{m} k_j \tilde{w}_j^D \qquad (4)$$

Fuzzy risk priority of failure modes are:

$$FRPN_i = \left(\tilde{R}_i^O\right)^{\frac{\tilde{w}^o}{\tilde{w}^o+\tilde{w}^s+\tilde{w}^D}} \times \left(\tilde{R}_i^S\right)^{\frac{\tilde{w}^s}{\tilde{w}^o+\tilde{w}^s+\tilde{w}^D}} \times \left(\tilde{R}_i^D\right)^{\frac{\tilde{w}^D}{\tilde{w}^o+\tilde{w}^s+\tilde{w}^D}} \quad , I = 1, .., n \ (5)$$

Therefore,we select four different professional and technical experts involved in the fuel system of FMEA assessment, first, given different weights based on experience and knowledge of the experts , relative weights are: 0.3 (E1), 2.5 (E2), 3.5 (E3), 0.1 (E1). According to Table 1, the failure mode of the fuel system have five kinds,according to the frequency of fault occurrence, the degree of severity and the detection to optimize 5 failure mode, according to the level of blurring listed in Table 1 and the above equation,we can obtain the frequency of the each failure mode, severity and the Overall fuzzy evaluation information degree of detected difficulty and overall evaluation degree of the importance information, according to the formula we calculate the risk of failure priority level ,results is in the following table 2:

Table 2 Risk factors fuzzy weights

Failure Mode	The frequency	Severity	Detection	Priority
1 (tank does not light)	(5.2, 6.2, 7)	(3.2, 4.2, 5)	(4.2, 5.2, 6.2)	5
2 (junction leakage)	(5.55, 6.55, 7.3)	(3.8, 4.2, 5.8)	(6.2, 7.2, 8.2)	2
3 (fuel gauge indicates jitter)	(7.05, 8.2, 8.6)	(6.05, 7.2, 8)	(4.2, 5.2, 6.1)	4
4 (switch indicates abnormal)	(3.2, 3 .. 7, 4.7)	(5.8, 6.2, 7)	(4.8, 5.8, 6.7)	3
5 (starter function failure)	(2.2, 4 .. 7, 4.1)	(5.2, 4.7, 4.2)	(2.2, 5.7, 4.0)	1
6 (level controller does not light)	(3.15, 3.5, 2.7)	(4.2, 3.3, 4.7)	(6.2, 3.5, 5.7)	6
Importance weights	(4.2, 6.2, 8.2)	(5.7, 7.7, 8.8)	(1.2, 3.2, 5.6)	

we can obtain the risk priority class of failure modes from Table 2:

FRPN5> FRPN2> FRPN4> FRPN3> FRPN1> FRPN6

3. FMECA method

FMECA is failure modes effects and criticality analysis, for analysis failure , causes and effects of product, so that we can modified the various stages of production and the feasibility study ,provide a meaningful reference for new product development or evaluation. Using this method,we need to determine the probability and severity rating categories of failure.

3.1 Determine Severity Type and Probability Level of Failure

Severity category is classify for the most serious potential consequences caused by the failure,firstly, by severity it is classify into four categories: When the failure mode can not be explicitly expressed in the four categories, according to the extent of the loss that we will represents an approximation of the classification, according to the severity of the failure,the system components can be divided into four categories.

Class Ⅰ (disaster): May cause death or system damage all;

Class Ⅱ (fatal): serious injury, equipment damage or task termination;

Class Ⅲ (critical): mild injury, equipment damage or performance degradation

Class Ⅳ (mild): does not cause injury or damage to the equipment, but if left unattended, lock-outs, which may lead to equipment failure.

It is related to not only the damage level but also the probability of the failure mode occurrence in using if the system is damaged,the probability of failure is divided into five grades:

Level A (frequent): 0.2 <P ≤ 1.0;   Level B (sometimes): 0.1 <P ≤ 0.2
Level C (occasional): 0.01 <P ≤ 0.1; Level D (rare): 0.001 <P ≤ 0.01
Level E (basically does not happen): 0 <P ≤ 0.001

For six kinds of failure modes,failure probability and severity grading shows in table 3:

Table3 failure probability and severity level of 6 failure modes

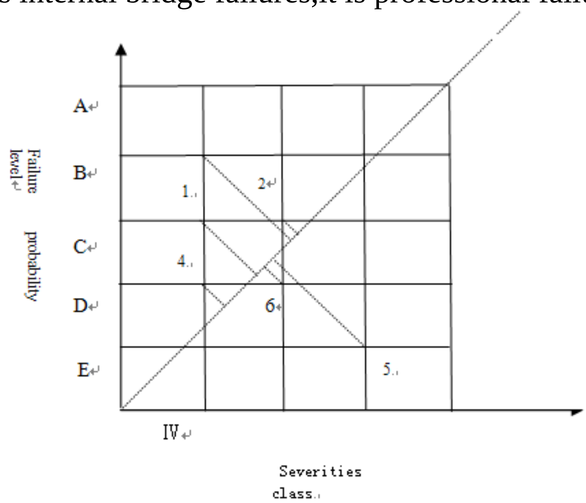
No.	Failure Mode	Severities	Failure probability level
1	Light does not shine	Ⅳ	C
2	Oil spill	III	C
3	Swing. Jitter.	III	D
4	Indicating abnormal	Ⅳ	D
5	Function failure	II	E
6	Light does not shine	Ⅳ	B

We use FMECA analysis the importance of each failure mode and the probability of occurrence to determine the fault law of the various components of the fuel system,failure mode,provides useful information for maintenance plans and troubleshooting,take preventive measures.

3.2 Hazard Analysis

Hazard analysis is performed by the combined effects of the occurrence probability and harm's degree of system failure mode,it is classified into quantitative and qualitative matrix method, using the former method when there is incomplete data, when there is sufficient data to use the latter, the paper collected failure data from 2009 to 2011,the data is more full,therefore we use qualitative analysis.

Judgment method: the method of dangers is: the distribution point of failure mode marked diagonal (dashed line OP in Fig), the distance from the intersection of the vertical and diagonal to the origin as a measure of the dangers of failure modes;the longer the distance, the harm is greater.As the qualitative analysis, we require the point in the same box marked have same dangers (such as (2) and (6) have the same dangers, (1), (3) and (5)). from the dangers of the matrix,(2) has maximum harm to the system, that is leaking fuel failure of electric switch,it is aging seals located in the landing gear compartment,it is mechanical engineering failures; (6) fuel level controller failure ,it is the oil level controller fault, it is mechanical damage, (5) the gas turbine starter is a Ⅱ fault severity level, but because of its level of probability failure is small , it is E so not particularly high harmfulness.(2), (6) and (1) probability failure is large relatively.(3) Quantity indicator for the ad hoc is internal bridge failures,it is professional failure, probability rating is D.



The dangers sort order of fuel system faulty is: 2> 6> 5> 3> 1> 4.

4. Conclusions

This paper analyzed fuzzy FMEA and FMECA of a certain type of aircraft fuel system fault conditions,we get priority hazardous Sort of six kinds of failure mode and dangers sort in the fuel system,we put it as the only fault in the system,in practical, if the fault is undetectable, we should be further analyzed to determine the impact of other failures related,design special control measures, research departments can update FMEA report timely, provide empirical data for a new round of equipment development,along the fault we can predict the remaining life of components accurately,so as to promote the realization of the equipment precision support gradually.

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