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Laser-Generated Macroscopic and Microscopic Surface Structures for the Joining of Aluminum and Thermoplastics using Friction Press Joining

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Abstract

Structural lightweight construction is increasingly utilized in the aerospace and automotive industry. Hybrid structures have great potential, especially with regard to load-specific component layouts. Usually, a surface pre-treatment is applied prior to joining dissimilar materials to improve bonding mechanisms such as form closure. In previous studies pulsed wave (pw) lasers were used for structuring metals. This paper presents the results of aluminum pre-treatment via a continuous wave (cw) single-mode fiber laser: macroscopic and microscopic structures were generated on the aluminum surface; the samples were joined with glass fiber reinforced polyamide using Friction Press Joining (FPJ), a method for joining metals and thermoplastic polymers in lap joint configuration. Using these new methods for surface structuring, shear strength was increased by 40 % compared to previous studies with pw lasers.

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Keywords: Laser Surface Treatment; Microscopic; Macroscopic; Friction Press Joining

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1. Introduction

In the aerospace and the automotive industry structural lightweight construction is essential for reducing the vehicle's overall mass and as a consequence the usage of fuel and energy. Current examples like the Airbus A380 and the BMW i3 show an increasing use of hybrid structures, using different metal alloys and polymers according to the particular requirements of the application. The development of new joining technologies is necessary for these materials since many conventional joining methods are not adequate. As an example, composite structures in the wing of the A380 were attached to the wing's metal skin by bolted aluminum brackets. Cracks occurred in these brackets during the operation of the aircraft leading to damage of the component [1]. A novel method for joining metals to thermoplastic (fiber reinforced) polymers in an overlap configuration is Friction Press Joining (FPJ). FPJ is based on a similar principle as Friction Stir Welding (FSW), except that no pin is used with the tool. A rotating tool is pressed onto a metal workpiece with an axial force (Fig. 1). The friction between the tool and the workpiece generates heat, which is conducted through the metal to the joining area, where the thermoplastic polymer is plasticized. A combination of the axial force and the plasticization causes a wetting of the metal surface with the polymer. The tool is then moved over the workpiece in a continuous movement. After the polymer cools, metal and polymer are joined. The involved bonding mechanisms are believed to be majorly induced by a form closure, but molecular adhesion also plays a role. Therefore, suitable techniques for surface structuring of the metal are required to improve the bonding mechanisms and to form a reliable joint.

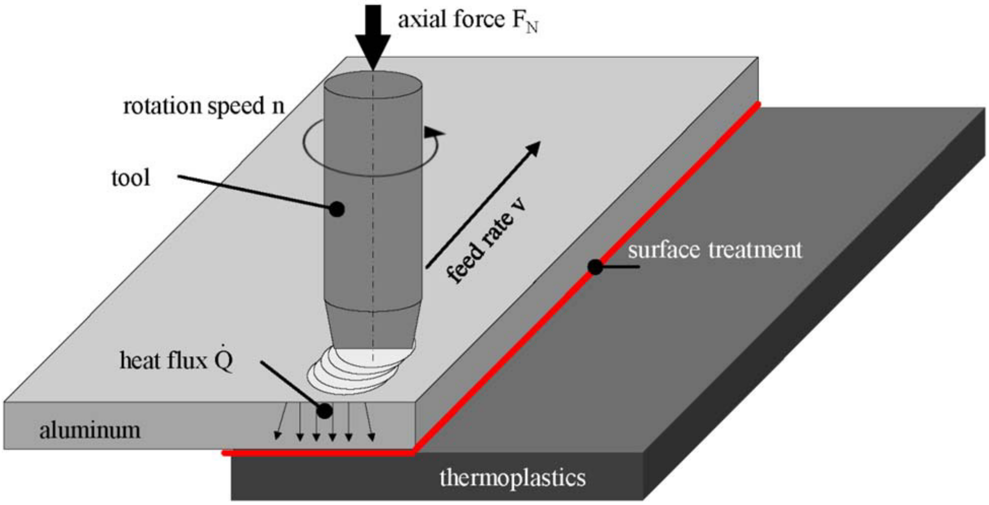

Fig. 1. Principle of Friction Press Joining (FPJ).

2. State of the Art

Fig. 2 shows methods for surface treatment of metals, which can be divided into mechanical, chemical and photonic processes. In previous studies [2, 3] a selection of these methods was examined with regard to their suitability as a pre-treatment of aluminum prior to FPJ with glass fiber reinforced polyamide. The shear strength was tested according to DIN EN 10002-1. Milling did not create undercuts for the polymer and the structures generated caused a notch effect, which led to the failure of the joint. Other mechanical processes like stamping and brushing did not result in high tensile shear strengths. Corundum blasting showed the best results out of the group of mechanical surface treatments with a shear strength of approximately 8 N/mm². Chemical processes like CAA (Chromic Acid Anodizing) created suitable surfaces for FPJ, but the achievable shear strength was lower than for corundum blasting. Additionally, the process of anodizing is complex and requires handling hazardous substances. The highest shear strength of approximately 10 N/mm² was achieved with surfaces structured by pulsed wave (pw) laser systems. The structures generated by this process were nanoscopic to microscopic.