Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 13 (2017) 671–678

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

Manufacturing Engineering Society International Conference 2017, MESIC 2017, 28-30 June 2017, Vigo (Pontevedra), Spain

Laser Texturing and Dissimilar Material Joining

E. Ukar[a,*], F. Liébana[b], M. Andrés[b], I. Marcos[a], A. Lamikiz[a]

[a]*Mechanical Engineering Dpt. (UPV/EHU), Pl. Torres Quevedo 1, Bilbao, 48013, Spain*
[b]*TECNALIA Research & Innovation, Parq. Tec. Bizkaia, C/Geldo Ed.700, Zamudio 48160, Spain*

Abstract

Laser texturing is a process used to remove material selectively. Metallic parts were processed in order to create a surface texture that enables metal-polymer joining. This kind of dissimilar joining is carried out combining a pressure fixture and heating using a direct diode laser source. In order to reach a good result, it is critical to texture the surface with correct parameters to generate surface features that maximizes the contact between materials and heating enough the materials to soften the polymer but without melting and degrading the material, so, a temperature control system is necessary to get best results. In this work, the texturing capabilities of conventional CW laser source were explored and numerical model was developed in order to simulate and control the process temperature in the joining interface.

Peer-review under responsibility of the scientific committee of the Manufacturing Engineering Society International Conference 2017.

Keywords: Laser texturing, dissimilar joining, modelling

1. Introduction

Laser texturing is a process used to remove material selectively. In metal parts, the material must be evaporated during the process. In order to minimize the heat input short and ultra-short pulse laser sources are typically used. Nevertheless, in some applications this is not a critical fact and conventional pulsed laser sources can be used. These applications include dimple generation to reduce friction coefficient [1] or surface texturing to improve

* Corresponding author. Tel.: +34 946014905; fax: +34 946014215.
E-mail address: eneko.ukar@ehu.eus

2351-9789
Peer-review under responsibility of the scientific committee of the Manufacturing Engineering Society International Conference 2017.
10.1016/j.promfg.2017.09.142

osseointegration in medical applications [2]. Another application is surface texturing to improve material adhesion in plastic-metal dissimilar joints.

In the automotive industry weight control in body-in-white structures is becoming a critical point in order to reduce weight and meet the actual environmental legislation. Combination of dissimilar materials allows significant weight reduction with optimal mechanical strength in critical areas [3]. One of the most interesting material combinations is aluminum and glass fiber reinforced plastic. Aluminum alloys present relatively high strength and high corrosion resistance, on the other hand, glass fiber reinforced polymers also have high strength-to-weight ratio and are easy to process. Combination of these two materials is interesting for automotive light parts manufacturing but the joint between them is still a critical point that must be addressed. Mechanical fastening [4] and adhesive bonding [5] are conventional methods to joint materials that cannot be welded. Mechanical fastening includes additional elements like rivets or bolts that increase the total weight and induce severe stress concentration, with direct impact on the mechanical properties. For adhesive bonding, the mixture of reactive components has to be spread on the substrates and wait until curing reaction is completed, making these joining process time consuming and unsuitable for massive industrial manufacture. As alternative, a combination of a pressing fixture with local heating by a laser beam allows joining the materials by partial melting of the polymer. In order to reach a solid joint it is necessary to previously prepare or texture the metal substrate. Solutions like surface anodizing are proposed on the literature [6] to improve the result. Anodizing takes from 10 to 30 minutes and needs aluminum part preprocessing. Other alternatives like laser texturing are faster, give similar results and are easy to implement using a conventional fiber laser [7].

In order to reach shear strength values over 25MPa, both, previous texturing and process parameters, must be optimal. With laser surface texturing the contact surface between materials is maximized but, this textured surface must be different depending on wettability and melt flow rate of the polymer. Typically, polymers with low melt flow rate require a texturing with less peak-valley height in comparison with high melt flow rate polymers, which are able to fill narrower features [7]. In the literature peak-valley height between 20 and 10µm is considered optimal for dissimilar joining [8]

Another key point in the joining process is the pressure and the temperature in the joining surface. Closed loop temperature control using a pyrometer is one of the best and most reliable ways to adjust the laser power in order to get a constant welding temperature. This control system is widely used in laser hardening process and can be used in dissimilar welding when direct access to joining surface is possible [9]. In metal-polymer laser joining, the laser heats the face opposite to the joint and there is no direct temperature control. On the other hand, depending on the scanning path followed during the heating, the thermal field in the joint interface is different and power cannot be corrected considering only the aluminum sheet thickness. Numerical simulation of thermal field is an alternative, but factors such us, laser energy distribution, the scanning path and material properties must be correctly modeled in order to get a useful tool.

The main target in the present work was to develop a reliable process for metal-plastic direct joints. To get successful joints was necessary to develop correct laser texturing parameters and develop a laser power control system in order to avoid plastic material over-melting or under-melting during the process. In this work, a conventional laser source was used in pulsed mode to modify the surface and prepare it for plastic-metal direct joint. The texturing was developed using a conventional CW laser, which is typically used in laser cutting and joining applications and is considered as unsuitable for laser texturing applications. Finally, a specific close-loop control was developed based on thermal field, which is calculated using own developed thermal model.

2. Laser texturing

The experimental tests were carried out using a 1kW fiber laser from ROFIN in combination with a scan-head from SCANLAB which maximum working space is 120x120mm. The maximum scanning speed of the scan-head is 10,000mm/s. On the other hand, the fiber laser wavelength is 1,060nm and the spot size is 100µm in diameter. The laser source can be operated in CW or pulsed mode up to 5kHz. This frequency determines the cycle duration time, not pulse duration. On the other hand, duty cycle parameter, given in percentage, adjusts the percentage of time within the cycle that laser source is switched on. So, the resulting pulse duration is controlled with both, pulse frequency and duty cycle percentage. For laser texturing operations the laser must be operated in pulsed mode. Since pulse duration