Study on the Reliability Evaluation of Typical Light Electric Aircraft

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Abstract. The reliability level of electric light aircraft is the core index of judging the safety level of its flight. In this paper, the theory and method of reliability determination of Rui-Xiang electric aircraft are studied from the perspective of intrinsic safety. On the basis of Extensive research and data analysis, it studies the reliability to determine the basic method and the basic structure and composition, discusses the key components and the critical degree of determination and calculation method. Then, using FME(C)A to identify key components of the aircraft landing gear systems, determine the harm degree of key components and calculate the critical degree of key components. The reliability level of Rui-Xiang aircraft are studied with comprehensively analysis. The results can provide theoretical guidance of reliability analysis and evaluation of the electric light aircraft.

Introduction

The Rui-Xiang seat electric light aircraft is designed by Liaoning General Aviation Research Institute. It strucks the maximum cruising speed can reach 150 km per hour, maximum launch distance of 3000 meters, maximum take-off weight of 480kg. The plane take off distance of 290 meters, landing distance of 50 meters. Battery is the power source of the aircraft.1.5 hours per charge, which can fly for 40 minutes. The aircraft completed the Civil Aviation Administration of China all the subjects of the examination and approval in Liaohe finance Lake general Airport.

At present, electric aircraft development faces a series of problems, such as electric power propulsion system key performance indicators low, technology is not mature, the weight is too large, its safety and reliability needs to be improved[1,2]. From the perspective of electric light aircraft essential safety, it focuses on the reliability. The study results can provide theoretical guidance for the electric light aircraft overall system safety analysis and evaluation.

The structure of Rui-Xiang two-seat electric aircraft system

Rui-Xiang two seater electric plane is divided into three systems, respectively, control system, structure system, dynamic system[3-5]. As shown in table 1.

Tab.1 The structure of Rui-Xiang two-seat electric aircraft system

Rui-Xiang electric aircraft	Manipulation of the structure	The throttle push rod; Brake assembly; Manual control system; Foot operating system; Resistance plate control structure
	structural system	Fuselage; Airfoil(Aileron assembly right (left); Main wing assembly right (left); Resistance plate assembly right (left)); Empennage(The vertical flat tail link assembly; Flat tail assembly; Elevator assembly; Rudder assembly); Undercarriage
	power system	Electromotor; Relay; Lithium battery; Screw propeller

Rui-Xiang two-seat electric aircraft reliability analysis of key components

1）The determination of key components

Applying FMEA[6]to determine key components, the key components can prone to security incidents or have great impact on the safety of the product when the component failure .Critical degree is the level of the influence about the product's safety when the component fails. The more serious the consequences of product safety accidents or the greater the impact on the safety of the product the higher the critical degree of the component.

The failure mode and effect analysis (FMEA) are used to analyze the key parts. The first part is to divide the product into the prescribed level. Commonly used agreement levels have the initial agreement level, the level of agreement, other levels of agreement and the lowest level of agreement. As shown in table 2.

Tab.2 Rui-Xiang electric aircraft system the definition of severe degree category

The severe degree of category	Punishment degree definition
I class (catastrophic)	Endanger people or the safety of the flight), such as such as, second-class aviation accidents and major environmental damage
II class (catastrophic)	Personnel injury or damage of aircraft parts (such as the third flight accidents) and severe environmental damage
III class (catastrophic)	Moderate injury, or affect the task to complete (such as fly by mistake, interrupt or cancel the flight, lower the quality of fly line, increase the difficulty of landing), the degree of environmental hazards, etc
IV class (disaster）	No impact or effect is very small, increase the unscheduled maintenance or repair

According to the level of the classification of the breakdown of the breakdown model determine the impact of the product to determine its severity. They can be defined for critical parts while its level onIorII.

2）Criticality analysis of key components

Hazard analysis is based on the comprehensive influence of the severity of each failure mode and the probability of the occurrence of the failure mode, division of products and other types of systems, so that it can be more comprehensive evaluation of the system may be the impact of product failures. CA is an extension or supplement to FMEA[7.8].

Failure mode frequency than alpha refers to the product of a certain fault ratio of prod uct all fault. Fault impact probability of beta is refers to the products under the condition o f a certain failure mode occurred, its influence eventually lead to “initial engagement level” a severe degree of grades of conditional probability. Its harmfulness to the single failure mode evaluation, should be calculating the damage of each failure mode $C_m(j)$：

$$c_m(j) = abl_pt,\ j = \mathrm{I}, \mathrm{II}, \mathrm{III}, \mathrm{I}V \qquad (1)$$

In order to evaluate the harmfulness of a product should calculate the damage of the p roduct: $Cr(j)$：

$$c_r(j) = \sum_i^n c_m(j) \qquad (2)$$

Type: i=1,2,3...,n; n of the product in the case of type j harsh degrees under the categ ory of total failure mode.

3）The key to calculate critical parts

Based on landing gear parts as an example to calculate, it analysis that is the key components of the landing gear on the prop, the needle roller bearing and before the torque arm. Analyzing harmfulness like table 3[9].

In the failure rate, failure mode frequency than alpha, beta and fault impact probability working time (t) according to the formula can be calculated under the condition of known fault mode harm degree.

Tab.3 the gear hazard analysis critical parts

Analysis: XXX review of: XXX approval: XXX date of filling: XXX

Initial engagement levels: Rui-Xiang two seater electric aircraft agreed levels:landing chassis

code	The product or function	failure mode	failure cause	grimness	failure rate $l_p(10^{-6}1/h)$	Failure mode frequency ratio a	Failure Effect Probability b	working time (t)	Failure mode harmdegree $C_{m(j)}$	Product harm degree $C_R(j)$
01	Front support	Pillar deformationis too large	Stiffness is not enough	II	15.6	0.02	0.8	0.33	0.0824	IIclass：0.0824
02	needle bearing	Bearing clearance is too large	abrasion	II	79.91	0.89	0.8	0.33	18.766	Iclass：2.611 IIclass：18.766
		Fell out of the ball	abrason	I	79.91	0.11	0.9	0.33	2.611	
03	Front boom	Torque Tube hole loose	Landing impact vibration	II	15.22	0.5	0.8	0.33	2.009	IIclass：2.009

Take code 02 as an example

$$c_m(\text{II}) = a b\, l_p t = 0.89$$

Because there is only one degree of severity in the code for 02

$$c_m(\text{II}) = c_r(\text{II}) = 18.766$$

The same code can be obtained in 02 $c_m(\text{I})$andc$_r(\text{I})$

Analysis of the key components of its obedience distribution function and the related parameters are shown in table 4.

Tab.4 The gear key components reliability model and related parameter list

symbol	Part Name	distribution form	Distributed parameter estimates
01	Front support	exponent distribution	λ=4.28×10-4 t=0.33
02	needle bearing	Weibull distribution	λ=2.74×10-3 a_1=2.25 t=0.33
03	Front boom	exponent distribution	λ=3.89×10-4 t=0.33

When product failure distribution obey exponential distribution[1,9,10]：

$$S = a.b.l_p.t.l e^{-lt} \qquad (3)$$

When product failure to obey weibull distribution[1,9,11]：

$$S = a.b.l_p.t.(1\text{-}e^{-(lt)^{a1}}) \qquad (4)$$

The key respectively of the needle roller bearing and before twisting the arms: S_1=3.53×10-11，S_2=2.138×10-8，S_3=7.81×10-10。The needle roller bearing under the condition of the harm degree I for key degrees $S_2(\text{I}) = 2.611\times10^{-9}$，In the case of hazard degree II for key degrees

$$S_2(\text{II}) = 1.877\times10^{-8}$$

So the key to

$$\text{S}_{总} = \text{S}_2(\text{I}) + \text{S}_2(\text{II}) = 2.1383\times10^{-8}$$

Comparison of the above can see clearly the key components of the size. According to the size of the key components of the, determine the harm degree of various key components, determine the relative importance of each key components.

Conclusions

The reliability of the electric aircraft depends largely on the key system and the key parts of the plane. Key components of the key degree depend on the hazard degree and failure probability of the component itself. Parts of the higher its key the greater the harm degree and its key the greater the degree of the failure probability is higher. This paper uses reliability model. Article mainly to the exponential distribution and weibull distribution reliability model, on this basis, respectively for the two system FMEA analysis it is concluded that the key components of this system. Again on the basis of the FMEA analysis of key components is analyzed, the key to calculate the various key components degree, determine the harm degree of various key components, determine the relative importance of each key components.

Believe that through the reliability analysis of two-seat electric aircraft as an example, there will be more comprehensive knowledge of electric aircraft. And, it will play a role in designing and improving.

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