AerospaceEurope Conference2020
BORDEAUX, FRANCE | 25 - 28 FEBRUARY 2020

Generating durable Ti/CFRP adhesive joints for aerospace structures by laser pretreatment

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KEYWORDS: laser, surface treatment, adhesive bonding, titanium

ABSTRACT:

Adhesive bonding of a microperforated titanium panel to a CFRP substructure is an innovative way to build a control surface (like wing or HTP) with hybrid laminar flow control. Pretreatment of titanium is essential to achieve a durable adhesive joint. IR laser and UV laser were compared for pretreatment of grade 2 titanium that was subsequently bonded with RTM6 resin. We report on the analysis of surface modifications by electron microscopy and of the adhesion properties by DCB testing.

1. INTRODUCTION

Reducing the CO_2 footprint is a key issue for the aero-industry in Europe. Drag reduction from skin-friction can be achieved by so called Hybrid Laminar Flow Control concepts (HLFC). The HLFC technology aims to remove large areas of turbulent flow at the main areas of the fin, the horizontal stabilizer or the wings by means of a suction system. Thereby high-lift performance is improved, additional engine thrust is avoided and consequently extra fuel burn and CO_2 emissions are reduced. A key technical issue is to build the HLFC structure as light and as cost-efficient as possible. This goal can be achieved by adhesive bonding of a microperforated titanium panel to a CFRP substructure housing the suction system. High demands on the structural integrity and durability of the Ti/CFRP joint exist. Typically, these can only be met with an adequate surface pretreatment of the titanium panel [1, 2]. Here we report on the study of laser treatment to improve bond strength and bond durability for this task.

2. EXPERIMENTAL

Grade 2 titanium was bonded with RTM6 resin and cured at 180 °C for 45 min. The IR laser system was from Cleanlaser (Nd :YAG CL300) with emission at 1064 nm. The UV laser system was from Coherent (CompexPro205 F) with emission at 248 nm (KrF). The titanium surface was analyzed by scanning electron microscopy (SEM) using a LEO Gemini 1530. For DCB testing a sample size of 110x25 mm was used. The thickness of the titanium was 0.8 mm and the thickness of the RTM layer was 0.2 mm.

3. RESULTS AND DISCUSSION

For surface preparation the titanium surface was pretreated using the IR laser or the UV laser. Fig. 1 compares the surface modification as observed with a scanning electron microscope (SEM) for the different treatments.

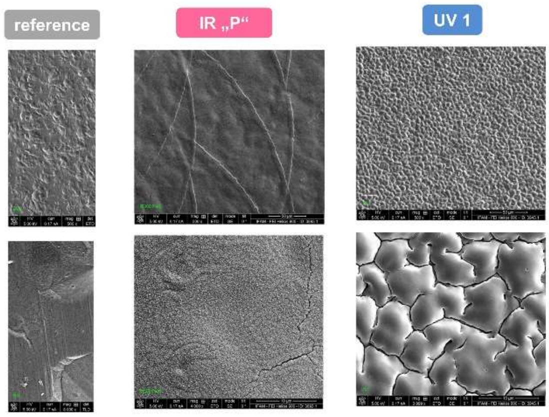

Figure 1. SEM images of the titanium surface. Magnification is 500x and 4000x for top and bottom row, respectively.

In comparison to the reference titanium surface both laser treatments alter the surface topography significantly. The IR laser treatment leads to the formation of a porous-like structure at the surface and the specimens are denoted “IR P” in the following. In contrast, the UV laser treatment induces a clod-like structure with superficial cracks at the surface and the corresponding specimens are denoted as “UV 1”.

To check the durability and bond strength, the surface of titanium specimens were prepared by the different laser treatments. Subsequently specimens were bonded with RTM6, aged under hot/wet conditions (80 °C and 50% rH) for up to 3000 h and then tested using DCB-type testing.

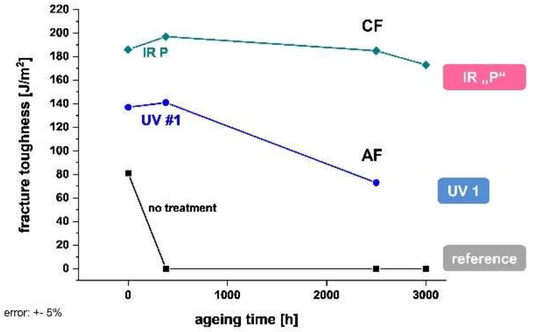

Figure 2. Fracture toughness as a function of ageing duration.

Fig. 2 shows the fracture toughness as a function of ageing duration for the different laser pretreatments. Both, the reference samples and the UV laser treated samples show a strong decrease in fracture toughness with ageing duration. Also in both cases an adhesive failure mode (AF) is observed. In contrast, the specimens with IR laser treatment do not show a decline in fracture toughness, even after 2500 h of ageing. As Fig. 3 shows, also a cohesive failure mode (CF) is still observed after this time.

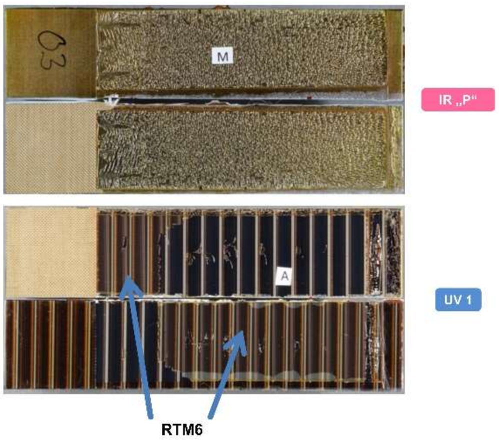

Figure 3. Fracture surface after DCB testing for IR and UV laser treatment after 2500 h of ageing.

The excellent stability of the titanium surface towards hot/wet exposure conditions can be also seen from Fig. 4.

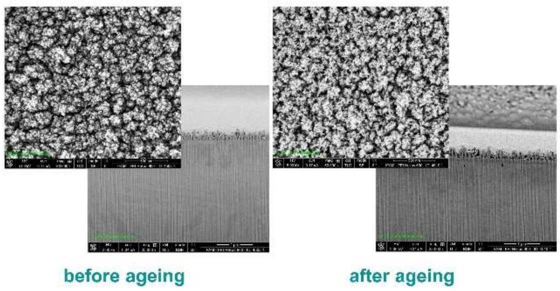

Figure 4. SEM images of the porous titanium surface in top view and as cross-section. (Magnification 60,000 x for top view and 25,000 x for cross section)

Fig. 4 shows the titanium surface after IR laser treatment before and after ageing (1000 h) in top view and as a cross-section. For this experiment the bare titanium surface was exposed to the environment in the climate chamber. No significant change in topography or thickness of the porous titanium layer by the hot/wet conditions is observed. This property of the titanium surface is considered to be essential in achieving a durable adhesive joint as shown in Fig. 2.

The results indicate that treatment with IR lasers can potentially be used successfully for pretreatment of titanium to manufacture titanium/composite joints of high quality and durability as required by the aero-industry. In addition, the laser treatment provides a « green » manufacturing technology eliminating the use of wet chemical processing of titanium.

4. REFERENCES

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5. ACKNOWLEDGMENT

Funding by the Cleansky 2 JTI is gratefully acknowledged.