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# Effect of surface treatment on adhesively bonded aluminium-aluminium joints regarding aeronautical structures

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ABSTRACT

The structural integrity of several structures could be determined by their joints strength. Over the years, adhesively bonded joints have been often chosen to achieve a compromise between mass reduction and higher mechanical strength. Among others, the reduction in stress concentrations, the ability of producing smooth surfaces with no discontinuities and the reduced weight penalties are some of the factors that make this type of joints so attractive. Normally, to increase the bond strength, the materials to be bonded must be subjected to a kind of surface treatment. For metals, and more specifically, for aluminium alloys, phosphoric acid anodizing and chromic acid anodizing have been the most used treatments worldwide. However, recent investigations show that these kinds of anodizing are detrimental to health due to the release of carcinogenic substances. With this in mind, it is of the utmost importance to find alternative surface treatments that can ensure an effective bond. In this paper, a vast experimental study was performed based in the single lap joint ASTM D 1002 standard method, with the objective of determining the best alternative surface treatment (Sulfuric Acid Anodizing and Boric-Sulfuric Acid Anodizing), for aluminium-to-aluminium joints, using two types of adhesives, namely the AF 163 and the EA 9658 AERO. Results show that the optimum surface treatment is different for each type of adhesive and this fact has a huge influence on mechanical behavior of this type of aeronautical adhesive joints.

## 1. Introduction

With the advances in manufacturing techniques, several improvements have been verified in structural adhesives. As a direct result of these improvements, the use of bonded joints in several aeronautical structures became very common nowadays.

Between other advantages, adhesively bonded joints allow a better load distribution, increases the service life, reduces machining cost and reduces the production complexity [1,2].

Despite the many advantages, bonded joints also suffer from a significant number of limitations. Among others, one can identify the bad adhesion to some substrates, weak resistance to cleavage stresses, degradation due to exposure to hostile environments and the difficult compromise between the quality of bonded joints and their costs [3].

However, in contrast to more conventional joining techniques, the major concern related with adhesively bonded joints is the lack of accepted guidelines to predict the joint strength. The aerospace industry, which has been developing the technology, is still

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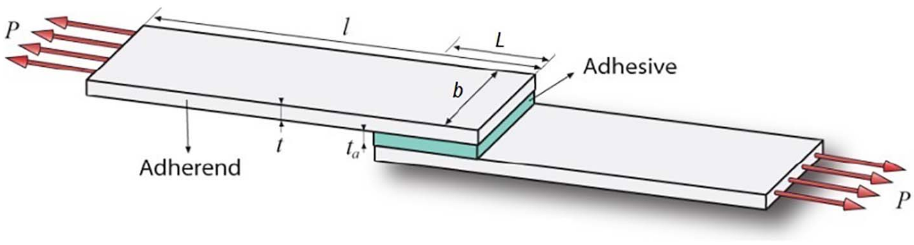


**Fig. 1.** Single lap joint, taken from A. Çalik [8].

designing joints mainly based in previous experience and rules of thumb.

Several studies show that the bond strength of an adhesively bonded joint depends on many factors, such as the bonded area, the environment in which the structure will be operating, the service temperature, the type of surface treatment applied to the adherents and, of course, the type of adhesive used [4–6].

Actually, some of the adhesives usually used to repair engine nacelle structures are being discontinued, so in some cases, it is of the upmost importance to find new adhesives that present a mechanical behavior equal or better than the old ones specified in the original design.

Moreover, there is a need of using surface treatments not detrimental to health, meaning that surface treatments such as phosphoric acid anodizing (PAA) and chromic acid anodizing (CAA) cannot be used due to regulatory directives, although they were used in the original design [7].

In this context, the objective of this paper is to find new alternatives to the Hysol EA 9689 adhesive, an adhesive produced by Henkel Loctite commonly used in aircraft repairs, which was recently discontinued. To achieve that, the mechanical behavior of aluminium-aluminium adhesively bonded joints was studied, considering two different adhesives, namely the AF163 and the EA9658 AERO. To improve adherence between adhesives and subtract, two different surface treatments were also considered, the Sulfuric Acid Anodizing (SAA) and the Boric-Sulfuric Acid Anodizing (BSAA). These surface treatments are not detrimental to health and are good alternatives to the PAA and CAA surface treatments.

The experiments were made using the ASTM D 1002 standard, which is based on the Single Lap Joint (SLJ). The SLJ present in Fig. 1, is one of the bonded joints most used in an aircraft, especially due to the ease of produce, inspect and repair [8].

## 2. Theoretical background

When the SLJ is analyzed theoretically or computationally, it is normally assumed a perfect adherence between the adhesive and adherents, with the failure occurring in the adhesive layer.

However, in real joints, this is not always the case and other types of failure can occur, especially failures related to the adherence between adhesive and adherent, please see Fig. 2. Due to this reason, the adherents' surface is usually treated with electrolytic passivation processes such as PAA or CAA. Furthermore, there are products that must be applied after the surface treatment and prior to the adhesive application, the so-called adhesion promoters and primers that, as well as the surface treatments, helps to improve the adhesion and, consequently, the strength of the joint.

### 2.1. Types of failures

When destructive tests are being performed in bonded joints, good indicators of the joint strength behavior are given by analyzing the adhesive layer after failure. In an adhesive joint, there is the need to assure a perfect adhesion between the adherents and the

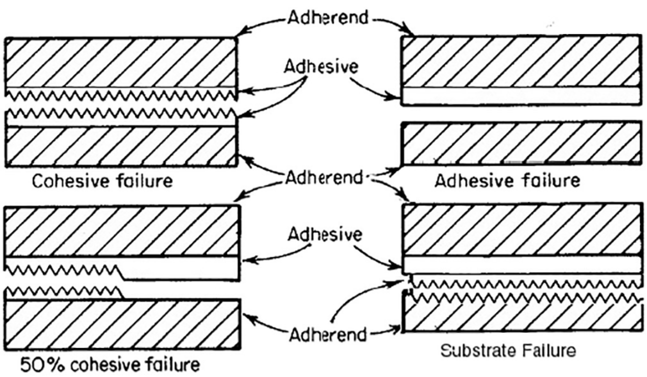


**Fig. 2.** Failure types in a bonded joint: cohesive failure on the top left; adhesive failure on the top right; adhesive-cohesive failure on the bottom left; adherent failure on the bottom right, taken from *J. Tomblin* et al. [10].