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AN EXTENSIVE STRUCTURAL MAINTENANCE PROBLEM CAUSED BY CORROSION ON AN AIRCRAFT

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ABSTRACT

The airworthiness of aircraft is valid only if all engines, structures and avionics systems are checked periodically and the faults are maintained according to international aviation maintenance rules such as FAA or EASA requirements. This study examines extensive corrosion damage seen in the aft cargo compartment of a Boeing 737-300, which was taken into My Technic Aircraft MRO Services' Hangar, ISG International Airport-Istanbul, Turkey for the C check and structural repair.

Through structural maintenance, many structural parts, including sections of the skin of the aircraft, were exchanged and repaired because the corrosion was quite extensive. The aluminum alloy patches used for skin repair were prepared by means of the English Wheel Tool. As a result, the corrosion damage on the skin was fixed by using a five-stage patch with dimensions of 2.7 meters in length and 1.6 meters in width.

Keywords: Aircraft Maintenance, Structural Repair, Corrosion, and Boeing 737-300

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INTRODUCTION

Nowadays, most parts of passenger aircraft are manufactured out of aluminum alloys. For this reason, corrosion control is vital for aircraft (A/C). The corrosion discovered on any part of A/C must be removed immediately by means of certain methods. Otherwise, the corrosion may tend to spread out to the other structural parts, which may result in structural failure or loss of life and money. This study deals with the corrosion caused by the leakage from lavatory systems in the aft cargo compartment of a Boeing 737-300, and its repair.

Before giving the details of structural maintenance, it will be useful to explain some basic information to readers about corrosion and the types of corrosion seen on aircraft structures.

What is Corrosion?

Corrosion is a natural phenomenon starting from production of metals. It is caused by chemical or electrochemical attacks to the metals. It deteriorates not only inside but also outside of the metals. Due to this reason, the metals must be protected against these attacks. There are ways to keep the metal materials from corrosion, such as painting, plating or adding strong material to pure metals (alloys) etc [Avstop, 2013; FAA, 2012; MEB, 2012].

The appearance of corrosion depends on types of metal material. It may be seen as etching or pitting with a white or grey powdery deposit, reddish rust or greenish film on the surface of the metal. If the corrosion is not checked properly, it may lead to structural failures [Colavita, 2013; FAA, 2012]. Therefore, all aircraft maintenance technicians must check all areas and carry out proper cleaning or repair according to the maintenance procedures.

Substances that cause corrosion are called corrosive agents. These include acid, air, salt, water, etc. For instance, sulfuric acid may cause severe corrosion, especially on the aluminum alloy parts of the aircraft. Human and animal wastes have the same impact on structural parts as well. Moisture, oxygen or chemicals in industrial areas may also behave as corrosive agents [Avstop, 2013].

Corrosion, as can be seen from its definition, may generally be divided into chemical and electrochemical corrosion. In both types, the metal turns into oxide, hydroxide or sulphate. It causes metals attacked to go to anodic change, and the corrosive agent to cathodic change. Corrosion becomes a major problem, especially for the aircraft operated in severe atmosphere and environment [Avstop, 2013; FAA, 2012; Tuncay and Kahya, 2007].

Chemical and Electrochemical Corrosion

In chemical corrosion, metals are directly in contact with the corrosive agents. For instance, smoke or spilled acid from batteries may contact with aircraft structural parts [FAA, 2012].

On the other hand, in electrochemical corrosion, along with being in contact with a corrosive agent, the metal is also linked by a liquid or gas, which can act as a conductor. This liquid is mostly water and may carry a very low current. Hence, it causes an electrolytic reaction that deteriorates the metal [FAA, 2012].

Common Corrosion Types on Aircraft Structures

For all kinds of aircrafts, interior surfaces of battery compartments, engine frontal and rear (exhaust) parts, interior surfaces and systems in wheel wells, landing gears, outer parts of the fuselage (skin), flap and spoiler gaps, avionics system components and their parts and bilge areas etc. are areas prone to corrosion. In these places, the following are the most common corrosion types [Avstop, 2013; FAA, 2012].

<u>Surface Corrosion</u>

Surface corrosion is a very basic corrosion seen on the surface of metals as pitting, roughening or etching, as well as powdery deposits. It may occur due to chemical or electrochemical attacks. Sometimes, this corrosion may expand under the paint or plate and may not be easily seen. Doing a closer inspection uncovers blisters, which are caused by the corrosion products. Specially, pitting is seen mostly on thick structural parts. Unless it is stopped, its deepness may increase. Therefore, it necessitates a long cleaning process or exchanging of affected parts. Another type of surface corrosion appears as a worm shape under the paint or plates. Figure 1 shows different surface corrosions [Avstop, 2013; FAA, 2012; MEB, 2012].

<u>Dissimilar Corrosion</u>

This type of corrosion occurs due to electrical contact caused by the deformation of isolation materials between dissimilar metals or alloys. In order to inspect the metal or alloy parts, they must be removed, since the corrosion may expand to invisible places. It is most probable to see this corrosion on aircraft, as aircraft cannot be constructed from one type of metal. Dissimilar corrosion is seen in Figure 1 [Avstop, 2013; Colavita, 2013; FAA, 2012].

<u>Fretting Corrosion</u>

Fretting corrosion is seen in between two surfaces that are tightly attached to each other. Even small vibrations during aircraft operation may cause the separator material to be worn. If undetected, this demolishes the inner surfaces and comes up with pitting and debris. Since the debris is stuck between the surfaces, it causes much more deformation with the presence of water vapor. Figure 1 illustrates fretting corrosion [Avstop, 2013; FAA, 2012].

<u>Stress Corrosion</u>

This corrosion appears as a result of constant tensile stress and corrosive environment. Stress may take place because of internal or external loads on any parts and may eventually result in cracking. Stress corrosion cracking may often be seen on copper, aluminum, some stainless steel and highly durable steel alloys. Stress corrosion may be seen in Figure 1 [Avstop, 2013; FAA, 2012; MEB, 2012].

<u>Inter-granular Corrosion</u>

Inter-granular corrosion is a type of corrosion that is mostly seen on aluminum and some stainless steel. It occurs due to the deformation of the internal structure of materials when heat treatment is applied during the manufacturing process. This type of corrosion is the most dangerous of the ones that may not be easily seen. Corrosion expands in among the grains of the parts. In the most serious cases, it shows on the surface of the part by exfoliation. Figure 1 includes inter-granular corrosion [FAA, 2012; MEB, 2012].

Figure 1: Various Types of Corrosion, a) Pitting Corrosion [Colavita, 2013], b) Surface Corrosion, c) Dissimilar Corrosion [Colavita, 2013], d) Fretting Corrosion [NACE, 2013] e) Stress Corrosion, f) Inter-granular Corrosion.

METHOD

In Aircraft maintenance, maintenance may be classified from light to heavy, as line, A, B, C and D checks, respectively. A and B checks are considered as light maintenance, while C and D checks are considered as heavy maintenance, which are to be conducted in a hangar environment. Corrosion control is carried out in C and D checks.

Exploring the Corrosion in the Aft Cargo Compartment

The Boeing 737-300 was taken into My Technic Aircraft MRO Services' Hangar to carry out its C check. After visual and liquid leakage inspection, extensive corrosion damage was seen in the aft cargo compartment. Previously, the same area of the aircraft had the same corrosion problem and so it had structural repair. However, for various reasons such as poor protection, inspection and leakage from the lavatory system etc, the same area became corroded again. The problem was more extensive than the previous case since it spread out to other important structural parts. A view of corrosion is given in Figure 2.

Figure 2: A View of the Corrosion in the Aft Cargo Compartment

Corrosion Cleaning Process and Preparation of the A/C for the Structural Maintenance

Firstly, traditional attempts to remove the corrosion in the aft cargo compartment were tried, but through a cleaning process, it appeared that the corrosion could not be removed. Therefore, the Structural Repair Manual (SRM) was examined to decide which method to use to get rid of this kind of corrosion. Eventually, it was clear that the SRM did not provide sufficient information about this extensive problem. A picture after the cleaning process is given in Figure 3.

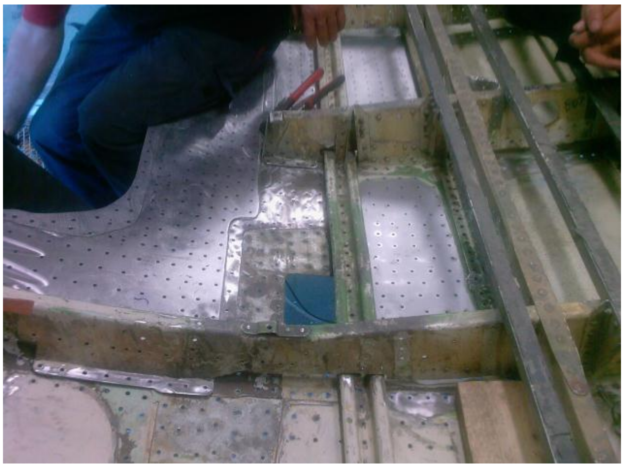


Figure 3: Aft Cargo Entrance Door - Corrosion Cleaning

As a result of correspondence between My Technic Aircraft MRO Services and Boeing Aircraft Company, it was decided to cut and remove heavily corroded parts from the A/C. A view of a cut in the aft cargo is given in Figure 4.

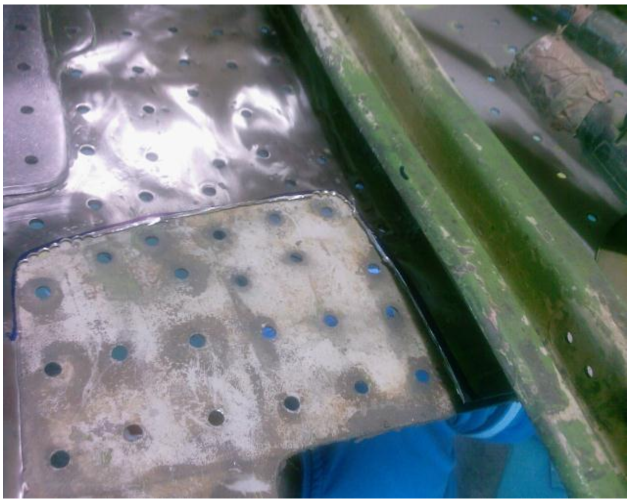


Figure 4: Removing Some Parts by Cutting from the A/C

In order to conduct a structural maintenance, there are rules to follow. For this structural repair, the rules were utilized and done as follows:

After removing passenger seats and jacking the A/C, two poles were put through the windows of the A/C. On each side of these poles, four other poles were attached vertically as seen in Figure 5.

a) b)

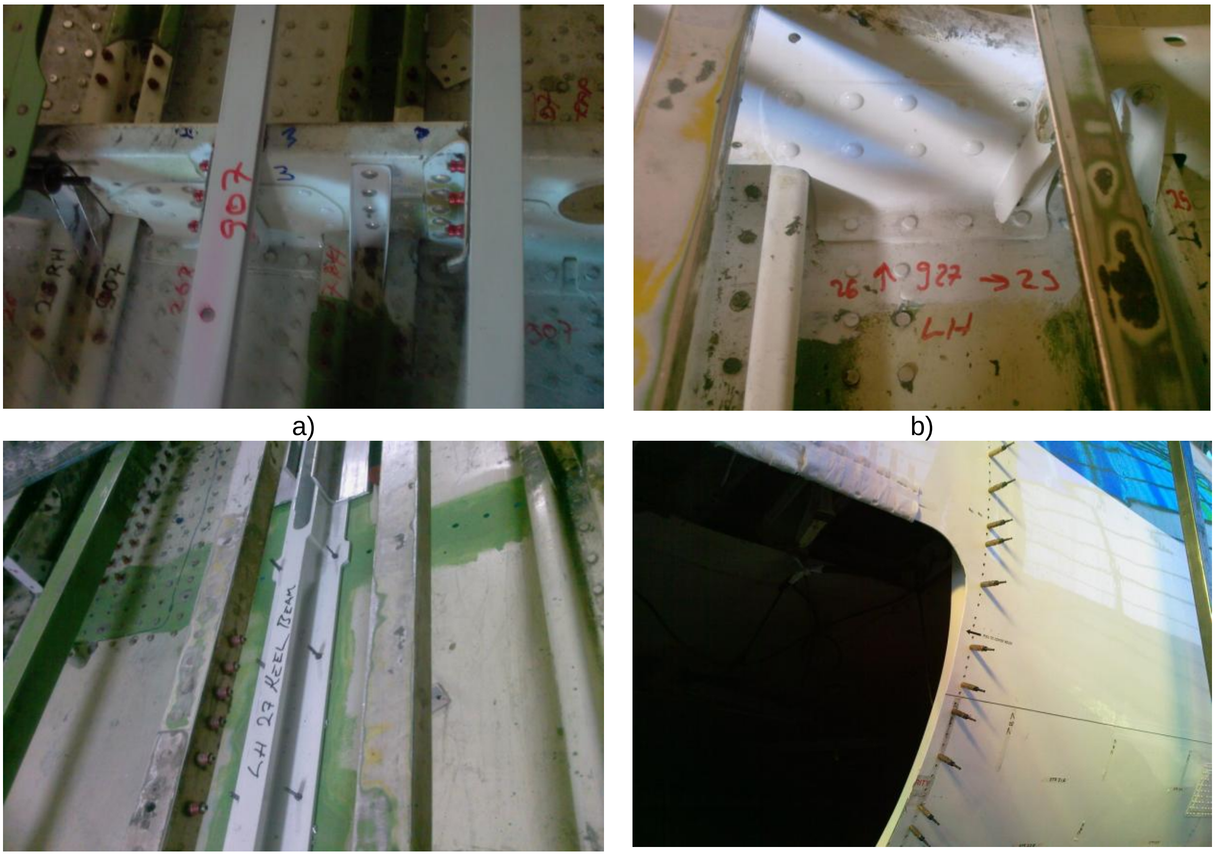
Figure 5: Preparation of the A/C for Structural Repair, a) The Poles put through Windows b) The Poles' Tips and Their Attachment with Vertical Poles.

A scale was used under each vertically attached pole to measure the changes of weight balance. The scales were checked daily to prevent the A/C from shifting. In addition, the aircraft was supported from its tail cone and under the fuselage. The process is seen in Figure 6.

a) b)

Figure 6: Preparation of the A/C for Structural Repair, a) A Structural Maintenance Technician is putting a Scale under one of the Poles. b) General View of the Preparation.

Except for the parts removed by cutting, in the aft cargo compartment, 747, 767, 787, 827, 847 and 887 body station numbered frames were changed. Also, some stringers and struts were changed. Some of them are seen in Figure 7.



a) b) c) d)

Figure 7: Some Changed Parts on the A/C. a) 907 Body Station Numbered Stringer Change b) 927 Body Station Numbered Frame Repair c) L/H 27 Numbered Keelbeam Change d) 767 Body Station Numbered Door Frame Change

Preparation and Assembling of Patches

After removing some structural parts, frames, stringers and struts, necessary measurements were done in length and width to determine the dimensions of patches. The thickness of the aluminum sheets was calculated thicker than the original sheets in that area. The aircraft manufacturer, Boeing Company, sent the technical drawing of the patches with the suitable sheet thicknesses. In the drawing, a five-stage patch with dimensions of 2.7 meters in length and 1.6 meters in width was given and the thicknesses of the sheets were, from the inside out, 0,032, 0,050, 0,063, 0,071, and 0,125 inches, respectively. The patches were prepared one by one by means of English Wheel Tool according to the technical drawing. Two or four Aircraft Structural Maintenance Technicians took part in preparing each patch. Preparing a patch took three days. In other words, a huge effort was spent. Figure 8 shows the English Wheel Tool and Structural Maintenance Technicians.

Figure 8: English Wheel Tool and Structural Maintenance Technicians

Since the patches are rather large, they were fastened to the fuselage of the A/C by means of belts. After that, necessary drilling processes were carried out, taking into consideration the old holes from the previous structural maintenance. How the patches were fastened to the fuselage is seen in Figure 9.

Figure 9: Fastening the Patches to the Fuselage of the A/C

Except for making sure that the patches fastened properly to the fuselage, the drilling process should be conducted meticulously. Otherwise, the inner patches may be damaged, which causes loss of money and time. Figure 10 illustrates the drilling and temporary fastening process.

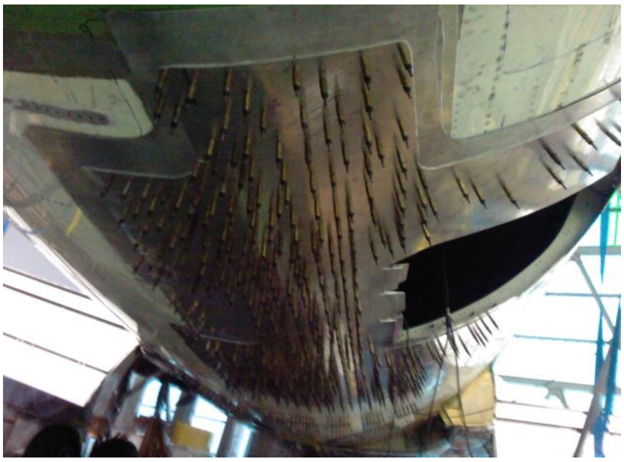


Figure 10: Drilling the Patches and Fastening to the Fuselage Temporarily

After the drilling process of all patches, the patches were trimmed and then undercoated in a paint workshop. Figure 11 includes photos from this process.

a) b)

Figure 11: Preparation of Patches a) While Applying Protective Solution b) Patches in the Paint Drying Oven

After the sealing process among patches, they were refastened to the fuselage and installed by means of solid rivets.

In structural maintenance, aluminum alloy patches recommended by the manufacturer were used. For this maintenance, 2024T3 aluminum alloy based sheet metals were utilized. Final status of repair is given in Figure 12.

CONCLUSION

Figure 12: Final Status of the Structural Maintenance

After completing the structural repair, system parts, which caused the leakage, were changed and checked. A Cabin Pressurization Test was applied and no air loss was detected. Afterward, the patches and other poorly painted parts were painted. At the end of the maintenance, it was specified that the maintenance did not cause any large change in A/C center of gravity, with approval of the Boeing Company. The A/C was released to service after conducting all other maintenance.

References

Avstop (2013), *"Corrosion Control for Aircraft",* Avstop.com, Aviation Online Magazine, http://avstop.com/maint/corrosion/index.html, 31.03. 2013.

Colavita, M., (2013), *"Occurance of Corrosion in Airframes",* Chemistry Dept. of CSV- Italian Air Force, http://ftp.rta.nato.int/public//PubFulltext/RTO/EN/RTO-EN-015///EN-015-06.pdf., 31. 03. 2013, Roma, İtalya.

FAA, (2012), *"Aircraft Cleaning and Corrosion Control"*, http://www.faa.gov/library/manuals/aircraft/amt_handbook/media/faa-8083-30_ch06.pdf., July 2012.

MEB, (2012), Uçak Bakım-Korozyon Modülü, Milli Eğitim Bakanlığı, Ankara, 2012.

NACE, (2013), NACE International-The Corrosion Society, *"Fretting Corrosion",* Web Site: http://www.nace.org/Corrosion-Central/Corrosion-101/Fretting-corrosion/, 31. 03. 2013.

Tuncay, A., Kahya O., (2007), Korozyon, UTED Aylık Havacılık Dergisi, Sayı 185, April 2007.