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Effect of plasma treatment in Aluminum and composites bonding joints: Shear load tests results

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Abstract

This paper presents the results of simple adhesive lap joint shear strength tests of materials under atmospheric plasma treatment conditions. The effects of surface activation of the shear joint by cold atmospheric plasma in the perspective of the adhesion promotion are discussed. Specifically, the changes in the maximum strength introduced by the plasma of coupon samples of aluminum and carbon fiber reinforced materials. Finally, the results of tests and some conclusions are reported.

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Keywords: plasma treatment; tests; adhesion promotion; composites; bonding

1. Introduction

The search for new more integrated light weight structures requires enhancement on the bonding joints mechanical properties. Currently some stiffened panels in aeronautics applications rely on fastened stringers to resistant shear panels. The adhesion promotion enhancements can enable the fasteners elimination, weight reductions and lower number part count.

In the other hand, the effect of plasma treatment on surface modification and the relevance to adhesion has been investigated and is available in literature [1].

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This document summarizes the studies, developments, tests and analysis that support the quantification enhancement on plasma treatment on bonding mechanical properties. The materials investigated are the most used in aeronautics applications, aluminum and carbon fiber reinforced plastics, composites.

The plasma source, or plasma torch, provides the atmospheric cold plasma. It has been developed specifically for the purpose of the objectives reported in this paper. The physical, electrical and electronic parameters of the plasma torch are not part of the scope of this paper. These plasma torch studies and development included the definition of the structure and frequency of the electric current input in relation to the gas- air- flow rate and the plasma temperature control, to cite the most relevant ones.

The shape of the plume was designed with certain geometry parameters and a dense plasma length between 15 and 25 mm. Also the design requirements included that a non specialist worker could operate it. The surface treatment process is developed to be easy to control and operation in room temperature/ ambient conditions as in a workshop set up.

The goal of this paper is to verify the surface activation after plasma treatment in terms of failure lap shear stresses in the bonding joints. The trials and tests are performed to achieve statistically relevant results. This document contains the procedures followed to provide the sample coupons, materials, and plasma activation parameters. Then the results of the shear load tests are provided with an analysis of results, conclusions and some recommendations on potential actuation follow up lines.

Nomenclature

Al	Aluminum
ASTM	American Society for Testing and Materials
CFRP	Carbon Fibre Reinforced Plastics
IPA	Isopropyl Alcohol

2. Methods and procedures

The surface treatment consisted on applying the plasma plume to the area under bonding conditions. The separation of the plasma source is within the length of the dense plume. The treatment is performed in the two sides of the coupons to be joined.

The plasma was applied during 10 minutes and uniformly along the surfaces to be joined and tested. The surface to be bonded is completely plasma processed. The plasma torch is physically separated between 15- 25 mm from the surface.

In order to avoid surfaces contamination, the two sides of the coupons were immediately joined by adhesive film and autoclave curing up to 180ºC.

Finally, in order to obtain the required coupon sizes for ASTM single shear tests [2-3], 1.6 mm thickness, 25.4 mm width, 177.8 mm long, squared bonded area 25.4 x 25.4 mm^2, the panels are cut in 6 to 8 coupons with a mechanical operation.

3. Materials

The materials to join are aluminum, Al, and composites, CFRP Carbon Fiber Reinforced Plastics. The aluminum selected is 2024- T42 sheet form [4]. The composite samples are pre-impregnated fabric carbon fiber reinforced plastics based on epoxy resins 180º curing temperature. The laminate is composed by 6 plies. The bonded joints under testing are Al- Al and CFRP- CFRP. It has not been considered hybrid joints Al- CFRP for these studies.

3.1. Aluminum coupons

The aluminum coupons are prepared under four different conditions:

- Aluminum coupons “as is”. The surface is just cleaned by isopropyl alcohol (IPA) application [5], typical 2 minutes abraded with IPA wetted cloth.