STRUCTURAL DESIGN APPROACHES TO IMPROVE ENVIRONMENTAL WORTHINESS OF HUMIDITY, FUNGUS, AND SALT FOG FOR AIRBORNE EQUIPMENTS

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Abstract

Humidity, fungus and salt fog are the three main corrosive environmental factors that may lead to aircrafts' failures in their storage and maintenance. In order to protect airborne equipments from this kind of corrosion, the destructive effects these conditions caused to airborne equipments are analyzed; the structural design principles and approaches for airborne equipments are put forward with typical cases; lastly some environmental control technologies are also provided.

1 Introduction

Airborne Equipments, as indispensable parts of the aircraft systems, play an important role increasingly. As functional and maintenance systems, they are required in diversified mission, to improve performances of the aircraft and ensure air safety. However, in the current reference implementation, humidity, fungus and salt fog are the three main corrosive environmental factors that may lead to aircrafts' failures in their storage and maintenance. Severe climatic environment threatens the availability and reliability of airborne equipments, combing with the environments in which they are transported, storage and employed, therefore, some effective protection measures must be taken.

2 Effects and Interactions of Humidity, Fungus and Salt fog Condition

Humidity, fungus and salt fog are typical climate environments on the sea, which often coexist and interact[1-3] (Fig. 1). There are two main effects of humidity on products. On the one hand, humidity would play a role in adsorption, condensation, absorption, diffusion and respiration, as a physical medium in the damage of material. The result is that the moisture infilt rates into material, leading to deformation, stagnant water, etc. On the other hand, humidity, as an environmental factor of the chemical properties, would form water film on surface of the product after being absorbed, leading to chemical and electrochemical corrosion of metallic material. The metallic corrosion caused by salt fog is in light of electrochemical reaction, based on galvanic corrosion. In addition, the main corrosion medium in salt fog is chloridion, the hydration energy of which is small, easy to adsorbed on metal surface. Also, it is not difficult for chloridion to penetrate through the oxide layer on surface of metal, enter into metal material, replace the oxygen atom in oxide, and form chloride because of its minor radius, enhancing the generation of metal oxide. As a kind of conducting solution, salt fog can decrease the dielectric surface resistance when it deposit. If dielectric material absorbs salt brine, its volume resistance would decline. The damage of fungus to metal material is accomplished by changing surface chemical and electrochemical property of the metal surface in nature. Furthermore, acidic material generated in metabolic process of fungus can corrode metal material. Many metalloid materials can provide carbon source and nutrition for the growth of fungus, which causes the failure of the material and production.

It is not easy for airborne equipments to damage by salt fog and fungus at the same time, since salt fog can restrain the growth of fungus. But the corrosion rate caused by salt fog is closely related with humidity. The corrosion rate is direct proportion to salinity in the condition that the percentage of salt is low, because the oxygen content in salt fog is increasing with the growth of its concentration, leading to the enhancement of depolarization and acceleration of corrosion. But, corrosion rate is inverse proportion to salinity after the concentration of salt exceeds a certain level, the reason is that the oxygen content in high concentration of salt fog would reduce. The corrosion caused by fungus is dependent on humidity, since almost all fungus only grows in appropriate humidity. Generally, the effective humidity for fungus growth is greater than or equal to 95% RH.

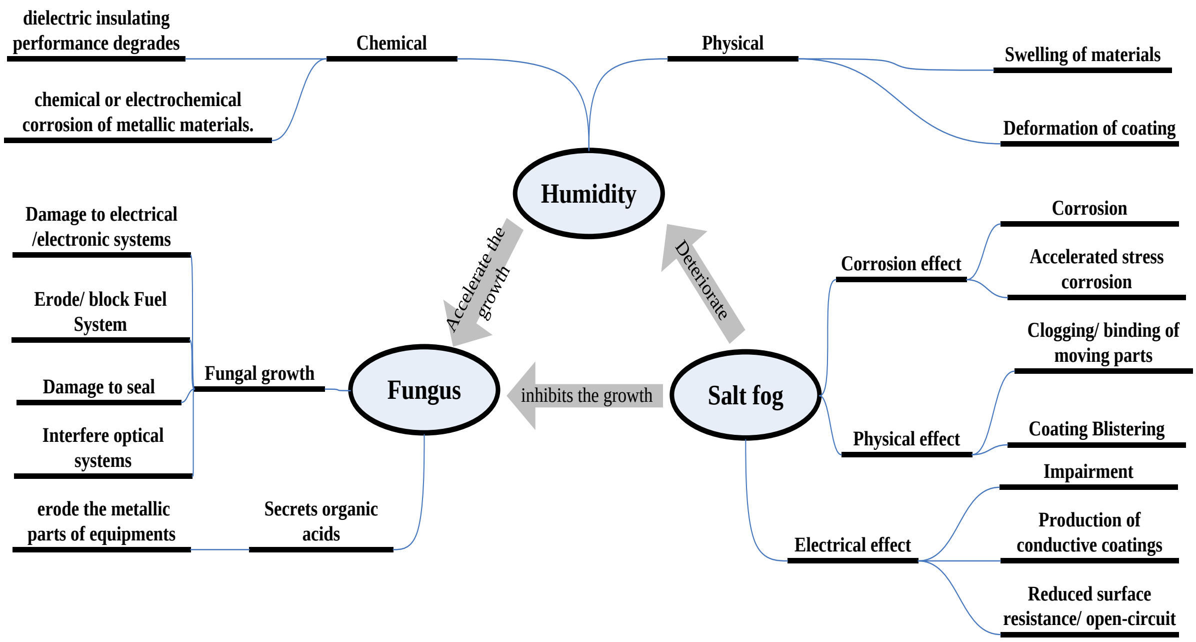


Fig. 1 Effects of the humidity, fungus and salt fog condition

3 Anti-corrosion Structural Design Approaches

The most effective measure to improve environmental worthiness of humidity, fungus, and salt fog for airborne equipments is to adopt proper structure design to improve its capability of preventing corrosion. Since metallic corrosion mainly concludes couple corrosion, crevice corrosion, intergranular corrosion, corrosive wear and stress corrosion, they must be avoided in structure design to the greatest extent. Some common measures to avoid the types of corrosion above are given in Tab.1.

3.1 General Structure Design

Tab.1 General Principles, Measures and Problems Solved of Structure Design

Design principles	**Measures**	**Function /Problems solved**
Avoid structures where stagnant water formed	Leave Drainage and vent in water and moisture retention space	Prevent micro-environment deterioration, which lead to salt fog corrosion or fungal growth on components much more severe than external environment
Avoid structural forms like spot welding or riveting	If structural forms like spot welding or riveting are inevitable, have the parts where crevice corrosion may occur coated or sealed.	Prevent crevice corrosion in humidity environment
Avoid the use of different types of metals in the same structure	If there are different metals in the same structure, have one plated with metal layer that is permitted to contact with the other metal, and pay attention to the electromagnetic compatibility requirements	Slow down electrochemical reaction intensified by the contact of different kinds of metals.
Avoid stress concentration caused by the structural form	Acute angle, as well as grooving and sudden changes in cross-section should be avoided in susceptible parts. And appropriate measures and techniques should be taken to eliminate internal stress	Prevent corrosion fatigue caused by salt fog
Size redundancy	thicken scantlings at the most prone to corrosion parts	Ensure safety even if corrosion is inevitably
Structured to ensure ease of repair and replacement for corrosive parts.	Ensure accessibility for repair at the most prone to corrosion parts	Regular maintenance will prevent the failure to a large extent

3.2 Sealed Structure Design

The damage caused by humidity, fungus and salt fog occurs only when they contact products surface directly. So, sealed structure design is the most favorable, which separates equipments from humidity, fungus and salt fog environments. Sealed structure design should follow principles below[4]:

● Characteristics of seals and relevant materials must be taken into account for the choices of sealing materials. The quality of materials has direct influence on reliability of equipments. Thus, the first step of sealed structure design is material selection.

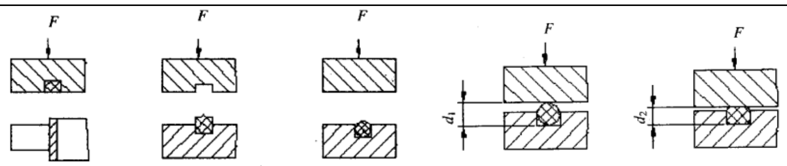
● It's as far as possible to select classical sealing techniques. The feasibility of new technique must be demonstrated as it can't be avoided.

● It is as far as possible to avoid the form of poor environments inside sealing chambers because of sealing. The purpose of sealed structure design against humidity, fungus, salt fog conditions is to control working conditions for components inside sealing chambers, but, things occasionally go athwart, sealing forms new poor conditions. For instance, the thermal conduction could reduce because of the thermal insulation of sealing chambers.

● High reliability is necessary for seal assemblies.

Generally, sealed structures can be classified into non-removable and removable ones. It is often to select non-removable sealed structures for nonperishable or one-off equipments, such as antenna pedestals, some waterproof connectors, ceramic filters, lifesaving equipments. Some rubber products, like rubber gasket, rubber rings, rubber sleeves, are usually used to achieve varying degrees of waterproof for removable waterproof sealed structures. However, severe corrosion would be caused once sealed structure design is improper. Structure design types, sealed techniques and relevant notices are showed in Tab.2.

Tab.2 Sealed Structure Design

Sealed structure	**Non-removable**	Used in the parts that do not need to repair or not easily damaged or one-off use.
	Assembly	
Closed Insulation Technology for electrical components	**Encapsulating**	Pour hot-melt resin and rubber to form complete isolated environment around electronic components.
	Packaging	Protect the components or parts by separate them into packages, which can significantly improve the ability of moisture-proof and insulation.
Notice	➢ Micro-climatic conditions caused by non-metallic materials of volatile compounds inside the equipment can lead to corrosion of zinc and cadmium plating, which result equipment failure. ➢ Once the gas-tight design fails, breathing effects caused Products damp and fit for fungus to grow. The larger the sealed container is the more serious breathing effects. So particular attention should be paid to the inspection work. ➢ Seal those parts that is sensitive to fungus or moisture into separate units as far as possible ➢ Only airtight sealed structure is valid in fungal growth environment.	

3.3 Sealing Materials

Many new types of solid macromolecule sealing materials are developed with the progress of science and technology, to solve various sealing problems, the techniques and performances of which are improved substantially. Several sealing materials are introduced as follows.

● Rubber

Rubber is the most common sealing material for electronic equipments. Rubber possesses some excellent performances, such as high elasticity, waterproof, airtight, high electrical resistivity, low density，which have been used most widely, even, sometimes is the indispensable material. The rubber suitable for sealing materials against the three environments must possesses some excellent performances, which includes high elasticity, low-compression permanent deformation, high oil- resistance, high water-resistance, fine anti- gas leakage, high damping, high corrosion and humidity resistance. The hardness and brittleness temperature of rubber selected shouldn't be too high. It has been found that the Shore hardness of sealing rubber should be less than 55, and brittleness temperature less than 50 ℃ .The environmental worthiness of rubber varies drastically for different type of one. It is necessary for the selection of type of sealing material to consider the operating environments, combing with performance and cost. Such rubber materials as Buna-N rubber, neoprene, pure rubber, fluoro rubber, silicon rubber, acrylic rubber, can be used as sealing materials.

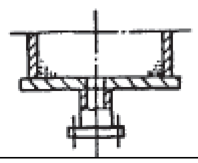
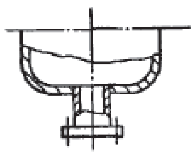
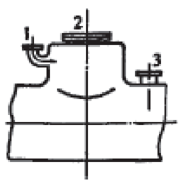
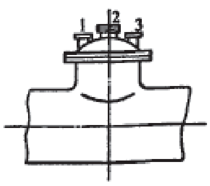
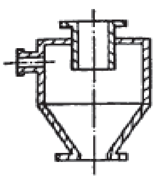
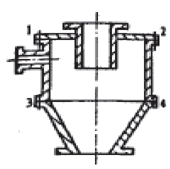
●Epoxy resin encapsulating compound

Epoxy resin encapsulating compound is a very important three proofings material because of its universality of use. It is mainly made of epoxy resin, plasticizer, padding, pigment, curing agent, accelerator, and other auxiliary materials, characteristics of which are heat-resisting, waterproof, high resistance, and high corrosion-resisting, dampproof, anti-mildew. But, it still has some defects, for instance, high contractibility, would bring stress concentration easily, and low vibration resistance, for which proper paddings are needed to improve performance in practice.

● Liquid sealing material

Liquid sealing material, also known as liquid gasket, is a type of sticky liquid material, which can form uniform, steady, continuous adhesion thin film, if it is filled into gap，providing high adhesion and thixotropy, coated on different patterns of joint surface. This material wouldn't cause metal skin corrosive. It has low binding force, but high cohesion strength, and, excellent metal monomolecular film, to achieve the purpose of airproof. liquid gasket possesses some excellent performances, including high gas tightness, preventing humidity from entering into gap of joint surface to cause corrosion effectively, strong oil and water proof, avoiding organic impurity into gap, and high insulating property, high shock resistance. In short liquid sealing material is commonly used in the field of anti-corrosion for electronic equipments.

4 Some Typical Cases about Structure Design

<table>
<tr><th rowspan="2">Parts</th><th rowspan="2">Problems</th><th colspan="2">Structure Design</th><th rowspan="2">Effects</th></tr>
<tr><th>Original Design</th><th>Improved Design</th></tr>
<tr><td>A certain type of airborne single computer</td><td>The LCD can’t normally operate, and much stagnant water was found in box after implementing alternating temperature humidity test. The conclusion is that stagnant water causes the failure of LCD.</td><td>Section bars are used in this computer, at the top and bottom of which closed boards are covered. There are no rubber sealing strip existed in the middle of cover boards and the box.</td><td>A vent is designed in the top and bottom cover boards to ameliorate the design of the box. Reduce the differential pressure inner and outer box under alternating temperature humidity condition to avoid the form of stagnant water.</td><td>No stagnant water is found in the box in the alternating temperature humidity test after the improved design adopted. This computer can operate in order in room temperature condition.</td></tr>
<tr><td>A type of antenna</td><td>The fixed pin fractured before long after used because of corrosion, leading to motion of parts, which caused water seepage failure in the antenna.</td><td>Brass is the prime metal material of antenna, in assembly of which steel fixed pins are used.</td><td>Replace steel fixed pins with stainless steel ones, the corrosion potential of which is equal to that of brass.</td><td>Avoid couple corrosion.</td></tr>
<tr><td rowspan="2">Soldering Structure</td><td rowspan="2">Crevice corrosion and stress corrosion occur.</td><td></td><td></td><td rowspan="2">Blind angle is avoided effectively to cut down crevice corrosion.</td></tr>
<tr><td></td><td></td></tr>
<tr><td rowspan="2">Damageable Structure</td><td rowspan="2">Local corrosion of the Good-sized component lead to complete scrap of large structures and big economic loss because of difficulty of repair.</td><td></td><td></td><td>Put corrodible parts(1,2,3) together properly which is convenient to repair and replace.</td></tr>
<tr><td></td><td></td><td>Apply assemble technology for entire structure in order to examine and repair easily due to corrosion.</td></tr>
</table>

5 Environmental Control Measures in Use and Maintenance

●Eliminate moisture through Drainage or air circulation.

➢ In order to prevent fungal growth on non-sealed product, temperature and humidity should be controlled and proper ventilation should be maintained;

➢ In order to reduce the corrosive atmosphere, local relative humidity should be controlled below 60%;

●Select proper packaging materials and storage condition. Avoid non-curable organic material, new paint surface or fresh wood to pack products.

●Fill Sealed packaging products with the inert gas around.

●Place desiccant in sealed equipments to reduce the inside humidity. Therefore, the corrosion process can be controlled to a minimum Even if the organic material will released HCl、H2S、SO2, organic acids and other corrosive gases.

6 Conclusion

The corrosion of airborne equipments is more and more severe with aircrafts widely used in more area，especially in subtropical zone and along the coast. This paper presents several types of proper measures by means of reasonable structure design to improve environmental worthiness of humidity, fungus, and salt fog for airborne equipments based on the analysis of interaction and corrosion effects of humidity, fungus, and salt fog conditions. In the mean time, environmental control should be taken into account in the process of use and maintenance.

7 References

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