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SciVerse ScienceDirect
Procedia Engineering 17 (2011) 428 – 432
Procedia Engineering
www.elsevier.com/locate/procedia

The 2nd International Symposium on Aircraft Airworthiness (ISAA 2011)

Selection of Wiring Environment and Failure Rate Comparison Analysis in Aircraft Wiring Risk Assessment

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Abstract

There has been a greater understanding of the importance of EWIS in aircraft safety in recent years. The expert opinion, a formal pair comparison experiment is applied to acquire wiring failure rate data. The selection of wiring environment and failure rate comparison is critical in doing the pair comparison experiment. Combined with a certain aircraft model, this paper studies the principles to choose wiring environment and the methods of failure rate comparison for aircraft risk assessment.

Keywords: paired comparison, wiring environment, aircraft wiring failure.

1. Introduction

There has been a greater understanding of the importance of the Electrical wiring interconnect system (EWIS) in aircraft safety in recent years [1]. Accurate EWIS component failure rate data is the key points of the EWIS safety assessment. The failure rate of wiring and cables depends on its environment and properties, and we need to acquire the failure rate for different failure modes under different environmental and operational conditions. However, the wire failure data for the different environmental and operational conditions found on aircraft was sparse; therefore, a failure function could not be created based on only historical data. So, using expert opinion, a formal pair comparison experiment should be applied to the problem of wire failure.

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doi:10.1016/j.proeng.2011.10.051

FAA has started a project to develop the risk assessment tool of electrical wiring interconnection System [2]. This project includes the results of a paired comparison workshop in which expert judgment was elicited on the effects of wire environment on wire failure rate [3]. The ARJ21 and C919 large airplane project of China are now facing the same problem [4]. Therefore, we have studied a project to acquire the failure rate of the wiring.

The expert opinion, a formal pair comparison experiment should be applied to the problem of wire failure. The approach is as follows: firstly, develop a theoretically sound model for wire failure. Secondly, select an additional number of failure environments for a paired comparison, by using NEL model, the relative failure rate can be acquired. Then, obtain a single failure environment for which there exists significant exposure time and failure data, and get the correction factor of the relative failure rate to true failure rate.

So, the selection of failure environments for a paired comparison is very critical. This paper discusses the selection of failure environments and failure rate comparison of Wiring Environment. This paper includes three parts. First part introduces the project of the failure date of wiring. Second part analyzes series of the factors contributing to the aircraft wiring failure and the breakdown of the factors that were used for the following expert judgment experiment. The third part analyses the principles to choose wiring environment and the methods of failure rate comparison for aircraft risk assessment. The fourth part concludes the achievement of the paper.

2. The contributing factors

The following table1 are the factors contributing to a certain aircraft wiring failure and the breakdown of the factors that were used for the following expert judgment experiment. The factors and the breakdown of the factors listed in table1 are being defined according to specific situation of the certain aircraft.

There are some other factors also contributing to wiring failure to some extent, such as conductor coatings, derating using, distances between installation bearings. With the help of the wiring designers, these factors are deleted from the model because they are not the main factors.

3. The selection of wiring environments and failure rate comparison analysis

3.1. The selection of wiring environments

From table1, we know that there are 13 environmental factors contributing to wiring failures. So, there are 2^{13} kinds of wiring environments. We should choose 17 sample environments for experts to compare because it does not need so many environments, this selection is very crucial, because the expert comparison work is based on these environments.

The selection should be based on the following principles:

i. Firstly, the environment must be existed in realism.

ii. Secondly, the change between environment comparisons will be the more minimal the better.

iii. Finally, it must be encompass a wide variety set of wiring environments.

Table2 only shows two selected environments. All the 17 environments are acquired according to the specific environment that the wiring may be suffered on the certain aircraft. These environments were selected in consultation with experts not participating in the elicitation and the designers of the aircraft. These environments encompass a wide variety set of wiring environments, and are typical environments from the landing gear system, avionics electronic equipment bay, the upper and bottom of the fuselage, nacelle of the certain aircraft and so on.

Table 1. Environmental factors and categories contributing to Wire Failure

Category	Variables	Levels			
		1	2	3	4
Wire properties	Wire gauge	4/0-8awg	10-16awg	18-22awg	24-26awg
	Conductor type	Copper	High-Strength copper		
	Insulation type	XLETFE	Hybrid (PI/FP)		
	Splices	No	Environmental	Non-environmental	
Bundle properties	Bundle Size	Large(>1.25in)	Medium(0.5-1.25in)	Small(0.2-0.5in)	Very small (<0.2in)
	Bundle protection	Not protected (open)	Some level of protection	Protected metal conduit	
	Curvature of wire	Low(diameter>10X)	High(diameter<10X)		
	Bundle orientation	Horizontal/ vertical	Longitudinal		
Zonal properties	Operations/main traffic	Low	Moderate	High	
	Operation temperature/ Pressure	Benign (P & T Controlled): Pressure and Temperature are controlled	D2 (P & T not controlled): Pressure and Temperature are not controlled	D3(High T & Strong P, both not control)	
	Vibration	Low	Moderate	High	
	Exposure corrosive fluid	Yes	No		
	Exposure conducting fluid	Yes	No		

3.2. *Failure rate comparison analysis of wiring environment*

Fourteen wiring experts were brought together for one-day workshop in which the expert opinion elicitation took place. The experts were given an overview of how the wiring environments and the variables break points were determined and how a paired comparison was conducted. The experts were asked to compare the 17 sample environments, that is, to separately finish 136 comparison tables for both shorting and open failure modes of wiring.

The comparison work is to determine which environment is more severe, that is, which environment is easier to subject to failure. The comparison table is shown as table 2, where the difference factors are highlighted. The comparison result depends on the differences of contributing factor between the two environments. That only one contributing factor is different between the two environments is the most ideal situation, because the experts can make a quick and more accurate answer. However, the fact is, there are often two or even more contributing factors are different between the two environments, and these contributing factors are contributing oppositely. So, it is hard to define which environment is easier to subject to failure.

i. Zonal properties are the first category to be considered, then bundle properties, and wire properties are the last one.

There are three categories factors contributing to wiring failure, which include bundle properties, wire properties and zonal properties. Factors such as high vibration, uncontrolled temperature or pressures, exposure to corrosive fluid or conducting fluid directly make the environment more severe. Since the technology of wire industry is mature enough, wire properties, such as wire gauge, conductor type and insulation type has seldom mainly caused wiring open or shorting failure.

ii. For wiring open failure or shorting failure, some factors are contributing more than the others.

For the open failure, the importance ranking is vibration, splices and curvature of wire. These three factors are contributing more than the others.

For the shorting failure, the importance ranking is exposure to corrosive fluid or conducting fluid, temperature and pressure, bundle orientation. These factors are contributing more than the others.

That means, for example, when consider shorting failure, if one environment is explosive to conducting fluid and benign (Pressure and Temperature are controlled), and the other environment isn't explosive to conducting fluid and D2 (Pressure and Temperature are not controlled). According to the above analysis, the environment explosive to conducting fluid is more severe and easier to fail.

Table2 Comparison 1

Wring Environment 1	Wring Environment 2
Wire gauge: 24-26awg	Wire gauge: 18-22awg
Conductor type: High-Strength copper alloy	Conductor type: Copper
Insulation type: Hybrid (PI/FP) composite	Insulation type: XLETFE
Splices: No	Splices: No
Bundle Size: Medium	Bundle Size: Medium
Bundle protection: Protected metal conduit	Bundle protection: Protected metal conduit
Curvature of wire: Low(diameter>10X)	Curvature of wire: Low(diameter>10X)
Bundle orientation: Horizontal/ vertical	Bundle orientation :Horizontal/ vertical
Operations/main traffic: Medium	Operations/main traffic: Medium
temperature/Pressure: D2 (P & T not controlled):	temperature/Pressure: D2 (P & T not controlled):
Vibration: High	Vibration: High
Exposure corrosive fluid: No	Exposure corrosive fluid: No
Exposure conducting fluid: Yes	*Exposure conducting fluid: No*
Which one is more severe: Environment 1 or 2?	

The situation would be often more complex when comparing one environment to another. For example, the comparison between environment 1 and 3, there are 9 different factors during the 13 factors between the two. It is difficult to determine which one is severe, since the weighting value is hard to know. Experiences of experts obviously are important for doing this.

4. Conclusions

There has been a greater understanding of the importance of EWIS in aircraft safety in recent years. The expert opinion, a formal pair comparison experiment is applied to acquire wiring failure rate data. This paper gives the principles to choose wiring environment and the methods of failure rate comparison for aircraft risk assessment. The study of this paper is based on a certain type aircraft, which effectively advanced the work of wiring risk assessment.

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