Security Analysis and Preventive Measures of EWIS

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Abstract. In the field of airborne electrical equipment safety, the major concern has been focused on the reliability of the equipment, and the long-term neglect of the connection of each of the airborne electrical equipment cable failure. In order to reduce the probability of wire fault effectively, separate it from the airborne electrical equipment system for research. Firstly, starting from the basic problem of the security of EWIS (Electrical Wiring Interconnection System), the steps of the quantitative analysis of the EWIS fault are given. Secondly, based on the analysis of the failure mechanism of the aviation wire, the advantages and disadvantages of different detection techniques are compared. Finally, the scheme of improving EWIS fault detection ability for the new and old aircraft with different maintenance modes is presented.

Introduction

After more than ten years of military and civilian aircraft, the wires, which are deep in the body, can produce cracks and wear. This failure was once thought to have little effect, but not enough attention for a long time, but this kind of fault can be in a common plane, there are hundreds of thousands of thousands, and difficult to detect. As a result, the line fault is one of the most common faults in the aviation electrical system, and its actual performance is different. There is the instability of the instrument, the operation of the machine is not working, the signal is not normal. In fact, once the cable failure, the consequences may be very serious, even fatal.

In the quantitative analysis of the safety and reliability of the aircraft, the failure of the wire is not considered. The reliability of the wire is mainly used to explain the connection between the components and components. FAA (Federal Aviation Administration) gradually realized the lead failure damage to flight safety; put forward the “EWIS (Electrical Wiring Interconnection System)” concept. For the research of EWIS security, it is necessary to make clear the analysis steps and the failure mechanism.

Research Methods of EWIS Security Analysis

EWIS Security Issues

The section headings are in boldface capital and lowercase letters. Second level headings are typed as part of the succeeding paragraph (like the subsection heading of this paragraph).

Because of the wide variety and large usage of the airborne equipment, the reliability of the wire is very complicated. Therefore, at present, there is not a kind of aircraft in the world, which will be implemented in the design of the EWIS security as a design input system to the entire development process.
Under the premise of considering the fault of the wire, the wire fault should be mainly solved in the quantitative analysis of EWIS safety:

(1) Safety analysis method and model for the fault of wire;
(2) The factors influencing the failure rate of the conductor and the influence mode, and the degree of influence and the relationship between the failure rate of the wire and the failure mode of the conductor;
(3) The basic failure rate data for a unit length conductor in a predetermined condition;
(4) The calculation model of conductor failure rate in multi-state.

**EWIS Security Quantitative Analysis Steps**

EWIS is a bridge to transmit energy and information between the parts, equipment and systems, the energy transfer and the different information will make the harm of wires is different, so the wire safety analysis must be combined with the service system (or equipment) safety analysis. The quantitative analysis can be divided into the following steps:

Step1: Isolated wire from components, equipment and systems, and according to the system functional decomposition and wire transmission of energy and information, to define the wires, and integrate them into the functional tree of the whole system;

Step2: The wire fault is regarded as an independent fault source. According to the logic decomposition of the system function, the path of the top event of the fault tree is determined;

Step3: The wire breakdown fault tree into the failure mode and effect analysis, and according to each bundle conductor layout, environment, specification, analysis of lead failure, determine the reliability of the data wire project safety analysis required;

Step4: Basic wire failure rate determined under various influencing factors, the main source of wire based failure rate data has three kinds, namely similar reliability data history of flight data, reliability test data, industry standard or related research reports;

Step5: To establish the method of calculating the failure rate of the conductor and the existing environment change, and to calculate the fault data of the actual conductor under various fault modes;

Step6: The actual fault data of wires are incorporated into the corresponding failure mode and effect analysis, and into the fault tree, to calculate the probability of the top event of the fault tree.

**EWIS Fault Analysis**

**Cause of Fault**

![Figure 1. Cause of fault.](image)
There are many kinds of fault forms of aviation EWIS wire, and the reason is the result of many factors [1]. As shown in Figure 1, the failure of the cable conductor is usually caused by the working environment.

**Fault Type**

According to the failure mechanism and the different expression patterns, the wire faults in EWIS can be divided into three types: arc, breakdown and aging. With the deepening of aging, the probability of arc and breakdown will increase rapidly. Arc and breakdown may also be the final result of aging.

![Figure 2. Fault type.](image)

**Arc**

In the aviation EWIS, no matter what kind of arc, the circuit will delay the use of electrical equipment, and easy to damage caused by high temperature insulation materials [2].

![Figure 3. Swissair flight 111 fatal arc.](image)

(1) Open circuit arc fault, began to separate motion in contact, contact pressure between them will be reduced, the contact area is reduced, the current density at the contact point is gradually increased, and the contact resistance and contact heat increases. If the discharge is stable, the breaking arc is generated.
(2) A vacuum arc is generated when the voltage between the two electrodes of the vacuum or the gas gap breaks down the vacuum or gas.

(3) When the cable plug of the airborne electrical equipment is connected to the voltage source, the electric arc discharge will occur before the two contacts are closed.

(4) The spark discharge can cause the shock wave with large pressure jump, thus the spark discharge to the arc discharge.

In extreme cases, an electric arc can cause a fire that could lead to a fatal aviation accident. For example, in September 2, 1998, the Swiss Airlines flight 111 was caused by a fatal arc. Therefore, we must always pay attention to the arc of the aircraft line.

**Breakdown**

The fundamental reason for the breakdown of the aviation EWIS wire is the failure of its insulation strength [3]. Breakdown can be divided into the following three situations:

1. External damage and mechanical damage and deformation caused by tension cable wiring, installation or manufacturing process of the bump, sprain will remain hidden;
2. Accident injury: if the ground or short circuit occurs, then the surface damage is not serious, but after a certain running time there may be the possibility of breakdown;
3. Protective layer failure: cable lead, lead, hemp skin skin steel armor has a lifespan, in bad condition, lead steel armor will be corrosion, hemp skin will fall off, resulting in the breakdown of the insulation layer and lose protection.

**Aging**

The most common failure of aviation EWIS wire is the aging of insulation. The aging speed of the cable is closely related to the conditions of use. When the external environment is bad, the aging time will be significantly shortened. Typical cable aging: thermal aging, mechanical aging, voltage aging, etc. [4].

1. Thermal aging refers to the chemical structure of insulating medium changes in the role of heat, the performance of the insulation performance of the decline, the essence is the insulation material under the influence of the chemical changes. It is easy to produce redox reaction in the long time of thermal insulation; large molecules are broken down into small molecules, resulting in the production of electrical treeing in the polymer, leading to the decline in insulation performance, the breakdown field strength decreases with the increase of the voltage time, leading to polymer insulation breakdown.

2. Mechanical aging is the aging of solid insulation systems subjected to various mechanical stresses. The insulation aging is mainly subjected to external mechanical damage, deformation, tension wiring laying or manufacturing process of the bump, sprain, the micro cracks. With the slow action of the force of the crack, and even to increase the phenomenon of partial discharge, the insulation performance of serious damage.

3. The cause of electrical aging is the long-term effect of electric field. Electrical aging principle is more complex, its appearance is not only simple physical or chemical action, but these results together complex functions, usually adopt the "performance of the intrinsic breakdown strength" to represent strong electric insulation resistance.

**EWIS Detection Technology**

The maintenance strategy of aviation equipment can be divided into three kinds: after maintenance, regular maintenance and condition based maintenance. The corresponding EWIS detection techniques are manual detection, program control detection and detection based on PHM (fault prediction and health management) technology.
Manual Detection

The manual detection of EWIS cable is a traditional physical current detection method. Manual detection is to detect the wire, the wire at both ends of a certain voltage, and then measure the current in the wire. In this process, there is a sensitive ammeter and the wire series, through the current meter to show the size of the current to determine the pros and cons of the wire. When the ammeter current is zero or very weak, it can be considered that there is an open circuit fault in EWIS. However, the manual detection of the main circuit can only detect the fault of the wire, and the whole process requires maintenance personnel to participate in the detection of low efficiency, heavy workload [5]. Therefore, the manual detection is often used in the case of after maintenance, that is, there is a fault in a certain range of EWIS, and the Ohm’s law is used to measure the disconnection of each section, to find out the specific disconnection position.

Program Control Detection

Aviation EWIS program control detection is divided into functional control detection and node control detection. They are mainly to judge whether or not the insulation performance of the conducting wire is good, and it is usually combined with the periodic inspection of the airborne electrical equipment.

The main function of the EWIS is to detect the specific function of the network, which will have a number of wires in the network as a whole. Then, the function of the network is tested by the method of program control. Under normal circumstances, when the input of the circuit network is in accordance with a predetermined condition, the electrical equipment in the circuit should have the corresponding output. If the input and output meet the design requirements of the circuit network, it is considered that the network is in good condition, otherwise, it is considered that the network is faulty and needs further investigation.

The detection of node control is based on the detection of EWIS local circuits with complex functions. Before the test, the circuit diagram is analyzed, and then the scientific detection sequence is determined according to the testability theory.

PHM Technology

Aviation EWIS is an organic component of the whole aircraft. The state monitoring can be incorporated into the PHM system of airborne equipment, the most prominent advantage of PHM system is the ability of fault prediction, which makes it possible to maintain the situation based on PHM technology. Usually the EWIS part of the PHM system can be composed of seven parts [6].
(1) Data acquisition and transmission, the part of the use of sensors to collect the relevant parameters of the EWIS information, data conversion and data transfer functions, to provide basic data for the PHM system.

(2) Data processing, this part from sensors and other data processing module and data signal, and the format of data processing into state monitoring, health assessment and fault prediction of subsequent processing requirements of parts.

(3) State monitoring module, which receives data from sensors, data processing and other state monitoring modules. Its main function is to compare these data with predetermined failure criteria to monitor the current state of EWIS. According to the predetermined parameters, the module provides fault alarm.

(4) Health assessment, which receives data from different state monitoring modules and other health assessment modules. The main purpose is to evaluate the health status of EWIS, and generate the fault diagnosis record and determine the probability of failure. Fault diagnosis should be based on a variety of health history data, working conditions and maintenance history data.

(5) Fault prediction, which can be used to make full use of the data of the above parts, which can be used to evaluate and predict the future health status of the monitored EWIS, including the remaining life and so on.

(6) Automated decision-making, which accepts data from state monitoring, health assessment and failure prediction. Its main function is to produce replacement, maintenance activities and other recommendations. EWIS can be taken before the failure to take appropriate measures to achieve the ability of PHM system management, to determine the scientific and reasonable maintenance time.

(7) Interface, which mainly includes the man-machine interface and the computer interface, and realizes the human-computer interaction between the maintenance personnel and the PHM system.

**Detection Technology Improvement Program**

The optimization of the EWIS detection scheme should be combined with the specific situation of the carrier, and the maintenance mode and the condition of the equipment should be considered.
Regular Inspection of the Old Aircraft

For the aircraft in service, the maintenance support mode is mainly based on the reliability centered periodic preventive maintenance. For the aviation EWIS, the cycle should be reasonably determined according to its reliability distribution characteristics. Although the cycle time is too short, it can reduce the maintenance workload, but also lead to a substantial increase in preventive maintenance workload. Although the cycle time is too long, it can reduce the workload of preventive maintenance, but the increase of the failure will lead to a dramatic increase in the number of repair work. At the same time, once the fault occurs, the light will affect the implementation of the normal flight; heavy may cause serious flight accidents. A scientific and reasonable cycle should minimize the total amount of preventive maintenance and repair maintenance, and reduce the probability of failure to an acceptable range. In general, exponential distribution in a EWIS under the condition of the wire cable life [7]; for various environmental stress distribution, no "memory" and the failure rate and utilization index, to determine the actual cable failure rate. Combined with the theory of reliability, the fault probability of the conductor is calculated, and the maintenance cycle is determined by two kinds of maintenance workload, the loss after fault and the weighted average.

Old Aircraft Increased PHM System

Compared with after maintenance and regular maintenance, condition based maintenance has great advantages, but it is necessary to consider all the problems at the beginning of design. For the active aircraft EWIS, by using the existing flight data and the installation of PHM sensors, it can have a certain degree of condition based maintenance.

The flight parameters include the aircraft attitude information, the communication data, the engine running state, the aircraft operating state data and so on. So in the current ground EWIS maintenance process, through the reasonable application of flight data, considering the data sampling rate, making full use of the existing flight data to determine whether the EWIS has fault or fault trend measures such as rate and data transmission, realizing to provide timely, accurate and abundant fault information for maintenance, so as to effectively prevent failure. This is a better solution to the application of PHM in active aircraft.

The military aircraft in the design did not take into account the prediction function of EWIS fault, the flight data to monitoring electric circuit of voltage and current, temperature and other related parameters, which is difficult to model and analyze fault information. Therefore, it is necessary to load the PHM sensor for the key nodes of the EWIS to collect and process the fault data. This avoids the PHM system on the whole aircraft, but also has the following problems [8]:

(1) Plane as a complete system, install any components in the machine are required after the demonstration and strict test, the PHM sensor volume, weight and have a great impact on the aircraft will be placed in bearing and pneumatic layout.

(2) Loading PHM sensor arrangement. The number and location of sensors have a great influence on the recognition accuracy of EWIS parameters. In general, the more sensors placed in the component, the more detailed the EWIS fault information, the better the accuracy of fault identification. However, the number of sensors is often limited by the cable arrangement, electromagnetic interference and the health status of the components due to the fact that there is no position in advance. Therefore, in order to ensure the realization of the function of the system, it is necessary to study the optimal layout of the sensor.

(3) Loading PHM sensor communication. There are many problems such as complicated cable connection and inconvenient installation and application. The application of wireless sensor network technology in the data transmission of PHM system, which is easy to install, not only can save a lot of cable connection, but also conducive to the optimal deployment of PHM sensors. However, it is necessary to consider the influence of electromagnetic interference on the reliability of data transmission in the complex electromagnetic environment.
New aircraft PHM

For the newly developed aircraft, the EWIS characteristic parameters should be considered as much as possible. These parameters refer to the performance parameters such as current, voltage, resistance to monitor the health status of the cable and electronic products. At the same time, by monitoring the environmental temperature, humidity, vibration and other parameters, and combining the damage accumulation model to predict the remaining life of the product to monitor the health status of EWIS wire and electronic products.

In addition, according to the actual monitoring of EWIS failure mechanism and model, in the manufacturing process and process the same made out of the same product, assumed to be monitoring EWIS with the special sample has the same performance and status, they work in the same environmental conditions, therefore, the sample can be made EWIS health monitoring characterization. As a result of the special sample has a shortened life expectancy in accordance with the known proportion and before the failure to monitor EWIS, and play the role of "fuse". If a series of such products are produced by varying the "acceleration" ratio, as in the EWIS, a "fault gauge" is built to predict the remaining life of the actual monitored EWIS.

In the case of a particular failure mechanism, if the relationship between the life of EWIS and the parameter (such as environmental conditions, working conditions, geometric dimensions, materials, etc.) is known, it can be used to predict the damage of the product by monitoring the working characteristic parameters and environmental parameters. And the residual life can be predicted.

Summary

Separate the EWIS from the electrical system for individual study. EWIS can further clarify the safety analysis method, and can be divided into three types of aviation wire fault: arc, breakdown, and aging. In the EWIS detection technology, manual detection due to the heavy workload, generally applicable to maintenance; program control testing, often combined with airborne equipment electrical inspection of road maintenance; PHM technology can monitor the health status of EWIS, can realize the condition based maintenance of aerospace wire. For better prevention of different EWIS fault plane, should take the following measures: for old aircraft inspection, should be integrated into the lead level of reliability and maintaining the workload, failure consequences and other factors, determine the scientific inspection cycle; for the case of installing PHM system for the old aircraft, we should start from the flight data, increasing sensors, the information transmission and so on. For the early design of the new aircraft PHM system, it is necessary to monitor the health status of the EWIS and predict the remaining life based on the measurement of the internal and external parameters of the EWIS and the simulation of the fault samples.

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