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Features of aircraft structures corrosion damage during storage under COVID-19 restrictions

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Abstract

The article considers the features of aircraft maintenance in accordance with the requirements of the corrosion protection and prevention program. Differences in aircraft maintenance procedures under COVID-19 restrictions are presented. Statistical data on the occurrence of corrosion damage under typical operation and during long-term storage are analyzed.

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1. Introduction

Corrosion is one of the main factors that potentially reduce the strength of the aircraft structure and could lead to the decreasing of the aircraft structure strength during long-term operation.

Tragic examples of such problem are the crash of the Boeing B737-297 of Aloha Airlines in 1988 and Antonov An-24RV of Stavropol Aviacompany near Cherkessk city in 1998. Analysis of the fractures showed the presence of fatigue cracks that had initiated in the focal (initial) zones of the skin damaged by corrosion. In addition, there were numerous through relatively short cracks – multiple site damages (Schijv, J., 1995). Also, presence of corrosion damage changes the failure mode of aircraft structure elements from global buckling to a local failure

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(Matthews, N., 2017). The combination of these factors has a catastrophic effect on the safe operation of the aircraft.

To avoid corrosion on aircraft structures it was a Corrosion Prevention and Control Program (CPCP) developed (Order 8300.12., 1993). CPCP is applied for all primary aircraft structures and for list of structures determined during designing of aircraft under Maintenance Review Board process (Maintenance Review Board, 2016).

CPCP consists of:

- a basic corrosion inspection task,
- inspection zones,
- time of task implementation - implementation thresholds and repeat intervals,
- corrosion levels that defined influence on structure strength and airworthiness.

Nowadays CPCP is an integral part of the Structural Maintenance Program (SMP). The objective of the CPCP is to control corrosion found on all structure listed in the SMP to low level.

The following Corrosion Level Definitions are applicable to each task in this program:

1) Corrosion Level 1:

- Damage occurring between successive inspections that is within allowable damage limits; or
- Damage occurring between successive inspections that does not require structural reinforcement, replacement or new damage tolerance-based inspections; or
- Corrosion occurring between successive inspections that exceeds allowable limits but can be attributed to an event not typical of operator usage of other aircraft in the same fleet; or
- Light corrosion occurring repeatedly between inspections that eventually requires structural reinforcement, replacement or new damage tolerance-based inspections.

2) Corrosion Level 2:

- Corrosion occurring between successive inspections that requires a single re-work / blend- out which then exceeds allowable limits, requiring a repair /reinforcement, or complete or partial replacement of structure listed in the Baseline (developed by Design Organisation) Program, or,
- Corrosion occurring between successive inspections that is widespread and requires a single blend-out approaching allowable rework limits.

3) Corrosion Level 3. Corrosion found during the first or subsequent inspections, which is determined (normally by the operator) to be an urgent airworthiness concern, requiring expeditious action. When Level 3 corrosion is found, consideration should be given to action required on other airplanes in the operator's fleet. Details of the corrosion finding and planned action(s) should be expeditiously reported to the appropriate regulatory authority.

Thus, any operator must develop a maintenance programs (which also includes the CPCP tasks) for each airplane in the fleet. Maintenance programs and schedules will give a list of tasks, with intervals quoted in units of flight hours, flight cycles or calendar time. The operator will use maintenance schedule to suit its own operations. Maintenance tasks implemented at a threshold designed to control an aircraft structure to Corrosion Level 1 or better.

Structural maintenance requirements are determined on the basis of continual maintenance to preserve or restore the inherent corrosion preventive measures and structural surface finishes.

Should corrosion be detected or should the corrosion inhibiting compound exhibit signs of deterioration during the performance of a structural task, the Corrosion Prevention Manual (CPM) should be referred to for appropriate corrective action. The CPM provides general information on inspection, detection, and removal of corrosion as well as preventive maintenance practices for corrosion control. Tasks in which periodic application of corrosion inhibiting compounds are recommended or required are contained in this section of this document.

While the restrictions that has been introduced due to COVID-19 pandemic minimizing, the world of aviation market still in state of gradual awaiting of the possible ways for transportation fleet restoration.

Main problems of the airplane materials degradation, caused by storage and non-intensive airplane's utilization.

The current maintenance programs consist of line and heavy maintenance. Line maintenance are directed to operative rectification of accumulated defects to ensure continuous operation.

The heavy maintenance directed to the inspection and repair of aircraft structure and its systems. It is subdivided into the system and structural checks (so-called C or D-checks). It is necessary to understand that during system checks airplane structure is also inspected, however the structural checks exists in order to maintain proper level of the structure integrity. In particular, the example of such structural check is SI8R6 during which the overall airframe

structure inspected and repaired as required. This is example of a deep and costly inspection that airlines have to conduct every 6-8 years or earlier, depending on aircraft utilization.

The maintenance program, introduced by airplane manufacturers may not cover the expenses and processes that on go during long-term storage and non-intensive flights. In addition, this check does not require special measurement, the removal of additional access panels, or cycling of hatches/doors not normally performed or removed in each particular check.

2. Analysis of corrosion findings

The main criteria for constructional material damage are presence of the low utilization, external weather and any minuscule damage of the external protective layer.

It is impossible to return the airplane utilization level to its usual condition during storage, as well as restore original external protective layer. The only measures to be taken it is usage of the proper storage measures.

The results of corrosion damage detection on a fleet of Boeing 737NG of an European airline were analyzed. Average age of the fleet was 17 years.

According to Advisory Circular (AC No: 43-4B, 2018) an aircraft's operational environment may affect the environment's corrosion severity, placing the operational environment in a mild, moderate, or severe category. It is determined by many factors, including airborne industrial pollutants, chemicals used on runways and taxiways to prevent ice formation, humidity, temperatures, or prevailing winds blowing from a corrosive environment. The corrosion severity of the airline operational environments for the fleet of aircraft operation environmental may be classified as mild and moderate.

The results of practical observation of corrosion during the long-term storage task cards (TC) procedures after COVID-19 restrictions for the 737NG fleet are represented in table 1.

Table 1. Results of B737NG inspections during special storage checks.

TC description	TC performed	TC findings	Relative TC finding, %	Check type
Passenger compartment floor structure -wet area	15	12	80	SI8R6
Forward cargo compartment floor structure	85	68	80	SI8R6
Aft cargo compartment -floor structure	35	35	100	SI8R6
Passenger compartment floor structure -wet area	52	52	100	SI8R6
Aft passenger compartment station 663.75 to aft pressure bulkhead wet area	12	6	50	SI8R6
Passenger compartment door cutouts	5	3	60	SI8R6
Passenger compartment floor structure - wet area	15	12	80	SI8R6

Based on the observed data, the vast amount of the places that were suspended for corrosion are located in the vicinity of the floor structure. The main contribution in the corrosion process has been made by excessive humidity or improper ventilation of these places.

The example of 737NG hard corrosion (Level 2) was found on the pressure fuselage area at the body station BS540, under forward wing-to-body fairing, near the ground air condition connection. A detailed inspection of this area revealed cracks of the external doubler of pressure skin, caused by corrosion. Repair of the damaged skin was planned. The possible cause of corrosion is the accumulation of condensed moisture from the front wall of the central fuel tank, which in turn creates a cell for its accumulation in the lower part of the Body Station BS540. As result water accumulation, corrosion and then cracks occurs.

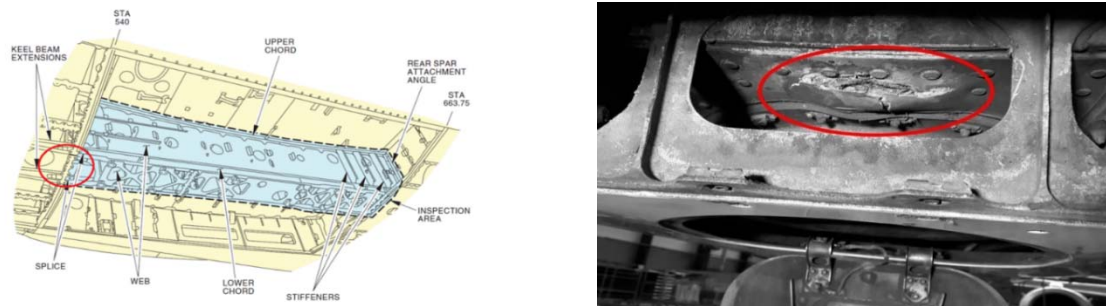


Fig. 1. Location and view of corrosion damage on body station BS540

To determine the level of corrosion damages during storage the results of the corrosion findings before the COVID-19 time storage (taken for 737 fleet from 2008 to 2011) were analyzed. Average age of the fleet was 18 years.

Table 2. Results of B737 inspections during normal operation.

TC description	TC performed	TC findings	Relative TC finding, %	Check type
Passenger compartment floor structure -wet area	17	9	52	C
Forward cargo compartment floor structure	94	44	47	C
Aft cargo compartment -floor structure	42	26	62	C
Passenger compartment floor structure -wet area	17	6	35	C
Aft passenger compartment station 663.75 to aft pressure bulkhead wet area	40	15	37	C
Passenger compartment door cutouts	6	1	17	C
Passenger compartment floor structure - wet area	17	9	52	C

In the next stage of the analysis, the relative results of corrosion findings during storage were compared with the relative results of corrosion findings during normal aircraft operation. The results of the analysis are summarized in a Table 3 and presented in Fig.2. It can be noted that the number of corrosion findings for the same zones has increased by 2 times in average.

Table 3. Comparison of corrosion damage findings results

TC description	TC finding during storage, %	TC finding during normal operation, %	Rate of TC finding changes, %
Passenger compartment floor structure -wet area	80	52	1,51
Forward cargo compartment floor structure	80	47	1,71
Aft cargo compartment -floor structure	100	62	1,62
Passenger compartment floor structure -wet area	100	35	2,83
Aft passenger compartment station 663.75 to aft pressure bulkhead wet area	50	37	1,33
Passenger compartment door cutouts	60	17	3,60
Passenger compartment floor structure - wet area	80	52	1,51

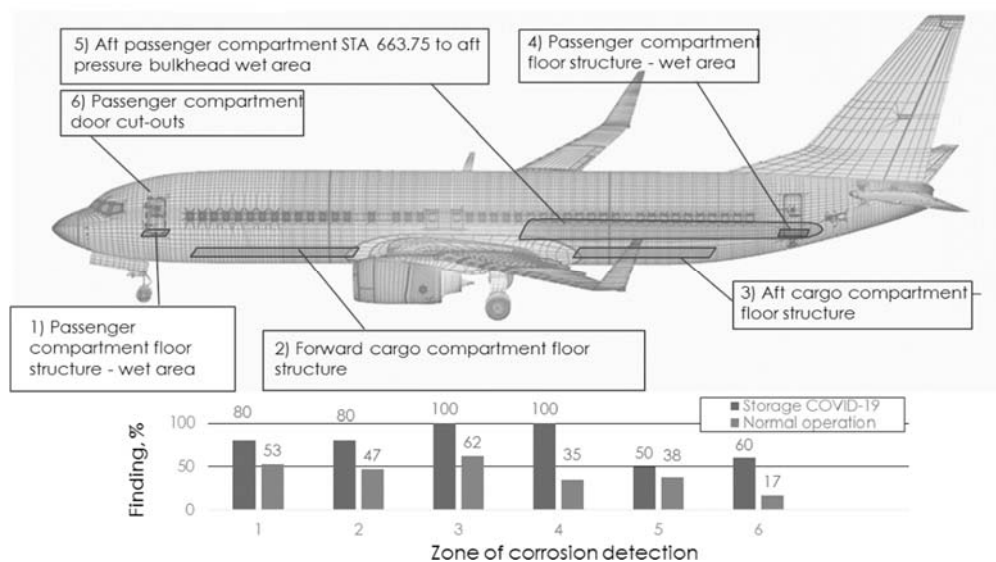


Fig. 2. Distribution of corrosion damage by zone

3. Conclusion

Such results of corrosion damages during long-term storage could be explained by the lack of information on corrosion damage:

- due to the fact that the aircraft were stored in special places in a dry climate;
- aircraft after long-term storage were not returned to operation (analysis of the technical condition of the structure is not carried out)

The proposed method for preventing the structural materials degradation is implementation of additional tasks for the maintenance program such as inspection of the fuselage and wing's lower part in order to prevent the corrosion propagation during storage. In order to create better environment for structural materials the special inhibition compounds such as preservation greases should be applied in order to give appropriate humidity level for structural members. According to the research that were made during observation for the storage process that was initiated by COVID-19 restrictions there were estimated that in general all the structural materials degradation has been observed because of excessive humidity level. The additional cause for the structural material degradation has been made by absence of the adequate procedures for the enhanced maintenance program inspections. Such measures as implementation of additional inspections of the part that subjected to the corrosion accommodation (mainly the lower part of the fuselage and wings) should have been implemented in the nearest time in order to prevent possible damages that occurs during long-term storage.

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