МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

КАФЕДРА КОНСТРУКЦІЇ ЛІТАЛЬНИХ АПАРАТІВ

ДОПУСТИТИ ДО ЗАХИСТУ

Завідувач кафедри

д.т.н, професор

_______ Сергій ІГНАТОВИЧ

«__ »_________2021р.

ДИПЛОМНА РОБОТА

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ МАГІСТРА

ЗІ СПЕЦІАЛЬНОСТІ
«АВІАЦІЙНА ТА РАКЕТНО-КОСМІЧНА ТЕХНІКА»

Тема: «Методика втомних випробувань при аналізі побічних ефектів застосування антикорозійних профілактичних сполук»

Виконавець: ___________ Сянбао ДУН

Керівник: д.т.н., професор ___________ Михайло КАРУСКЕВИЧ

Охорона праці: к.т.н., доцент ___________ Вікторія КОВАЛЕНКО

Охорона навколишнього середовища:
д.т.н., професор ___________ Тамара ДУДАР

Нормоконтролер: к.т.н., доцент ___________ Сергій ХИЖНЯК

Київ 2021

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
DEPARTMENT OF AIRCRAFT DESIGN

PERMISSION TO DEFEND

The head of the Department

Dr. of .Sc., professor

__________ Sergiy IGNATOVICH

«___ »___________2021.

MASTER DEGREE THESIS
ON SPECIALITY
"AVIATION AND SPACE ROCKET TECHNOLOGY"

Topic: «Fatigue test procedure for corrosion preventive compounds side effects analysis»

Fulfilled by: ___________ **Xiangbiao DONG**

Supervisor:
Dr. of Sc., professor ___________ **Mykhailo KARUSKEVYCH**

Labor protection advisor:
Ph.D., associate professor ____________**Victoria KOVALENKO**

Environmental protection adviser:
Dr. of Sc., professor ____________ **Tamara DUDAR**

Standards Inspector _____________ **Sergiy KHIZHNYAK**

Kyiv 2021

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Факультет аерокосмічний

Кафедра конструкционных літальних апаратів

Освітній ступінь «Магістр».

Специальность 134 «Авіаційна та ракетно-космічна техника» Спеціалізації «Обладание повітряних суден»

ЗАТВЕРДЖУЮ
Завідувач кафедри
д.т.н., професор
__________ Сергій ІГНАТОВИЧ

«___» ___________2021 р.

ЗАВДАННЯ
на виконання дипломної роботи студента
СЯНБАО ДУН

1. Тема роботи **«Методика испытаний на усталость для анализа побочных эффектов антикоррозионных составов»**, затверджена наказом ректора від 08 жовтня 2021 року №2173/ст.

2. Термін виконання проекту: з 11.10. 2021р. по 31.12 2021 р.

3. Вихідні дані до проекту: Інформація стосовно проблеми корозії літаків та сучасних методів захисту, інформація стосовно можливості побічних ефектів застосування антикорозійних профілактичних сполук.

4. Зміст пояснювальної записки: Аналіз стану проблеми, порівняльний аналіз методів захисту від корозії, вибір типового зразка заклепкового з'єднання, розробка режимів навантажування, рекомендації стосовно виявлення негативних побічних ефектів застосування антикорозійних сполук.

5. Перелік обов'язкового графічного (ілюстративного) матеріалу: презентація PowerPoint з основними компонентами нового методу обґрунтування антикорозійних сполук.

6. Календарний план-графік

№ пор.	Завдання	Термін виконання	Відмітка про виконання
1	Аналіз стану проблеми	8.10.2021 – 12.10.2021	
2	Порівняльний аналіз методів захисту від корозії	13.10.2021 – 16.10.2021	
3	Вибір типового заклепкового з'єднання для проведення втомних випробувань	17.10.2021 – 22.10.2021	
4	Вибір режимів втомного навантажування	16.11.2021 – 30.11.2021	
5	Рекомендації стосовно визначення негативних побічних ефектів застосування антикорозійних сполук	30.11.2021-7.12.2021	
6	Вирішення задачі захисту охорони праці	7.12.2021-15.12.2021	
7	Вирішення задач захисту оточуючого середовища	15.12.2021-20.12.2021	

7. Консультанти з окремих розділів

Розділ	Консультанти	Дата, підпис	
		Завдання Видав	Завдання Прийняв
Охорона праці	к. біол. н., доцент Вікторія КОВАЛЕНКО		
Охорона навколишнього середовища	к. т. н, доцент Тамара ДУДАР		-:-

8. Дата видачі завдання: "11.10. 2021 р.

Керівник дипломної роботи _____________ Михайло КАРУСКЕВИЧ
Завдання прийняв до виконання _____________ Сянбао ДУН

NATIONAL AVIATION UNIVERSITY

Aerospace faculty

Department of aircraft design

Educational Degree "Master"

Specialty 134 «Aviation and space rocket technology»

Educational professional program «Aircraft equipment»

APPROVED BY
Head of department
Dr. of Sc., professor
___________ S.R. Ignatovich
«___» ____________2021 р.

TASK
For the master degree thesis
Dong Xiangbiao

1. Topic: **«Fatigue test procedure for corrosion preventive compounds side effects analysis »**, approved by the Rector's order №2173/ст. «8» 10. 2021 year.
2. Period of work execution: : 11.10. 2021р. - 31.12 2021.

3. Initial data: Unformation regarding the problems of Aircraft corrosion and methods against corrosion; information regarding side effects of corrosion preventive compounds.

4. Content: State-of-Art analysis, comparison of the methods against corrosion, selection of the typical riveted joints specimens for the tests, loading regimes development, recommendation of the test procedure for the negative side effects reveal.

5. Required material: PowerPOint presentation with main components of the proposed method for corrosion preventive compounds selection

6. Thesis schedule:

№	Task	Термін Виконання	Відмітка про виконання
1	State-of-Art analysis	8.10.2021 – 12.10.2021	
2	Comparison of the methods against aircraft corrosion	13.10.2021 – 16.10.2021	
3	Selection of the typical riveted joints specimens for the fatigue tests	17.10.2021 – 22.10.2021	
4	Fatigue loading regimes development	16.11.2021 – 30.11.2021	
5	Recommendation of the test procedure for the negative side effects reveal.	30.11.2021-7.12.2021	
6	Work on Labor protection problems	7.12.2021-15.12.2021	
7	Work on Environment protection problems	15.12.2021-20.12.2021	

7. Special chapter advisers

Chapter	Consultants	Date, signature	
		Task Issued	Task Received
Labor protection	PhD, associate professor Victoria KOVALENKO		
Environmental protection	PhD, associate professor Tamara DUDAR		

8. Date: 11.10. 2021 year.

Supervisor ______________ Mykhailo KARUSKEVICH
Student ______________ Xiangbiao DONG

ABSTRACT

Master degree thesis “Fatigue test procedure for corrosion preventive compounds side effects analysis”

71p., 41 fig., 4 tables, 21 references

Master's degree thesis "Improving aircraft fatigue characteristics by optimizing riveted joints"

89 pages, 78 figures, 2 tables, 19 references

This master's thesis is dedicated to studying the effects of the compounds used on aircraft fatigue when the aircraft is anti-corrosive

Computer-aided design CAD/CAE methods have been used, especially CATIA and ABAQUS.

The practical value of diploma work is to improve the reliability and service life of aviation structures by studying the side effects of anti-corrosion compounds.

The materials for the master's degree and diploma can be used in the education process of aviation industry and aviation major.

AIRCRAFT, CORROSION, FATIGUE, CORROSION PREVENTIVE COMPOUNDS, SIDE EFFECTS PREVENTION

РЕФЕРАТ

Магістерська робота «Процедура випробування на втому для аналізу побічних ефектів антикорозійних сполук»

71с., 41 рис., 4 табл., 21 посилання

Магістерська робота «Підвищення втомних характеристик літака шляхом оптимізації заклепкових з’єднань»

89 сторінок, 78 рисунків, 2 таблиці, 19 літератури

Ця магістерська робота присвячена вивченню впливу сполук, що використовуються на втому літака, коли літак є антикорозійним.

Використовувалися методи автоматизованого проектування CAD/CAE, особливо CATIA та ABAQUS.

Практична цінність дипломної роботи полягає у підвищенні надійності та терміну служби авіаційних конструкцій шляхом вивчення побічної дії антикорозійних складів.

Матеріали для отримання ступеня магістра та диплома можуть бути використані в процесі навчання авіаційної промисловості та авіаційної спеціальності.

ЛІТАКИ, КОРОЗІЯ, ВТОМА, ПРОФІЛАКТИКА КОРОЗІЇ, ПРОФІЛАКТИКА ПОБОЧІВ

ABBREVIATIONS

ICAO – International Civil Aviation Organization;

EASA – European Union Aviation Safety Agency;

FAA – Federal Aviation Administration;

FAR – Federal Aviation Regulations;

MP – Mechanical properties;

MC – Mechanical characteristics;

SE – Side Effects

CPC – Corrosion Preventive Compounds

CONTENT

INTRODUCTION

Airframe issues related to corrosion have been plagued by the aviation industry for decades. The metals that make up aircraft components are subject to many different forms of corrosion. This process is accelerated by many factors, including long-term exposure to industrial liquids, salt, and moisture. Other corrosive substances, or more internal problems, such as condensation formation and water leakage in toilets and kitchens. Failure to detect and treat certain forms of corrosion, such as stress corrosion cracking and corrosion fatigue, may lead to catastrophic failures.

Complicating the problems related to corrosion is the age factor. Of the total number of commercial aircraft in operation, about a quarter are more than 20 years old. As the aircraft ages, it will be repeatedly exposed to the environment that accelerates the effects of corrosion. Although some corrosion control measures have been taken to improve the safety of aging aircraft in operation, there is still a lot to learn and do.

To protect aviation constructional metals they are treated by the complex of methods: oxidizing, claddings, covering by resistant to the environment paints, etc.

Recently the additional protection being used is application of Corrosion Preventive Compounds (CPC). These materials are oil and inhibitors containing liquids. They are able to build protective films on the metals surface, to penetrate into the gaps, to displace water from the gaps between the sheets of aircraft skin.

At the same time the penetrating properties of CPC cause the problemthat has been found by some researches: the cases of the fatigue life reduction after the CPC application were observed. It is becomes evident that the selection of the CPC for the aircraft protection must be grounded on the complex of test procedures, first of all on the result of fatigue tests of the coupons covered by CPC.

The aim of the work is to develop the procedure of the fatigue test to reveal negative side effects of CPC application.

To gain this aim, the following **objectives** should be solved:

1. To analyze the current state of the aircraft corrosion problem.
2. To analyze methods of the aircraft protection against corrosion.
3. To determine the typical riveted coupon design for fatigue tests.

4. To determine the regimes of fatigue loading for fatigue test procedure to reveal negative side effects of CPC application.
5. To develop recommendation on the mandatory procedure for the negative side effects of CPC reveal.

The international standards CS25, FAR25 have been used during the work on presented Master's thesis.

The guide for the Master's work issued by the aircraft design department was used in all stages of the work on the diploma work.

PART 1. AIRCRAFT CORROSION PROBLEM

1.1 The trouble zones of the aircraft structure

As shown in Figure 1.1, a small amount of corrosion accumulates and a huge aircraft will be scrapped. The corrosion of an aircraft depends on a number of factors. Such as the protection conditions in the aircraft manufacturing process, maintenance during the service period, and the environment in which the aircraft is located. If we can find corrosion in the early stage of corrosion, it will be very necessary to take effective measures in the nearest repair or replacement.

Fig. 1.1 - Corroded and abandoned aircraft

The corrosion process requires special conditions to occur: presence of electrolyte and contact of dissimilar metals, thus the probability of the corrosion increases were the electrolyte is most probable and were the insulation between the metals are damaged or absent. Below the examples of most trouble zones in the aircraft primary structure are shown.

Battery compartment. It cannot be ignored that the battery compartment (Figure 1.2) is one of the most representative failure points on the aircraft, which is true on any type of aircraft. Although we ventilate, seal, and paint the battery box area, and we do our best, corrosion is unavoidable. This is due to the smoke generated by the overheating of the battery that we can hardly control. In general, the smoke inevitably diffuses to the internal structure, and the internal surface is not protected, so it is very easy to be corroded.

a)

b)

Fig.1.2 - Corrosion in the battery compartment of the Piper aircraft (a and b)

Kitchen. Kitchens are also places where corrosion often occurs. Behind toilets, sinks, and stoves, waste, food, and moisture can easily accumulate together, and corrosion often occurs in these places (Figure 1.3). The bilge area under the toilet and galley has a complex structure, but the regular maintenance of these areas is indeed very critical.

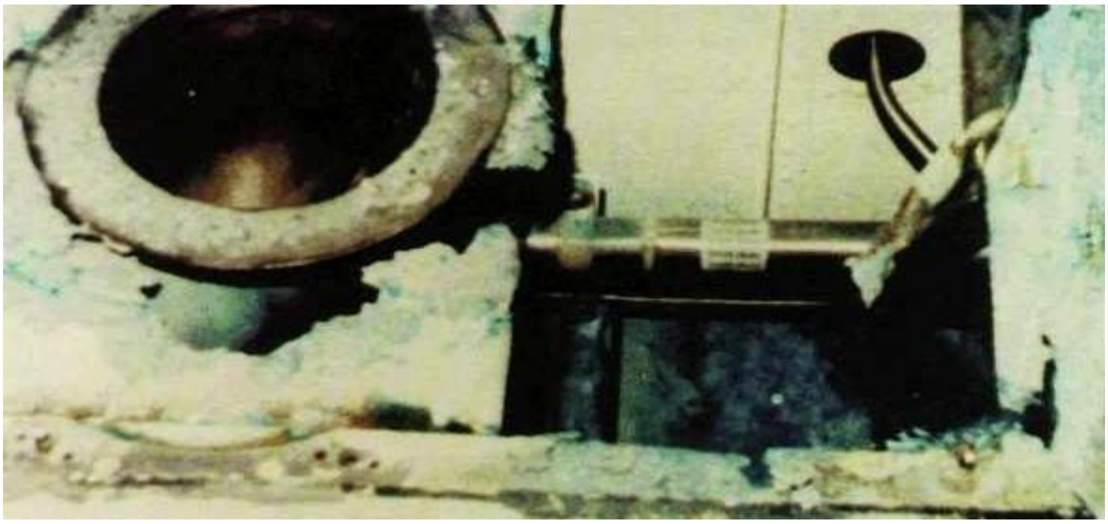


Fig. 1.3 - Typical damage to floors around toilets, buffets and kitchens

Aircraft bilge area. In the real situation, the bilge area of the aircraft is almost always the fault zone. The bilge area is a natural collection station for waste oil, hydraulic oil, water, dirt or debris in daily aircraft operations. Under normal circumstances, the oil will cover someone, which will cause the water to settle to the bottom area of the bilge area, but it is hidden. This is a concealed illusion and a potential corrosive cell.

Except for the bilge area, the water stagnation area or drainage area is a point of failure. The drain hole is located at the lower part of the aircraft because it facilitates the collection of liquid and the drainage of water. These drainage holes generally do not fail unless they are blocked, which is usually caused by debris or sealant, or when the aircraft is in an unleveled state.

Landing gear and wheel well area. The landing gear and wheel well areas are the places that suffer the most from the impact of air. These two areas of the aircraft are often in contact with soil, water, salt, and flying debris on the runway, which can easily cause mechanical damage to the protective coating and surface (Figure 1.4).

Fig. 1.4 - Landing Gear Wheel Door

Corrosion of graphite composites. Many alloys are used in aircraft manufacturing. When these alloys are in contact with graphite composite materials, they can cause permanent corrosion complications. Graphite/epoxy material is an excellent cathode, which provides good conditions for galvanic corrosion. When the external environment is suitable, such as in a high humidity or salt water environment, the epoxy/graphite composite material may become extremely reactive. At this time, we must apply a sealant between the metal/composite interface to prevent moisture from intruding and causing current erosion.

The front area of the aircraft engine. This place also often faces corrosion problems. Due to the continuous mechanical abrasion caused by dust, flying debris, dust and gravel on the runway, the protective coatings and finishes are hardly hit, and the metal is easily exposed to the natural environment. In addition, the radiator core and fins of the reciprocating engine are also very fragile.

Special electrical equipment. Corrosion not only occurs in the main structure of the aircraft, but also in special electrical equipment.

Fig. 1.5 – Electrical motor corrosion.

Spot welding skin. This part of the component is another highly sensitive area. Since moisture and other corrosive agents may stay in the metal plate layer, crevice corrosion will occur.

Fig. 1.6 – Fuselage bilge Corrosion

Rear pressure bulkhead. This place (fig.1.6) is especially worthy of attention.

Fig. 1.7 - Different corrosion patterns are expected in the pressure bulkhead area

Corrosion will eventually cause the skin to warp or the solder joints to bulge out, eventually leading to fracture.

There is usually liquid accumulation under the floor, which can cause severe corrosion damage.

Non-destructive testing methods, such as ultrasonic, eddy current and radiographic testing, they are usually used to detect corrosion.

Fig. 1.8 - Due to the high possibility of moisture accumulation, the longitudinal beams (stringers) of the fuselage were corroded

Air conditioning system and auxiliary flight control surface. Parts of the air conditioning system are susceptible to corrosion, The auxiliary flight control surface is also prone to corrosion, which was discovered during aircraft repairs, working under worms and high humidity environmental conditions.

Fig. 1.9 - The trim label of the aircraft horizontal stabilizer

Fig. 1.10 - Corrosion was found on the inner flap control link

Fig. 1.11 - Corrosion of the flap control link

1.2 The types of the corrosion.

All corrosion defects can be classified according to the nature of corrosion process, intensity of the damage, danger of the corrosion spot. Below the most widely happened types of the corrosion are described.

Exfoliation corrosion. It turns into a powdery white or gray deposit. This type of corrosion is because two different metals are in contact with each other in an electrolyte environment, which can be solved by detailed design, protective treatment, and special assembly techniques (metal sealing, electrical insulation).

The symptoms of exfoliation corrosion are spalling and loss of metal thickness. Problems caused by swelling and peeling of exposed grain ends due to machining.

Fig. 1.12 - Exfoliation corrosion

Pitting corrosion. Pitting corrosion is localized corrosion. Corrosion occurs in a small area on the metal surface, forming a cavity. Pitting corrosion is one of the most destructive forms of corrosion. The ratio of the deepest depth of the pitting coefficient. Deep pits are caused by corrosion divided by the average permeability calculated based on weight loss. Pitting corrosion is usually formed passively. Metals and alloys such as aluminum alloys, stainless steels and stainless alloys are found to be chemically or mechanically damaged when the ultra-thin passivation film (oxide film) is not re-passivated. The resulting pits can become wide and shallow or narrow and deep, which can quickly penetrate the wall thickness of the metal.

The specific shape of pitting corrosion can only be identified by metallography, where a cross-section of a sample with pits can determine the shape, size and penetration depth of the pit.

Fig.1.13 - Pitting corrosion: a- profiles of the pitting corrosion; b – surface of the metal damaged by the pitting corrosion

For defect-free "perfect" materials, pitting corrosion is caused by the environment (chemical), which may contain corrosive chemicals, such as chlorides. Chloride is particularly harmful to the passivation film (oxide), so pitting corrosion will start at the oxide fracture.

The environment may also establish a differential aeration tank (for example, water droplets on the steel surface), and pitting corrosion can start at the anode site (the center of the water droplet).

For a homogeneous environment, pitting corrosion is caused by materials that may contain inclusions (MnS is the main culprit for pitting corrosion in steel) or defects. In most cases, the environment and materials will lead to the formation of pits.

Environmental (chemical) and material (metallurgical) factors determine whether the existing pit can be re-passivated. Adequate aeration (supplying oxygen to the reaction site) can promote the formation of oxides, pitting the site so that the damaged passivation film (oxide) can be re-passivated or healed-the pits are re-passivated and will not occur Pitting. If the material contains a sufficient amount of alloying elements, such as Cr, Mo, Ti, W, N, etc., the existing pits can also be passivated again. These elements, especially Mo, can significantly increase the Cr enrichment in the oxide, thereby healing or repassivating the pits.

Filiform corrosion. It is a special form of corrosion that occurs under some thin coatings in the form of randomly distributed filamentous filaments. Filament corrosion is also called "base film corrosion" or "filament corrosion". Filamentous corrosion occurs on surfaces coated with a layer of organometallic films, which are usually 0.1 mm thick. The corrosive attack mode is characterized by the appearance of filaments emanating from one or more sources in semi-random directions. Filaments are thin tunnels composed of corrosion products that swell and rupture beneath the coating.

a)

b)

Fig.1.14 – Surface photo and scheme of the process

Filamentous corrosion can be visually identified without the use of a microscope. Filamentous corrosion was observed on the surfaces of steel, magnesium, and aluminum plated with thin coatings of tin, silver, gold, phosphate, enamel, and lacquer. Filament corrosion was also observed on the paper back aluminum foil.

Filament corrosion is a special case of crevice corrosion.

During the propagation process, water is supplied to the head of the filament due to the high concentration of ferrous ions dissolved on the surface of the steel substrate from the surrounding atmosphere through osmosis. Due to the low concentration of soluble salts (iron has precipitated as iron hydroxide), osmosis tends to remove water from the inactive tail.

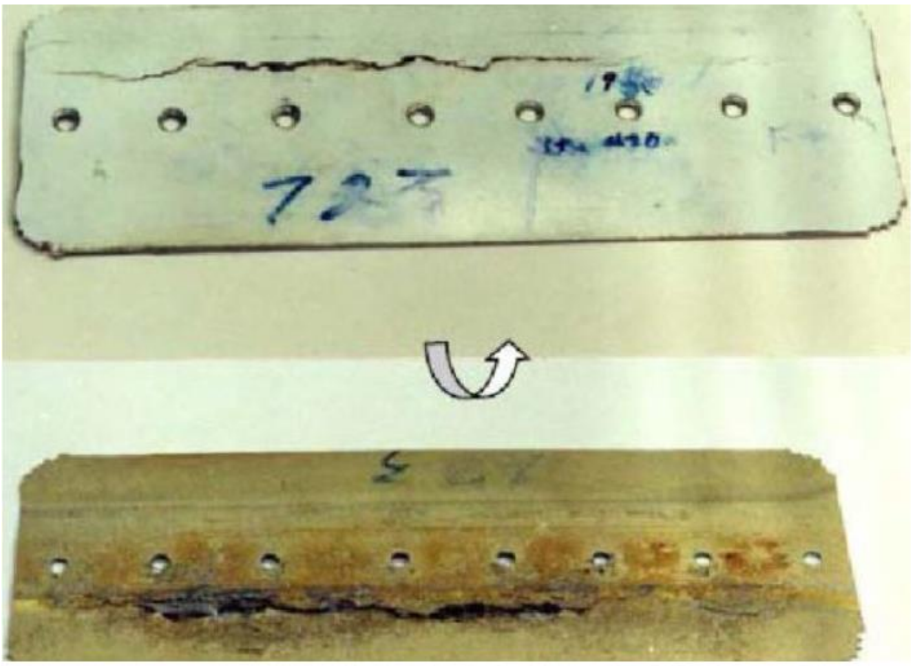
Filament corrosion or under-film corrosion can be prevented by the following methods: a) Relative humidity control; b) The use of brittle paint.

Crevice corrosion

The main symptom of crevice corrosion is severe local corrosion along adjacent surfaces. Corrosion caused by the penetration of oxygen and corrosive agents into the joint. Corrosion can be prevented by effectively sealing adjacent surfaces from corrosive substances.

Crevice corrosion is a kind of localized corrosion that occurs in the gap between two surfaces or on the inner metal surface. The gap is usually very narrow and does not provide loops. The corrosive fluid can flow in freely, but cannot flow out, thereby creating an environment where the corrosive fluid remains stagnant. Crevice corrosion is similar to the galvanic corrosion we discussed before, but there are some differences. In galvanic corrosion, the corrosion cell consists of two metals in a single environment. However, the corrosion unit in crevice corrosion consists of a single metal part exposed to multiple environments. Due to the different concentration of the compound in the fluid system, crevice corrosion will occur, thus forming an electrochemical cell.

a)



b)

Fig.1.15 - Crevice corrosion: a – general scheme of the process; b – process in the design

Intergranular corrosion. The microstructure of metals and alloys consists of crystal grains separated by grain boundaries.The intergranular corrosion corrosion is along the grain boundary or the local area close to the grain boundary, and most of the grains are basically unaffected. This form of corrosion is usually related to chemical segregation effects (impurities tend to be enriched in grain boundaries) or specific phases precipitated in grain boundaries. This kind of precipitation can produce areas with reduced corrosion resistance nearby.

Attacks are usually related to the segregation of specific elements or the formation of compounds in the boundary. Then by preferentially eroding the grain boundary phase or corrosion in the area near it, the area has lost the elements required for sufficient corrosion resistance-so that the grain boundary area becomes the anode relative to the rest of the surface. Corrosion usually proceeds along the narrow path of the grain boundary. In the case of severe grain boundary corrosion, the entire grain may fall off due to the complete deterioration of the grain boundary. In any case, the mechanical properties of the structure will be severely affected.

A typical example is the sensitization of stainless steel or weld corrosion. The chromium-rich grain boundary deposits will cause local depletion of Cr adjacent to these deposits, making these areas vulnerable to corrosion by certain electrolytes. Reheating the welded parts during multi-pass welding is a common cause of this problem. In austenitic stainless steels, titanium or niobium can react with carbon to form carbides in the heat-affected zone (HAZ), leading to a specific type of intergranular corrosion called knife line corrosion. These carbides accumulate near the weld bead and cannot diffuse due to the rapid cooling of the weld metal. The problem of knife line attacks can be corrected by reheating the weld metal to allow diffusion to occur.

Many aluminum-based alloys are prone to intergranular corrosion due to the presence of the anode phase of aluminum along the grain boundary or due to the copper depletion zone adjacent to the grain boundary in the copper-containing alloy. Alloys that have been extruded or otherwise processed in large quantities have a microstructure of elongated and flat grains and are particularly vulnerable to such damage.

The exfoliation corrosion discussed above is another form of intergranular corrosion associated with high-strength aluminum alloys. Alloys that have been extruded or otherwise processed in large quantities, have a microstructure of elongated and flat grains, and are particularly susceptible to such damage. The corrosion products formed along these grain boundaries exert pressure between the grains, and the final result is a lifting or floating effect. Damage usually starts at the end grains encountered in the machined edges, holes, or grooves, and then develops throughout the cross-section.

The photo below shows the microstructure of Type 304 stainless steel. The left picture shows the normalized structure, and the right picture shows the "sensitized" structure, which is prone to intergranular corrosion or intergranular stress corrosion cracking.

Fig. 1.16 - Intergranular corrosion

Exfoliation corrosion is a subcategory of intergranular corrosion. This type of erosion is caused by local differences in composition, such as coring commonly found in alloy castings. Grain boundary precipitation, especially chromium carbide in stainless steel, is a recognized and recognized intergranular corrosion mechanism. The precipitation of chromium carbide consumes the alloying element-chromium in the narrow band along the grain boundary, which makes the area anodic to the unaffected grains. If under tensile stress, the chromium-depleted zone becomes the preferential path for corrosion attack or crack propagation.

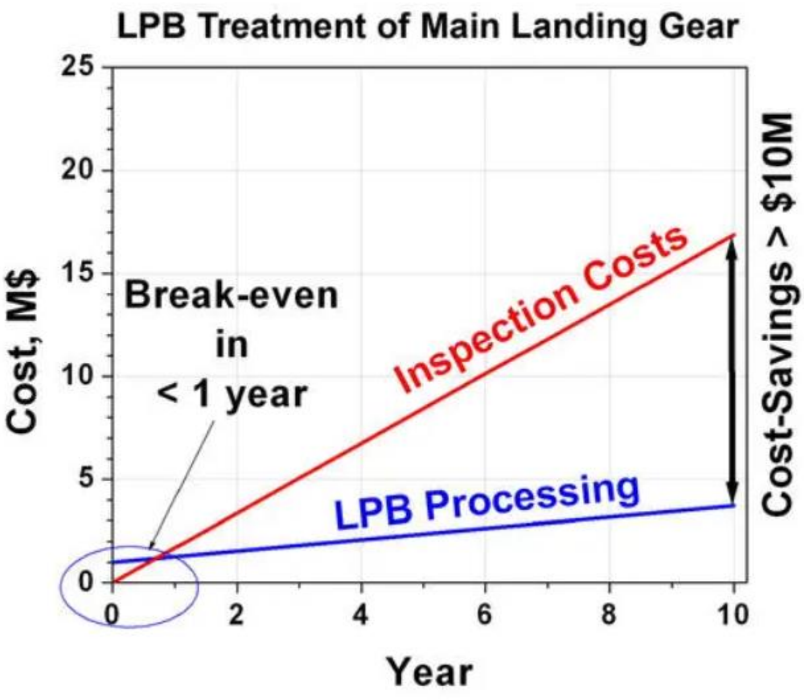
Fretting corrosion. Fretting corrosion (also known as abrasion corrosion or tribo-oxidation) can occur at the interface of two highly loaded surfaces that should not move relative to each other. However, vibration may cause the surfaces to rub together, leading to wear, called fretting. This friction removes the protective film on the metal surface. With continued friction, the metal particles sheared from the metal surface combine with oxygen to form metal oxides. As these oxides accumulate, they can be damaged due to abrasion and increased local stress. The most common examples of fretting corrosion are the smoking rivets on engine fairings and wing skins. This is a corrosion reaction that is not driven by the electrolyte. In fact, moisture may inhibit the reaction.

Fig. 1.17 - The result of fretting-caused by so-called blind rivets

Fretting fatigue failure will affect the blades at the contact surface of the aircraft engine rotor and the dovetail column of the blade. Through many studies, we have a clear understanding of the basic mechanisms involved in the mode II shear microcrack initiation, mode I crack propagation and final failure.

Stress Corrosion Cracking (SCC). Stress corrosion cracking (SCC) is caused by the simultaneous influence of tensile stress and a specific corrosive environment. The stress may be due to the applied load, residual stress in the manufacturing process, or a combination of the two.

a)



b)

Fig. 1.18 - Stress corrosion: a-The chemical process of stress corrosion;b- Stress corrosion of landing gear

Uniform corrosion or general corrosion, sometimes referred to as corrosion, is defined as a corrosive attack (degradation) that is more or less evenly distributed across the exposed surface of the metal (see figure below). Uniform corrosion also refers to corrosion that occurs at approximately the same rate on exposed metal surfaces.

Cast iron and steel will corrode uniformly when exposed to open atmosphere, soil and natural water, resulting in rusty appearance.

Microbiological corrosion. According to reports, microorganisms and their by-products in aircraft fuel tanks can cause serious damage to components such as organic coatings and weaken the structural properties of aluminum alloys. In the past, jet fuel pollutants included a variety of bacteria and fungi. The most common pollutant is the fungus Hormoconis resinae. However, the jet fuel community has changed due to changes in fuel composition, and now it is mainly bacterial pollutants.

Fig.1.19 - An example of a fuel filter that is contaminated due to microbial growth

Operators should pay attention to two facts when using fuel:

All hydrocarbon fuels have microbes living and growing in them, and these microbial sulfur-based by-products are released into the fuel.

All hydrocarbon fuels contain water, and when combined with sulfur-based by-products, sulfuric acid is released into the fuel.

1.3 Anti-corrosion method

Active corrosion protection. The purpose of active corrosion protection is to affect the reaction that occurs during the corrosion process. It can not only control the contents of the package and the corrosive agent, but also control the reaction itself to avoid corrosion. Examples of this method are the development of corrosion-resistant alloys and the addition of inhibitors to aggressive media.

Passive corrosion protection. In passive corrosion protection, damage is prevented by mechanically isolating the contents of the package from aggressive corrosive agents, for example by using protective layers, films or other coatings. However, this type of corrosion protection neither changes the general corrosion ability of the package content nor the corrosiveness of the corrosive agent, which is why this method is called passive corrosion protection. If the protective layer, film, etc. are damaged at any time, corrosion may occur in a short period of time.

Cathodic protection (application of sacrificial anode). The Galvanic series not only provides information on the correct selection of materials, but also information on the manufacture of cathodic protection, such as amphibious aircraft for operation in salt water.

When dissimilar metals are in electrical or physical contact (the former passes through the electrolyte), galvanic corrosion occurs. The process is similar to a simple DC battery, where the more active metal becomes the anode and corrodes, while the less active metal becomes the cathode and is protected. The electromotive force (EMF) series can be used to predict the metal that will corrode when it comes in contact with another metal based on whether the metal is a cathode or an anode relative to another metal.

Cathodic protection is an electrochemical method of corrosion control, in which the oxidation reaction in the galvanic cell is concentrated on the anode and inhibits the corrosion of the cathode in the same cell.

Cathodic protection was first developed by Sir Humphrey David in 1824 as a means of controlling corrosion on British naval vessels.

Cathodic protection can be achieved by two widely used methods:

By coupling a given structure (such as aluminum) to a more active metal (such as zinc or magnesium). This creates a galvanic cell in which the active metal acts as the anode and provides electron flux to the structure, which then becomes the cathode. The cathode is protected and the anode is gradually damaged, so it is called a sacrificial anode.

The second method involves applying a direct current between the inert anode and the structure to be protected. Due to the electron flow structure, it can be prevented from becoming an electron source (anode). In an impressed current system, the anode is buried, and a low-voltage direct current is applied between the anode and the cathode.

1.4 Corrosion Preventive Compounds.

Although progress has been made in the development of new structural materials and improvements in maintenance procedures, corrosion is still a widespread and costly problem in aircraft. As the service life of the aircraft increases, this problem becomes more obvious and dangerous.

Fig.1.20 - Protective coating produced by ARDROX (DINITROL)

Let us consider a more popular anti-corrosion compound, DINITROL AV-8.

AV-8 is a super-permeable water displacement, corrosion-inhibiting compound, leaving a non-sticky, firm film. Range of use: used to protect all commonly used aerospace metals and alloys.

DINITROL AV 8 can be used in all areas of the fuselage. In areas exposed to severe corrosive conditions, heavy-duty compound DINITROL AV 100D is required for the outer coating.

Cover movable parts before handling, unless the spray can be adequately controlled.

If this is not possible, it is recommended to use the soft wax DINITROL AV 25.

Application method: DINITROL AV 8 can be applied by dipping, brushing or spraying.

Can use DINITROL ACS-SYSTEM (airmix) or DINITROL airless application system for spraying.

The operating data of the spraying equipment can be found in the DINITROL Aviation Technical Manual.

Applicable regulations and certifications:

1. AIRBUS INDUSTRIE TN 007.10138, type I, level 3.
2. Boeing Material Specification BMS 3-23 F, Type II.
3. Bombardier CMS 565-06, Type I
4. MCDONNELL DOUGLAS DMS 2150. ATR
5. Fokker Aircraft BV
6. Gulfstream Aerospace Corporation.
7. Pilatus.
8. Piper.
9. Lockheed Martin Corporation.
10. Embraer.

Ardrox's widely used products are shown in Table 1.1.

Table 1.1 - Ardrox preventive compound

In some researches it was found that CPC applied to the riveted joints can lead to the reduction of the aircraft components fatigue life.

There are many types of CPC on the market, making the problem of CPC probable negative side effects very important, but the relevant public information is very limited.

At present, aircraft fatigue phenomena have been analyzed at different scale levels and different fatigue stages. Therefore, the same method should be used to analyze the side effects of CPC applications.

The interaction between CPCs and metal components must be discussed from the following aspects:

a) The influence of CPCs on the dislocation process in the initial stage of fatigue;

b) The influence of CPCs on crack growth;

c) The impact of CPC on the redistribution of forces in aircraft rivet components.

The proposed work mainly focuses on the influence of CPCs on on the force redistribution of aircraft rivet components.

Conclusion to part 1.

Despite the development of new constructional materials, improvement of aircraft manufacturing processes, implementation of new protective materials, corrosion remains crucial problem, influencing aircraft service life.

One of the trouble zones of the aircraft is a fuselage structure, especially bilge area, with is riveted structure.

Corrosion Preventive Compounds (CPC) are very much effective protection materials. The number and types of CPC and their types increase with a time. At the same time, the analysis of the literature devoted to the CPC application to the protection of riveted joints, reveals the probability of negative side effects, for example fatigue life.

The actuality of the problem causes the necessity of the presented work.

The aim of the work is to develop the procedure of the fatigue test to reveal negative side effects of CPC application.

To gain this aim, the following **objectives** should be solved:

6. To analyze the current state of the aircraft corrosion problem.
7. To analyze methods of the aircraft protection against corrosion.
8. To determine the typical riveted coupon design for fatigue tests.

9. To determine the regimes of fatigue loading for fatigue test procedure to reveal negative side effects of CPC application.

To develop recommendation on the mandatory procedure for the negative side effects of CPC reveal.

PART 2. FATIGUE TEST PROCEDURE FOR CORROSION PREVENTIVE COMPOUNDS SIDE EFFECTS ANALYSIS

The experience of the researches conducted by the Aircraft Design Department at National Aviation University as well as results of the researches carried out in some research centers of aviation industry proves the necessity of the fatigue tests of the aircraft coupons covered by the Corrosion Preventive Compounds.

2.1 Specimens for the investigation of the CPC negative side effects on the aircraft riveted joints.

Fatigue test use standard specimens and special coupons of the aircraft structure. Example of the standard specimens for fatigue test are shown in fig.2.1 – 2.2.

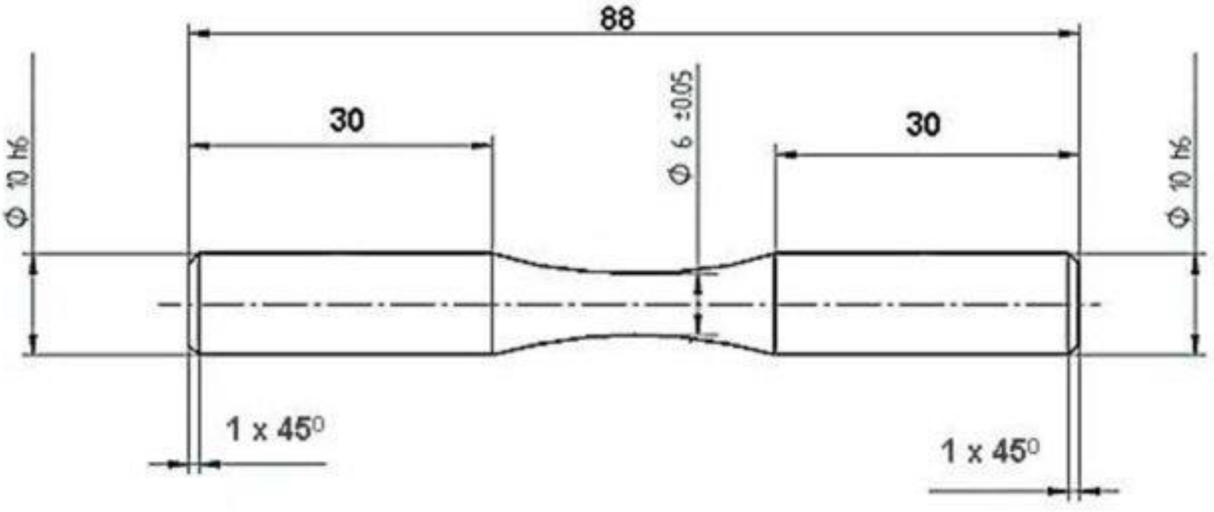


Fig. 2.1 - Typical circle-cross section sample for fatigue test according to ASTM E466 Standard

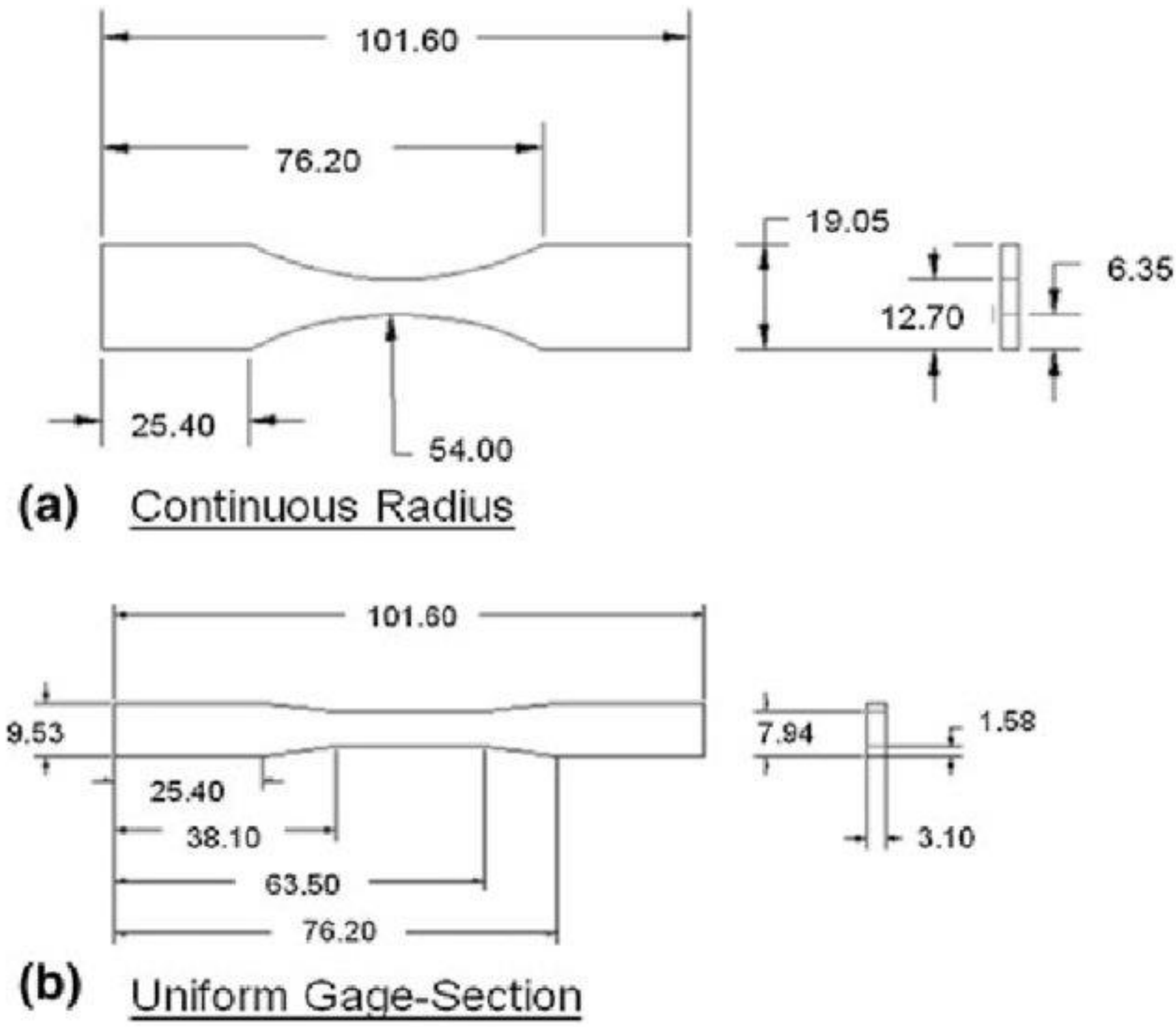


Fig.2.2 - ASTM flat fatigue specimen dimensions (mm): a - continuous radius, (b) uniform gage-section

Shown above standard specimens allow estimation of the mechanical properties of constructional materials, but are not able to answer the question on the possible negative side effects of the application of Corrosion Preventive Compounds. It is because the mentioned influence, as it was proposed by some researches, caused by the CPC influence on the friction between the components of riveted joints. Thus, the specimens for CPC influence analysis on fatigue life should reflect main design features of the structural element treated by the CPC.

The analysis of the aircraft riveted joints has allowed development of the specimen for fatigue test for CPC influence on the fatigue life.

Typical riveted joint specimen could be manufactured as follow (fig.2.3).

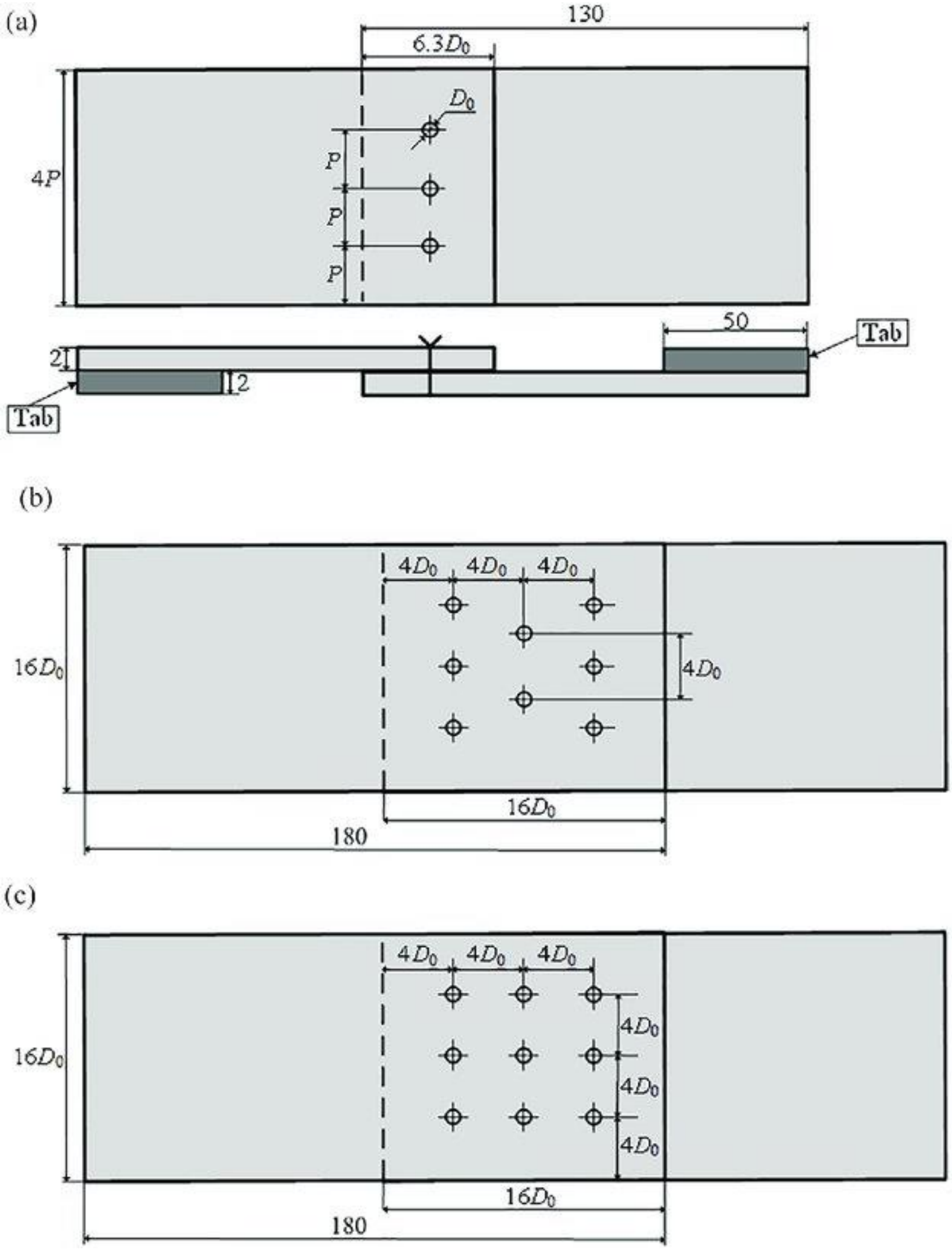


Fig.2.3 - Riveted specimens in fatigue tests: a - single-row riveted lap joint; b - triple-row riveted lap joint with staggered riveting; and c - triple-row riveted lap joint with in-line riveting

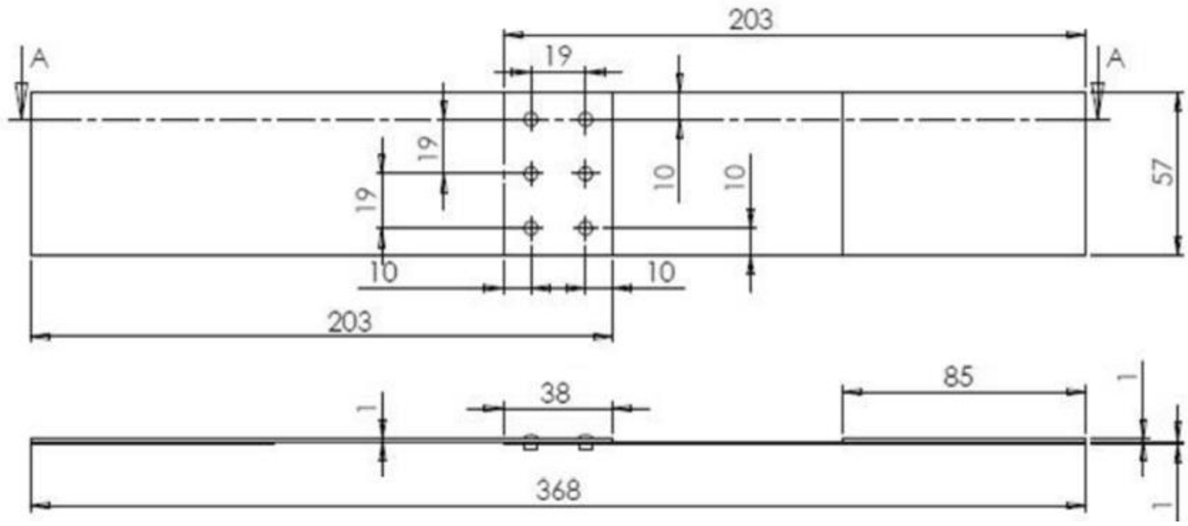


Fig.2.4 – Specimen of the riveted joint used in light aircraft

The selection of the specimen design has been done as a result of the analysis of design of the ANTONOV aircraft, presented in the National Aviation University (fig.2.5).

Fig.2.5 – Riveted joints in the design of An-24 fuselage

It should be mentioned also, that specimen must be manufactured from constructional alclad aluminum alloy D16AT or its analogue 2024T3 (table 2.1).

Table 2.1 – Mechanical properties of 2024T3

Density	2780 [kg/m^3]
Young's Modulus, E	73.1 [GPa]
Shear Modulus, G	28.0 [GPa]
Poison's Raito, ν	0.33
Ultimate Strength	483 [MPa]
Yield Strength	385 [MPa]
Shear Strength	283 [MPa]

Chemical composition of the selected material is presented in fig. 2.2.

Table 2.2 – Chemical composition of the 2024T3

Al	Ti	Zn	Cr	Si	Fe	Mn	Mg	Cu
Bal	0.15	0.06	0.02	0.07	0.18	0.58	1.67	4.82

Fatigue tests of the riveted joints coupons can be conducted with application of Hydro-pulsating fatigue test machine MUP-20 owned by Fatigue and Fracture Laboratory of Aircraft design department (fig.2.6).

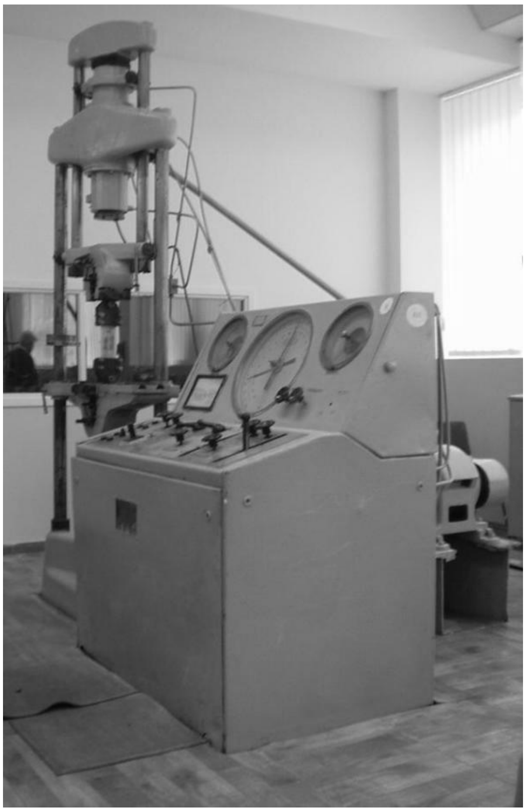


Fig. 2.6 – Fatigue test machine for the investigation negative side effects of CPC application

Selection of the test regime of loads is performed on the base of data related to the operational loads. Typical spectrum of loads is shown in fig. 2.6.

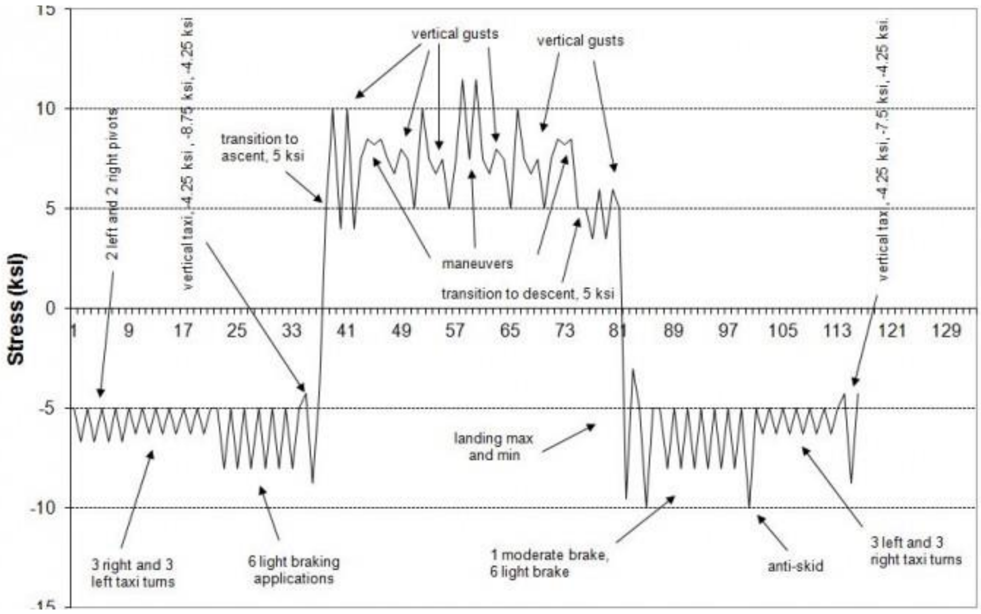


Fig.2.6 – Loads on aircraft wing in flight and on the ground

Aircraft is loaded in the flight and on the ground. The air loads are caused by the pressurization, maneuvers, wind gusts, motor vibration, flutter, buffeting, etc. The main source of the ground loads is unevenness of the aerodrome field, acceleration at the rolling, etc.

These loads can be applied only one time during the flight as well as many times. The loads can be classified also as regular and irregular.

Loads caused by the cycle Take off – Flight – Landing are regular, these loads cause about 60-80% of the fatigue damage during the aircraft service life.

Random loads are loads caused by the wing gusts, aerodrome unevenness, etc.
Loads applied to the aircraft differ by the shape of the loading cycle, stress ratio, sequence of loading, frequency.

The typical loads on aircraft, their amplitude and frequency are presented in table 2.3.

Table 2.3 - Loads on the aircraft during the 1000 hours of flight

Loads	Number of cycles per hour of flight	Frequency, cycles per min	Load coefficient
Wind gusts	(1-15) 10^5	0,3-5,0	0,05-0,70
Maneuvers	(1-5) 10^3	5-20 per flight	0,1-0,7
Pressure in cabin	(2-10)10^3	1 per flight	0,2-0,4
Aerodrome uneveness	(1-5) 10^5	1-5	0,05-0,70
Buffeting	(0,7-5) 10^7	2-20	0,01-0,05
Motor vibration	(0,7-3) 10^8	20-100	0,005-0,02
Acoustic vibration	(0,5-50) 10^9	100-10000	0,001-0,01

Taking into account that fuselage skin loaded mainly by the pressurization (fig.2.7) the correspondent stresses should be selected for the investigation of the negative side effects of the CPC application for the protection of riveted skin. For components made of aluminum alloys the maximum stress level is equal to 100,0 MPa.

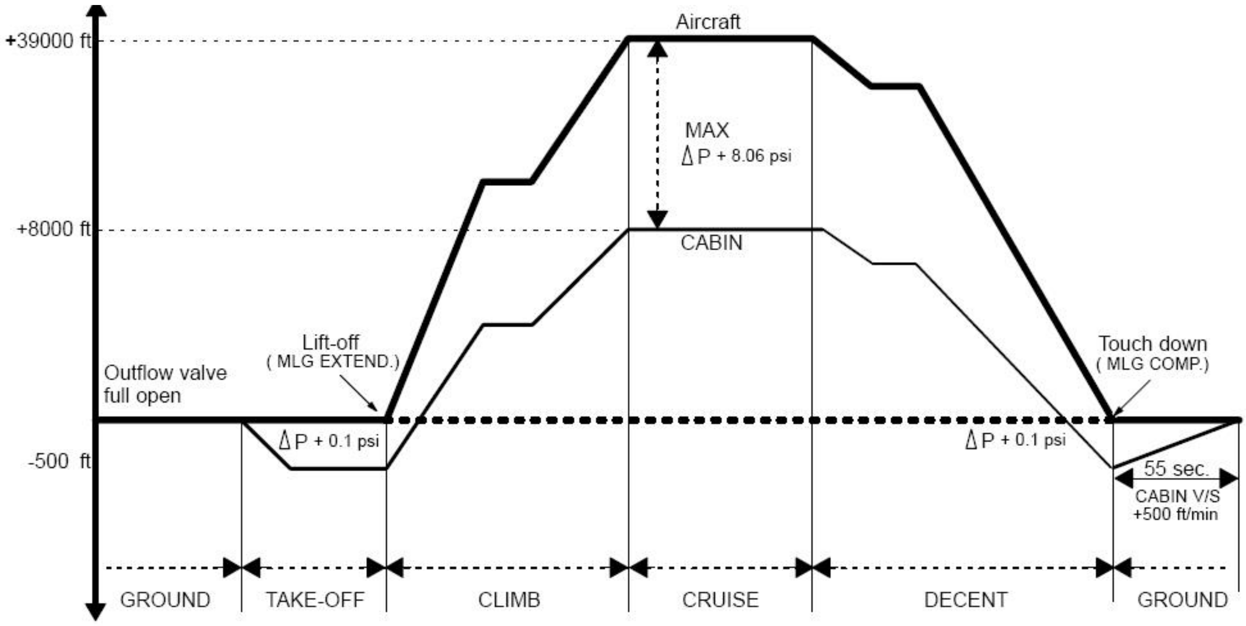


Fig.2.7 – Pressure difference in the cruise flight

Treatment of the specimens by CPC will be conducted by spraying of one side of specimen. The penetration of the CPC into the gap between the sheets of the skin will be produced by the oscillation of the specimen at the process of the fatigue loading. In the real conditions of the aircraft operation the additional factor influencing penetration effect is pressurization.

The time gap between the treatment and fatigue test beginning could be the important factor influencing side effect of the CPC application, but the investigation of this impact factor requires special cycle of researches.

At the first step of the test program the regular loading of structural riveted components should be carried out.

Among another components of the test program the investigation of the CPC on fatigue crack propagation as well as CPC influence on fatigue crack nucleation period should be considered.

Conclusion to part 2.

Corrosion Preventive Compounds require complex investigation of their functional properties.

The investigation of the negative side effect of Corrosion Preventive Compounds must be the mandatory component of the test program. As one of the possible side effect caused by the redistribution of the forces between the components of riveted joints due to the reduction of a friction, the investigation program should include the fatigue tests of riveted joins treated by the Corrosion Preventive Compounds.

The concepts of the specimens and test program selection have been developed, Loading regimes selected on the base of the aircraft load spectra analysis.

PART 3. ENVIRONMENTAL PROTECTION

The development of aviation environmental protection plan is very necessary.

Aluminum, titanium, steel and composite materials have become the basic structural materials of aircraft , once the aircraft material has corrosion problems, it will not only hinder the performance of the aircraft itself, but even cause huge losses to people's lives and property safety in serious cases. Corrosion is a surface phenomenon where materials interact with the environment. Electrochemical corrosion occurs at the solid-liquid interface between solid materials and electrolyte solutions, and chemical corrosion occurs at the solid-gas interface between solid materials and the surrounding gas environment.

3.1Natural materials for aircraft manufacturing

Corrosive materials will have a great impact on the environment, such as air pollution, acid rain, carbon dioxide, toxic gases, etc.

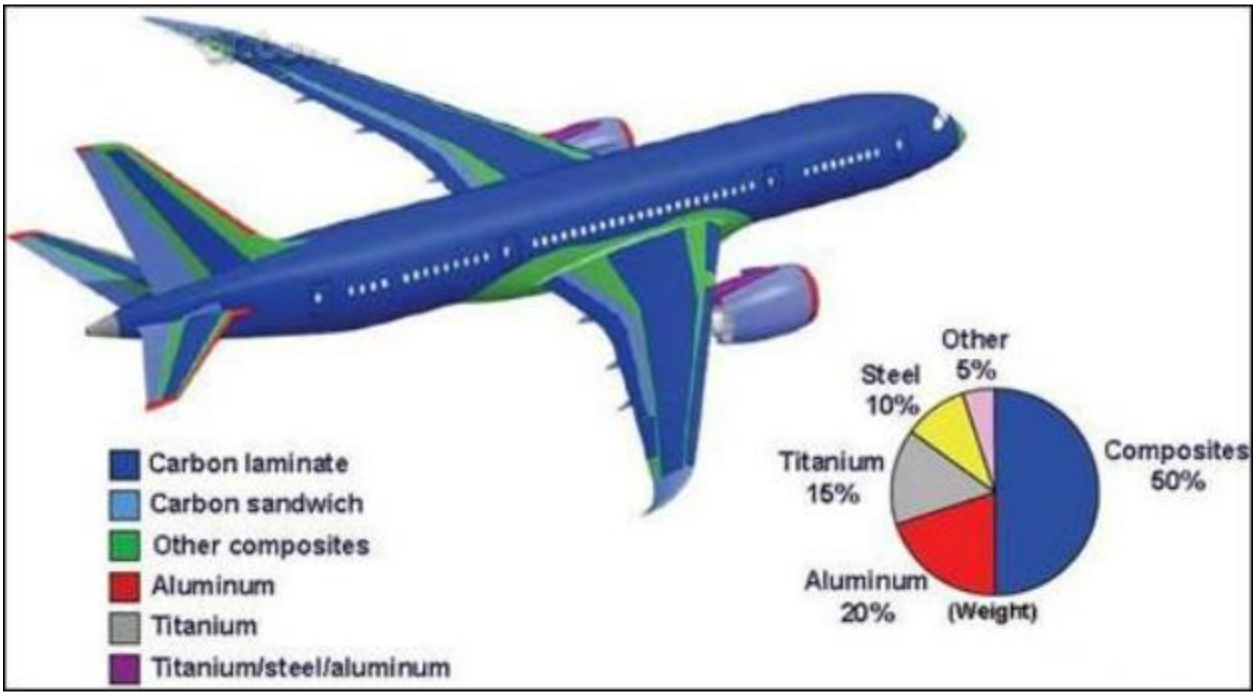


Fig.3.1 – Classification of aircraft materials

It can be seen from Figure 4.1 that in the current aircraft design and manufacturing, composite materials are used in close to general proportions. On the one hand, composite materials have relatively good anti-corrosion properties, and on the other hand, composite materials are environmentally friendly, so they are widely used. However, there are still aluminum alloys, titanium alloys, magnesium, copper, and other materials on the aircraft, which are extremely susceptible to corrosion, and after being corroded, improper management and handling will have a relatively large impact on the natural environment.

If the aircraft's corrosion-damaged materials are improperly handled, it will cause serious harm to environmental protection. How to make reasonable use of the aircraft at the end of its life and properly handle it is an important issue facing the entire aviation industry.

Approach. There are usually two processing methods, machine-level processing and component-level processing.

The whole-machine-level processing is suitable for those aircraft that are relatively well-preserved or have a certain commemorative significance. This type of processing to maintain a certain integrity of the aircraft mainly includes the following methods.

（1）Give it to the museum for exhibition.

（2）Gift to the security department for acting use.

（3）Modified to use in other venues.

（4）Enter civil aviation related units, such as aviation academies or maintenance units for teaching and training use.

Component-level processing is to decompose the aircraft. According to the degree of decomposition and the destination of the decomposition products, there are mainly the following methods.

(1) Become a second-hand aviation material and put it back into use.

(2) As a collection for aviation enthusiasts.

(3) Material recycling.

(4) Garbage disposal.

Efforts to reduce environmental impact. Atmospheric corrosion problems are common in the manufacturing, storage, use and transportation of metal products. According to reports, for example, China’s annual losses due to atmospheric corrosion account for about 2.5% of the national economy. Among many corrosion control methods, adding vapor phase corrosion inhibitor as an efficient and economical protection method has attracted more and more people's attention and favor. Vapor phase corrosion inhibitors, also known as volatile corrosion inhibitors, usually have a small molecular weight and can automatically volatilize corrosion inhibitor molecules or groups at room temperature to inhibit atmospheric corrosion of metals. Although the vapor phase corrosion inhibitor does not have to directly contact the metal surface when in use, it can protect the surface, cavity, pipe, groove and even the gap of the metal product, so it is especially suitable for the complex structure of metal products and components. Non-coating protection, with long anti-rust period, simple operation and low cost. In recent years, domestic and foreign countries have begun to accelerate the development of new vapor phase corrosion inhibitors. At the same time, a variety of vapor phase corrosion inhibitor-based vapor phase rust prevention technologies have emerged, and they have been widely used in machinery, military, chemical and other fields.

Figure. 3.2—YC711 Meteorological Environmental Protection Corrosion Inhibitor

The amount of vapor phase corrosion inhibitor added is generally small, and the concentration in the corrosive medium is also very low, but the effect of retarding the corrosion process is very significant. Nitrite dicyclohexylamine and cyclohexylamine carbonate are two commercial vapor phase corrosion inhibitors with good corrosion inhibition performance. They can passivate the surface of ferrous metal to protect the metal. The subsequent corrosion inhibitors such as benzotriazole, dicyclohexylamine chromate and guanidine chromate can also protect a variety of metals exposed to the atmosphere. Recently, with the introduction of the ISO 14000 environmental management series standards, early vapor phase corrosion inhibitor products such as nitrite and chromate that are harmful to the human body and the environment have been gradually eliminated or banned, while the low- or non-toxic new type of vapor phase The research, development and application of corrosion inhibitors have developed rapidly[2].

Efficient general purpose gas phase corrosion inhibitor. Organic amines. This kind of gas phase corrosion inhibitors can release free small molecular amines or hydroxyl radicals through hydrolysis and dissociation reactions to adsorb on the metal surface to inhibit the metal corrosion process; at the same time, NH3 dispersed in the gas phase has a certain degree of acid gas Neutralization, thereby strengthening the role of macromolecular amines to prevent the corrosion process. Martin [5] used imidazoline and low-molecular-weight amine to compound in a certain proportion, which can be used in gas pipelines and has a certain corrosion inhibition effect. Ammonium nitrobenzoate can be adsorbed on the active site of the metal surface to replace water molecules or convert low-valence oxides into high-valence oxides. Cycloheximine-N-nitrobenzoate can be adsorbed on the surface of Fe or Ni to play a protective role, and it will increase with the increase of time and temperature. Most nitrobenzoic acid amines have a strong protective effect on Fe or Zn, but the protective groups are different depending on the metal. For example, for Fe and Zn, dinitrobenzoic acid>single-molecule nitrobenzoic acid>benzoic acid>amine; but for Cu, dinitrobenzoic acid>benzoic acid>single-molecule nitrobenzoic acid.

Vaporizable amino acid alkyl esters .This kind of corrosion inhibitor is non-toxic, has good corrosion inhibition performance and volatility. The amino acids used include aliphatic amino acids (cysteine, glutamic acid, etc.), which contain aromatic groups. Or heteroatomic amino acids (tryptophan, glycine, etc.) [7]. For the selection of alkyl esters, generally the alkyl group with 4 to 7 carbon atoms can provide better gas phase durability. The use of tertiary alcohols to esterify amino acids can prevent the dimerization reaction from occurring, and the tertiary alkyl esters finally obtained will exhibit long-term corrosion inhibition.

Gasifiable Amino Acid Alkyl Ester. These compounds generally contain atoms such as O, N, S and P, which have a strong adsorption effect with metals and form stable complexes or chelates, and are easily formed within or between molecules A large number of hydrogen bonds thicken the adsorption layer and form a barrier that prevents H+ from approaching the metal surface [9]. At present, the commonly used heterocyclic gas phase corrosion inhibitors include cycloheximide, piperidine, azole compounds, morpholine derivatives, etc., in which cycloheximine has a seven-ring structure and the others are six-ring structures. Thiazole derivatives [10] can be used at high temperatures and are highly effective vapor phase corrosion inhibitors to prevent CO2 corrosion. Morpholine derivatives can not only inhibit the corrosion of steel, but also have a good protective effect on Cu, which can be adsorbed on the surface of Cu through O. The research of Zhang Daquan et al. [11] showed that morpholino benzoate is an excellent mixed gas phase corrosion inhibitor, which has an inhibitory effect on the anode and cathode.

Heterocyclic compounds. With the advancement of organic synthesis technology, new structures of oligomeric vapor phase corrosion inhibitors can be synthesized by controlling the polymerization of corrosion inhibitor molecules. Generally, this kind of vapor phase corrosion inhibitor has the following properties: (1) Low toxicity, the toxicity of the polymer is much lower than that of a single molecule; (2) High efficiency, multiple corrosion inhibitor groups are introduced through the polymerization reaction ; (3) Versatility, the synergistic effect between the corrosion inhibitor groups enhances the functionality of the corrosion inhibitor. Zhang Daquan et al. [12] synthesized a morpholine dimer——bis-(morpholinomethyl)-urea, which is a kind of excellent performance of ferrous metal vapor phase corrosion inhibitor, and it also has certain effect on non-ferrous metals such as Cu and Al. The corrosion inhibition effect.

Green low toxicity gas phase corrosion inhibitor. With the improvement of human awareness of environmental protection, the extraction of corrosion inhibitors from natural substances has become one of the more widely used methods in anti-corrosion technology. Han Ying et al. developed a CH corrosion inhibitor using the residues of natural wild plants to prepare traditional Chinese medicine. Through research, they found that it is an adsorption film-type corrosion inhibitor with good corrosion inhibition effects. Rauscher et al. evaluated the corrosion inhibitors of plant extracts containing N, S, O and unsaturated bonds, and the results showed that they all have a corrosion inhibition efficiency of more than 90%. Qi Yong studied phytic acid, an extract from oils or cereals, and found that phytic acid is a highly efficient and multifunctional gas phase corrosion inhibitor, which can chelate a film on the metal surface to prevent further corrosion of the metal. Cai Huiwu developed ZH-1 environmentally friendly vapor phase corrosion inhibitor, and evaluated the corrosion inhibition performance of the product through different experiments.

Vapor phase corrosion inhibitor for multi-carrier application. There are more than ten reports on the application of vapor phase corrosion inhibitors at home and abroad. The vapor phase corrosion inhibitor powder can be packed into gauze or non-woven gauze bags or spread directly on different parts of the mechanical equipment; or the vapor phase corrosion inhibitor can be mixed with an appropriate amount of binder and active material to be uniform, and compressed into different shapes of tablets , Pills and other lozenges; in addition, methods such as foam particles, vapor rust preventive water, vapor rust preventive oil, vapor phase emitters, etc. can also be used [2], generally based on vapor rust preventive materials, which can be directly applied. It can also be coated or impregnated on the carrier for use. Mao Fagen developed a new type of vapor phase corrosion inhibitor wax film oil, which can not only take advantage of the advantages of vapor phase corrosion inhibitors, but also have the characteristics of wax film oil leaving a layer of waxy solids after volatilization. . At present, the most popular corrosion inhibitor is the gas-liquid phase composite corrosion inhibitor. The research of Kuznetsov et al. proved that the gas-liquid composite corrosion inhibitor can effectively slow down the CO_2 corrosion of oilfield equipment. Russia's и-1-A, НКВ-4, НКАВ-1 and

American Visco 970 are all highly efficient gas-liquid phase corrosion inhibitor compound products. In addition, VCI paper (cloth) is also a common form of application at home and abroad. At room temperature, vapor phase anti-corrosion paper (cloth) can slowly emit a gas, which migrates to the metal surface with corrosive gases in the air, forming a protective film to play a passivation effect .

In general, among the currently developed vapor phase corrosion inhibitors, there are not many products that have truly achieved commercialization and practical application, and the application research of vapor phase corrosion inhibitors needs to be strengthened. Most vapor phase corrosion inhibitors can only protect a single metal, and the synthesis and development of efficient general-purpose vapor phase corrosion inhibitors will still be a major research content in the future. For gas phase corrosion inhibitors of natural origin, although their impact on the environment during the extraction, synthesis, and application stages is very small, their molecular weight is usually relatively large, and the volatility will be limited to a certain extent, so in the future work Attention should be paid to the compounding and optimization of natural products with different molecular weights and active groups to improve their volatility and corrosion inhibition efficiency. In addition, the carriers of vapor phase corrosion inhibitors vary depending on the metal parts to be protected, so the development of multi-carrier application technology is also an important link in the research of vapor phase corrosion inhibitors.

With the continuous emergence of various new materials and testing and characterization methods, the research on the variety, performance and mechanism of vapor phase corrosion inhibitors has also been greatly developed. The establishment of various volatile adsorption theories of vapor phase corrosion inhibitors and the proposal of corrosion inhibition mechanism have made people have a deeper understanding of vapor phase corrosion inhibitors. The application of various new methods also provides a wealth of means for the evaluation of vapor phase corrosion inhibitors, allowing for the discussion of corrosion inhibition mechanisms from multiple perspectives.

The future research of vapor phase corrosion inhibitors will mainly focus on the following aspects:

(1) The research and development of general high-efficiency vapor phase corrosion inhibitors. Synthesize a new and efficient vapor phase corrosion inhibitor through molecular design, and comprehensively use a variety of methods to perform performance characterization and evaluation to clarify the corrosion inhibition mechanism.

(2) Development of low-toxicity and green gas phase corrosion inhibitor. Pay attention to the extraction of substances with corrosion inhibitor groups from natural plants and marine animals, and reduce the malignant impact on the environment during the preparation and use of corrosion inhibitors, and seek carriers for different vapor phase corrosion inhibitors to increase economic, social and environmental benefits .

(3) Study on the compounding of vapor phase corrosion inhibitors. Screen low-cost, readily available corrosion inhibitors for compounding, to solve the difficulty of single-component insurmountability, and to obtain the mechanism of action of different components and metal surfaces in the compounding synergistic system.

(4) Combining thin liquid film conditions to develop a new type of testing technology for the study of the mechanism of vapor phase corrosion inhibitors. Using the test technology of metal corrosion behavior under thin liquid film conditions for reference, the corrosion inhibition behavior of vapor phase corrosion inhibitors at the metal interface is studied, and the electrochemical corrosion inhibition mechanism of vapor phase corrosion inhibitors is further explored.

The development of green, non-toxic and degradable corrosion inhibitors will greatly reduce the environmental pollution caused by aviation corrosion.

3.2 Recovery method of aluminum alloy scrap from aviation industry.

A method for producing aluminum-containing remelt blocks for the manufacture of aluminum alloys for the aviation industry, wherein:

(1) a scrap mainly containing aluminum alloys for the aviation industry is supplied in the supplying step.

(2) the scrap is in the melting step Melted in a furnace to obtain an initial liquid metal.

(3) in the separation step, the initial liquid metal is purified by step crystallization to obtain a solidified mass and remaining liquid.

(4) in the recovery step The solidified block is recovered to obtain a remelted block. This method is particularly advantageous for the recovery of aluminum alloys used in the aviation industry, because it can particularly purify iron and silicon in 2 series or 7 series alloy scraps, but does not remove other elements such as zinc, copper and magnesium.

This method particularly involves the recovery of waste materials generated during the production process of the aerospace industry and the aerospace industry.

(1) In the supply step, supply scraps mainly containing aluminum alloys used in the aviation industry.

(2) In the melting step, the waste is melted in a furnace to obtain an initial liquid metal.

(3) In the separation step, the initial liquid metal liquid is purified through stepwise crystallization to obtain a solidified mass and remaining liquid.

(4) In the recovery step, the solidified block is recovered to obtain a remelted block.

3.3 The final destination of the eliminated aircraft-the aircraft disassembly site

The end of the plane's life.

Fig.3.3 - bandoned Royal Air Force Airport

This may not be a cemetery, these aircraft shells will not be left here to slowly rust. Rather, they are the lifeblood of the scrap aircraft recycling industry.

Mark Gregory, founder of Air Salvage International, said: "If you take these engines and parts off, their value is higher than the price of selling them as an aircraft. . This company is responsible for the collection and dismantling of discarded jet airliners. "People used to take these planes to vacation or travel across the Atlantic," he said.

Every year, 50 to 60 passenger planes land here to complete their last flight. The wings cast huge shadows covering the surrounding villages like chocolate boxes, and the planes rumbled and landed to the ground.

Figure 3.4 -Molion site of Aircraft Recycling International Company

Narrow-body jet airliners like Boeing 737 or Airbus A320 can take 8 weeks to complete recovery, while large airliners like Boeing 747 or 777 can take 10 to 15 weeks.

With changes in aviation safety and noise regulations and the expansion of aircraft manufacturers' production, the replacement rate of aircraft has risen rapidly in recent years, and many commercial jets have been retired prematurely.

Currently, 400 to 600 commercial airplanes are dismantled worldwide every year. This generates a lot of waste-about 30,000 tons of aluminum, 1,800 tons of alloys, 1,000 tons of carbon fiber, and 600 tons of other parts are disassembled from old aircraft every year.

Fig.3.5 - ommercial aircraft dismantling site

This situation is likely to go from bad to worse. According to the prediction of the International Civil Aviation Organization (ICAO), as many as 18,000 aircraft in the fleet may be retired in the next 13 years.

Conclusion to part 3.

The choice of aircraft anti-corrosion compounds and the storage and disposal of scrapped aircraft will have an impact on environmental protection, which will attract more and more attention in the subsequent aviation development process, and will also become the aviation industry’ s need to consider more carefully. The problem of formulating a strategy is narrowed down.

PART 4. LABOR PROTECTION

4.1 Introduction

Labor protection is a compulsory part of every graduate student. We have to spend a lot of time to understand that this is not only responsible for laboratory safety, but also for the lives of staff. Therefore, what we need to understand is：

Analyze the occupational safety status of selected workplaces.

Effectively identify harmful and dangerous factors.

Compare the production environment and labor process with current standards.

Thinking about improvement measures for occupational safety management and creation.

Understand working conditions and study labor protection laws.

Safety is an eternal theme. Labor protection work is the lifeline of laboratories and even enterprises. It is an important part of safety management, especially aviation machinery work. We must pay full attention to labor protection work. Doing labor protection work will be in the work of safe production. Play a huge role.

We need to analyze the hazards in the laboratory and the characteristics of these hazards to ensure that we can use the laboratory in a way that ensures personal safety. At the same time, we also need to analyze the fire hazards that may occur in the laboratory to ensure that when an accident occurs, Correctly adjust the fire extinguishing process. The school regulations have clear regulations on the working environment, the type of environment in which students complete the experiment, what harmful gases and liquids in the laboratory environment, and the handling of hazardous chemicals. For the engineering environment, the specifications are also very noteworthy for the use of computers and machine tools[3]. The following is an analysis of the university’s requirements for laboratories and the risk factors of the work and research environment in combination with the relevant regulations of the Chinese and Ukrainian laboratories, and how to deal with it in emergency situations.

4.2 Analysis of working conditions at workplace

During the analysis of working conditions in the workplace, we especially need to determine the most common one or two unfavorable factors among harmful and dangerous factors, formulate detailed labor protection measures for common risk factors, and conduct necessary standard verification calculations.

Check and improve the measures. Our goal is to improve the labor protection management system and create safe and healthy working conditions.

Especially now that COVID-19 exists all over the world, workers in the aviation industry must pay attention to this new protection project when they are engaged in the industry.

Workplace

As shown in Figure 4.1, the completion of this paper is mainly in hangars and aviation maintenance bases, combined with computer simulation technology, mainly by observing the corrosion parts of the aircraft and detecting the causes of corrosion to determine the type of corrosion that occurs on the aircraft , And then simulate and analyze the repaired parts through computer software, and then repair and protect the anti-corrosion compound according to the aircraft corrosion situation. Therefore, the experimental conditions required to complete this round are a computer and a computer room.

Figure 4.1 shows the halt room for civil aviation maintenance. The computer room I use is NAY’ s school computer room and personal computer. Generally, the area of the engine room for civil aviation maintenance is approximately: the hangar hall is 155 meters wide, 85 meters deep, 23 meters high in the grid, and 21 meters high in the hangar door. The equipment used is mechanical tools such as screwdrivers, various working pliers, rubber hammers, etc., electronic tools such as electronic testing equipment, electronic corrosion analysis equipment, etc., and other tools such as respirators, ear protectors, etc.

This article refers to the use of equipment used by civil aviation personnel, but most of them are under observation of the corroded skin of the aircraft and computer-based analysis.

Fig.4.1 - A civil aviation maintenance plant in China

Working conditions

During line maintenance, the maintenance officer will perform a transit inspection of the appearance of the aircraft to check whether the aircraft is abnormal, whether there is any phenomenon such as lightning strikes, bird strikes, etc., whether the fuselage is corroded, or fluid leakage (fuel, engine oil, hydraulic oil, sewage), Then look at whether there are tire patterns on the wheels and brakes. After that, the flight attendant went to the cockpit to meet with the crew to understand the status of the aircraft and the amount of fuel required for the next flight, and opened the log book of the aircraft to check whether the crew had recorded the failure of the aircraft.

After the transit inspection, there is no abnormality and there is no system failure after the flight, and the engineer will sign and release the aircraft flight record book, which means that the aircraft can safely carry out the next flight mission. The engineer's signature represents his responsibility for the safety of the aircraft, and it is not just casually signing and releasing. If an accident occurs during or after the flight, if the accident is due to negligence in maintenance or inspection, it will be prosecuted to the last engineer who signed the release. In the slightest, the license will be suspended or revoked, and in the worst case, the law will be prosecuted. Or imprisonment.

Base maintenance is carried out in the hangar. The maintenance and inspection carried out are more rigorous than line maintenance. The inspection of base maintenance requires the removal of more items (such as covers, cabin interiors, seats).

The base maintenance of an aircraft can be as short as two to three days, and the length can range from two to three months. The base maintenance will carry out major repairs such as landing gear replacement, engine replacement, modification operations, and aircraft fuselage white iron repair and replacement.

4.3 List of harmful and dangerous production factors

4.3.1Noise

The working environment of maintenance personnel is noisy. The working environment is also a big challenge. Their working environment is very noisy, so they need to wear earmuffs. However, their work requires communication with colleagues. If they wear earmuffs, they sometimes cannot hear what the other party is saying. Not only that, maintenance personnel often work on the apron in the open air, regardless of the sun or rain, they have to bite the bullet. If the plane arrives at night, we will work under the shining of moonlight and flashlights[6].

Long-term exposure to a certain intensity of noise will have an adverse effect on the human body. The main hazard is the damage to the auditory system, which is manifested as hearing loss mainly due to hearing loss in high frequency bands. Hearing loss has gradually changed from temporary hearing threshold displacement to permanent displacement. With the increase of working years of noise exposure, hearing loss has further developed. Workers' high-frequency hearing is obviously impaired, but it has no effect on daily communication in life. When the hearing loss affects the language frequency and reaches a certain level, the daily conversation ability will be affected, and even deafness may occur[8] .

Hearing damage caused by noise is irreversible, and there is currently no effective drug treatment.

4.3.2 Side effects of chemicals

As a maintenance personnel, there are many kinds of work, but it is inevitable that you will be exposed to chemicals during cleaning, maintenance and inspection, and many types are often highly toxic or toxic.

4.3.3 Limb injury and limb damage

It is often a problem of shoulder and waist pain. Regardless of whether it is disassembly, sheet metal, or even decoration, there will be a situation of lifting heavy objects; and many people do not squat down when lifting heavy objects, but directly bend down and lift up hard. It is easy to flash to the waist or cause pain in the waist muscles. In severe cases, it will lead to a herniated disc. When they are carrying heavy objects, due to the wrong posture or heavy objects, the shoulders are hard to carry, and they are also easy to strain the muscles. Therefore, mastering the correct essentials for lifting is a basic common sense that every person who has been engaged in mechanical work for a long time must learn.

The last point is the problem of the feet. The reason is that wearing three kilograms of work shoes between the hangars for a long time, the ankle, heel and Achilles tendon will be strained to varying degrees. There are no specific preventive measures. But there is a way that everyone who works on locomotives and quasi-locomotives should learn, that is, come back from get off work every day, boil a pot of hot water, and soak your feet for half an hour to promote blood circulation and relieve fatigue from working a day.

4.3.4 COVID-19 infection

At present, the situation of prevention and control of the new crown pneumonia epidemic is still severe. The mutant strain has the characteristics of strong transmission ability, fast transmission speed, high viral load, and severe symptoms. In addition, the flow of people in civil aviation airports is large, and the channels of communication are diverse, so the staff is facing a great risk of new crown infection.

4.4 Formulation of labor protection measures

Noise labor protection

In order to avoid hearing loss when workers are exposed to productive noise, the emphasis is on prevention and personal hearing protection.

(1).Various sound insulation earplugs and earmuffs are effective personal protective equipment. The state stipulates that protective equipment must be used when working in a noise environment above 85dB.

(2).Strengthen occupational health inspections before and during noise operations. Hearing examinations should be carried out regularly, and effective intervention measures should be taken as soon as possible.

(3).For workers working in environments exposed to strong noise, they shall undergo occupational health inspections before starting their jobs. Those who have occupational contraindications for noise operations shall not engage in noise job operations.

Regarding labor protection of work chemicals

When engaged in aviation maintenance work, it is common to receive chemical hazards, hair loss, and radiation exposure. It is best to change into a tank suit and wear a gas mask for self-protection. You can usually eat more cod liver oil, cystine, vitamin B6, or sesame paste, black sesame pills, these health products have the health effect of solid hair and hyperplasia[4].

The second is respiratory infections, pharyngitis and other problems. Because the working environment is unsatisfactory. Dust, powder, CBC, and polished paint are all small solid particles, particles, etc., which have a serious impact on the respiratory tract, so wear a gas and dust mask to be safe Preventive measures are necessary.

Labor protection for physical injury and health injury

In civil aviation maintenance, the staff have to make mechanical contact, and they are very susceptible to physical trauma. The health of the staff should be protected.

1.Strengthen the pre-training of staff.

2.Under the requirements of safety management, formulate some emergency measures to ensure the safety of working conditions.

3.Each laboratory should be equipped with a part-time safety officer to be responsible for the safety of the laboratory. Safety personnel should be trained and possess certain safety knowledge and skills.

4.First, conduct safety education and training for the operators. After mastering the safety management methods and basic knowledge, the experimental operation can be started after being familiar with the operating procedures.

5. The Civil Aviation Group shall actively promote and popularize general first-aid knowledge and skills, such as first aid treatment for burns, trauma, poisoning, and electric shock. Maintenance workshops should conduct regular safety inspections to form a system that actively commends the advanced and seriously investigates and handles accidents[7].

6. When the maintenance plant undertakes maintenance and inspection tasks, the safety responsibilities shall be clarified.

7. The equipment, materials, tools and other items in the maintenance workshop should be placed neatly and reasonably arranged. All maintenance rooms shall clean up waste products in time, and shall not pile up items unrelated to the maintenance work to ensure that the safe passage is unblocked.

8. The Civil Aviation Group shall strengthen the management of safe electricity use, and shall not modify, dismantle and repair electric facilities without authorization; please do not pull wires, and there shall be no bare wires in the laboratory; no objects shall be stacked in the power switch box to avoid electric shock or burning; use high-voltage power electricity Wear insulated rubber shoes and gloves, or operate with a bumper; if someone gets an electric shock, cut off the power immediately, or isolate the wire from the body with an insulator, and then perform rescue operations.

9. When the maintenance personnel are in contact with dangerous goods such as flammable, explosive, highly toxic and bacteria, they shall use and store them in strict accordance with the relevant management regulations, and have reliable safety precautions at the same time

Labor protection under the COVID-19

Implementation of hierarchical management of entry security ground staff, according to the level of personnel exposure risk, divided into three risk levels of high, medium, and low.

Persons in high-risk positions are those who have direct or close contact (within 1 meter) with incoming passengers or crews, and those who have imported high/medium risk cargo (including luggage), aircraft and aviation waste (garbage, sewage, etc.) and entry Passengers, crews, and cargo transfers (including baggage) are used by people who have direct contact with unsterilized facilities and equipment; personnel in intermediate-risk positions are those who have direct or close contact with personnel in high-risk positions (within 1 meter), and those who have direct contact with Persons in high-risk positions who are in direct contact with undisinfected facilities and equipment; personnel in low-risk positions are those who have direct or close contact (within 1 meter) with personnel in medium-risk positions under effective protection[1].

The ground personnel participating in the entry security must be managed by real-name systems and all employees must be registered.

All employees and the entire process must be vaccinated against the new crown virus and have a vaccination certificate to work; they should regularly participate in technical training on epidemic prevention and control, and they can only work after they have passed the assessment of theoretical knowledge and operational skills. Operation; during the duty period, it is necessary to strengthen the awareness of prevention and control, pay attention to personal protection, avoid the risk of cross-infection, pay attention to the health of the body at any time, and perform personal protection in accordance with the corresponding risk level and standardize the putting on and taking off process. Relevant units should provide adequate and effective personal protective equipment and disinfection products for entry security ground personnel, and arrange for special personnel to supervise and inspect the process of putting on and taking off protective equipment by personnel at high-risk positions.

Conclusion to part 4.

In this chapter, we analyzed the equipment used to complete this thesis and the safety of employees in the industry, and proposed measures to help protect employees according to the environment, including the use of electronic equipment, maintenance labor Matters needing attention, harm to human body and possible dangerous factors during maintenance. Corresponding analysis was carried out, and the method of safe and standardized maintenance labor was put forward in the process of completing this article. At the same time, combined with the requirements of labor protection in our country, measures for protection and maintenance work have been proposed. Finally, around the current impact of the COVID -19 epidemic in the aviation industry, the epidemic labor protection method has been proposed for maintenance labor under the condition of ensuring labor wor**k.**

GENERAL CONCLUSION

Wide application of Corrosion Preventive Compounds require special attention to the probable negative side effect. Analysis of the available experimental data has shown that the influence of CPC on fatigue characteristics of aircraft riveted joints is rather expected in some cases.

To prevent the negative side effects of Corrosion Preventive Compounds the special verification program must be developed and implemented in to the practice.

One of the important component of this verification program is an investigation of the Corrosion Preventive Compounds of riveted joints fatigue life. The procedure of the riveted joins fatigue test to reveal negative side effects of CPC application has been developed in presented Master's work.

To gain this aim, the following objectives were be solved: the current state of the aircraft corrosion problem has been performed; contemporary methods of aircraft protection against corrosion were analized; typical riveted coupon design for fatigue tests was determined; regimes of fatigue loading for fatigue test procedure to reveal negative side effects of CPC application were determined.

The developed procedure for the negative side effects of CPC reveal is proposed as a recommendation for mandatory Corrosion Preventive Compounds verification.

REFERENCE

1. International Organization for Standartization. (2017). *Corrosion tests in artificial atmospheres — Salt spray tests* (ISO Standard No. 9227:2015) https://www.iso.org/standard/63543.html

2. International Organization for Standartization. (2017). *Corrosion of metals and alloys — Alternate immersion test in salt solution* (ISO Standard No. 11130:2017). https://www.iso.org/standard/71867.html

3. O'Neill, P.H., Smith, R.J. (1973) *A short study of the effect of a penetrant oil on the fatigue life of a riveted joint*. Aeronautical research council. Current paper No.1305. https://reports.aerade.cranfield.ac.uk/bitstream/handle/1826.2/1318/arc-cp-1305.pdf?sequence=1&isAllowed=y

4. Schijve J., Jacobs F.A., Tromp P.J. Effect of an anti-corrosion penetrant on the fatigue life in flight-simulation tests on various riveted joints, National Aerospace Laboratory NLR, TR77103, 1977-08-31

5. Kolkman, H.J. (1982) *Effect of penetrant on fatigue of aluminium alloy lap joints*. Aerospace Engineering Reports. NLR-TR 82104 U. http://resolver.tudelft.nl/uuid:68a135af-d367-4c9f-ba4a-28491aa1217e

6. Jaya, A., Tiong, U. H., & Clark, G. (2010). Surface Damage in Riveted Aircraft Aluminium Lap Joints, in the Presence of Lubricants. *Materials Science Forum*, *654–656*, 2434–2437. https://doi.org/10.4028/www.scientific.net/msf.654-656.2434

7. Jaya, A., Tiong, U. H., Mohammed, R., Bil, C., Clark, G. (2010). Corrosion treatments and the fatigue of aerospace structural joints. *Procedia Engineering 2*, 1523–1529. https://doi.org/10.1016/j.proeng.2010.03.164

8. Starikov R. Fatigue behaviour of mechanically fastened aluminium joints tested in spectrum loading.October 2004 International Journal of Fatigue 26(10):1115-1127 DOI: 10.1016/j.ijfatigue.2004.03.006

9. Shankar K; Baird JP; Clark R; Williamson HM, 1997, 'Optical examination of load transfer in riveted lap joints using portable holographic interferometry', in *Proceedings of SPIE - The International Society for Optical Engineering*, pp. 158 – 163.

10. Morris G. Defining a standard formula for fastener flexibility in lap joints. PhD dissertation, Delft University of technology, 2004

11. Skorupa M., Skorupa A., Machniewicz T., Korbel A. (2009) An Experimental Investigation on the Fatigue Performance of Riveted Lap Joints. In: Bos M.J. (eds) ICAF 2009, Bridging the Gap between Theory and Operational Practice. Springer, Dordrecht. https://doi.org/10.1007/978-90-481-2746-7_26

12. Purry, C. Fien, A. Shankar, K. (2003). The effect of corrosion preventative compound on fatigue crack growth properties of 2024-T351 aluminium alloys. *International Journal of Fatigue, 25,* 1175–1180. https://doi.org/10.1016/j.ijfatigue.2003.08.016

13. Sarah J.H. Kuhlman, Garry H. Abfalter, Ryan Leard, Jim Dante. (2003). Environmentally assisted fatigue crack growth rate testing with corrosion prevention compounds. Heat treating and surface engineering. *Proceedings of the 22nd heat treating society conference and the 2nd international surface engineering congress, USA,* 347-354. https://www.asminternational.org/home/-/journal_content/56/33542825/CP2003HT347

14. Chinese Labor Protection Law

15. European Union Health and Safety Legislation website.

16. International Finance Corporation. 2007.General EHS Guidelines-Occupational Health and Safety.

17. International Labor Organization SafeWork website.

18. Guidelines on occupational safety and health management systems.

19. International Organization for Standardization. 2018.Occupational health and safety management systems .

20. National Institute for Occupational Safety and Health.

21. Peking University Laboratory Requirements.