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Galvanic corrosion of aircraft bonded joints as a result of adhesive microcracks

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Abstract

This paper studies the root causes of a corrosion failure found in the Airbus A320 CFM56-5b intakes. This failure occurs in a dissimilar materials joint and is strongly related to the adhesive loss of integrity at very low temperatures. The ductility reduction of the adhesive at low temperatures promotes the microcracks formation within the adhesive layer of the bonded joint, which in turn sparks the corrosion process. These microcracks allow the infiltration of dust, moisture, contaminants and salt water in the interface between the adhesive and adherents, which promotes the creation of a dielectric between the joint adherents and consequently their galvanic corrosion. Results show that the thermal strains of the dissimilar joint materials at very low temperatures significantly reduces the adhesive load margin reserved for drag loads. Some remarks are drawn in order to improve the joint corrosion resistance.

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Aircraft bonded joint; epoxy adhesive microcracks; galvanic corrosion; aluminium alloys; adhesive selection;

1. Introduction

Scientific based research in corrosion of composite aircraft structures has been made during decades, especially in aluminium sandwich structures. Currently, the 2024 T3 (duraluminium) and 7075 T6 aluminium alloys are the most studied where the major focus has been on pre-treatments, coatings, and eco-friendly approaches in corrosion prevention processes Bierwagen et al. (2010). The front end of recent corrosion research is on the pursuit of alternative coatings based in nano-particles in order to achieve effective barriers to corrosion in aluminium aerospace alloys Voevodin et al. (2006). Moreover, corrosion research has been also focused in corrosion resistance improvement of aluminium alloys by developing new heat treatments. The major objective is to reduce the aluminium alloys susceptibility to stress-corrosion cracking, which has creating huge concerns about air transport safety Cina (1974). In general, the presence of corrosion damage reduce the fatigue lives of components to a severe extent and has been the focus of intense research in the 7075 T6 aluminium alloy DuQuesnay et al. (2003). Moreover, on this same alloy, studies were

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conducted to modelling the effect of exfoliation corrosion in the fatigue strength of corroded structures Liao et al. (2007). In these studies non-destructive evaluation techniques has been used to correlate the exfoliation level with the structure remaining fatigue life. Non-destructive testing techniques (NDT) have been playing a important role in corrosion research, specially in the field corrosion monitoring and repairs on condition Achenbach and Thompson (1991). In this paper, a corrosion failure commonly found in the A320 turbofan intakes is analysed. This failure occurs in the contact region between the intake acoustic panels and the titanium attachment ring. Figure 1 depicts the A320 intake geometry, and the corrosion failure spot. The intake inner barrel comprises three acoustic panels made of aluminium sandwich structures attached to the titanium ring with lockbolts, please see Figure 1 b).

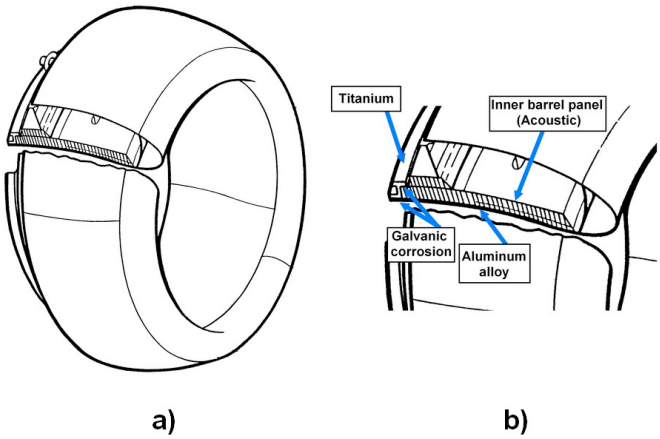

Fig. 1. A320 intake a) geometry and assembly b) inner barrel panel.

Figure 2 shows a typical corrosion pattern found in the intake acoustic panels where galvanic corrosion is found between the titanium ring and the aluminium doubler. The galvanic dielectric has its root causes in the adhesive microcracks, therefore understand the integrity loss of the bonding adhesive is crucial to fully characterize this failure. Microcracks are strongly related to high stress levels experienced by the bonding adhesive, thus in this study it is performed a finite element analysis to understand the loading type and stress level that cause the adhesive damage. The focus in simulations was the low temperature effect on the adhesive integrity by correlating the thermal stress level at the dissimilar materials interface with the adhesive shear lap strength. The major concern was the stress levels at the interface place between the titanium attachment ring and the aluminium doubler. Titanium and aluminium have different thermal expansion coefficients, thus under low temperatures they will experience different contraction strains. Due to that, in the dissimilar materials interface, we will find a relative contraction resulted from different strain levels, which creates interface stresses. These stresses will be the same experienced by the adhesive, since its function is to bond both surfaces without slipping.

2. Materials and Methods

The A320 acoustic panels are made of two aluminium alloys, namely the AA 2024 T3 for the outer skins and doublers and the AA 5052 for the honeycomb core. Moreover, the bond adhesive of the titanium-aluminium joint is the Hysol EA 934, which is a first-generation adhesive. In this study, the bond performance of a second-generation adhesive, the Hysol EA 9394, is correlated with the EA 934 strength for several thermal loadings. The idea is to inspect the viability of replacing the EA 934 by the EA 9394 adhesive in order to improve the joint resistance against corrosion. Figure 3 shows the EA-934 and EA-9394 stress vs. strain response at room temperature. The trend lines of these curves depicted in each graph will be used to estimate the adhesive thermal stresses.

The temperature range of structural adhesives is high; usually the working temperature ranges from -50 °C to 150 °C. At high temperatures they have a ductile behaviour, but at low temperatures they are brittle and become prone to microcracks formation. During the life cycle of an aircraft is more likely that they experience more often very low temperatures in the field than high temperatures, especially the ones near the upper working limit, which only occur

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