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Temperature controlled laser joining of aluminum to galvanized steel

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Abstract

Reliable joining of 6000 series aluminum alloy to galvanized steel is a challenge for current manufacturing technologies. To control and limit the formation of brittle intermetallic phases, mixing of both metals in liquid state has to be avoided. It has been shown that laser weld-brazing is a possible process. Thereby the aluminum and zinc layer of the galvanized steel are molten and the steel remains solid during the process. In addition, to avoid zinc degassing, the aluminum melt bath temperature has to be below zinc boiling temperature of 907°C. To meet these requirements a temperature controlled laser process was developed, allowing to join the two materials without flux and filler material. The thickness of the intermetallic layer shows a dependency on the set temperature used to control the process. At optimum set temperature the thickness of intermetallic phases can be limited to about 5 µm. Tensile strengths of the joints of up to 75% of the aluminum base material were achieved.

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Keywords: Laser joining; dissimilar materials; temperature control; intermetallic phase

1. Introduction

Multi-material constructions like aluminum with steel are more and more demanded by car manufacturers, driven by the aim to reduce weight in car body construction. This enhances the interest of dissimilar metal joints by laser joining technologies. However, laser joining of aluminum to steel is a challenging task due to their incompatibility.

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Mixing both materials in liquid state leads to a complex formation of brittle intermetallic phases. The differences in melting points of aluminum and steel can be used to limit the formation of intermetallic phases in the weld. This can be realized by a laser weld-braze process. Thereby the aluminum is molten in a heat conduction laser weld process whereas the steel remains solid. A schematic illustration of this process is shown in Fig. 1. The solid steel dissolves in the aluminum melt, and intermetallic layers are formed only at the Al-St interface. The growth of intermetallic phases is dependent on the temperature at the Al-St interface and the process duration which has been investigated in detail by Bouayard et al. (2003). The intermetallic layer has to be less than 10 µm to achieve good mechanical properties for this joining process. This has been shown by Radscheit (1997) and was confirmed by Laukant (2007). It has been shown in several experimental studies that a zinc-coating on the steel sheet must be present to obtain wetting for the liquid aluminum on the solid steel, if not using a flux. This is mostly due to the fact that on galvanized specimens aluminum spreading occurs on a liquid zinc layer (T_{melt} = 419°C[1]) and not on a solid steel. A review on these studies is given by Gatzen et al. (2014).

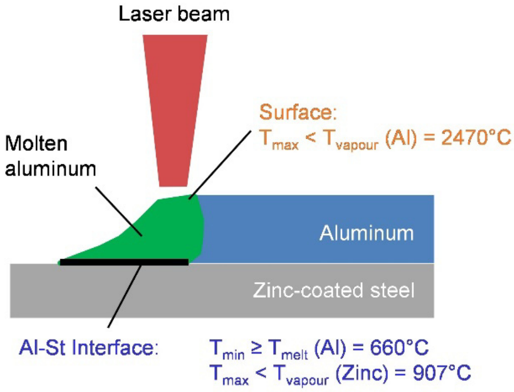

Fig. 1. Schematic illustration of laser weld-braze process for fillet weld condition.

To establish a stable process regime the temperature at Al-St interface has to be above the melting point of aluminum which is at 660°C[2]. In addition, to avoid zinc degassing, the aluminum melt bath temperature has to be below zinc boiling temperature of 907°C[1]. To stay in a heat conduction laser weld mode the temperature at the surface of the molten aluminum has to be below the boiling temperature of 2470°C[2].

A temperature controlled laser process was developed to meet these requirements, allowing to join the two materials without flux and filler material.

2. Conception of temperature controlled joining process

2.1. Experimental setup

The schematic setup for the temperature controlled joining process is drawn in Fig. 2(a). The experiments were done with a TruDisk 5001 laser and a delivery fiber with 200 µm core diameter. The laser has a maximum output power of 5000 W at the wavelength of 1030 nm. To focus the laser beam on the workpiece a dual beam optics was used. Each focus diameter was 750 µm and the power distribution was kept constant at a ratio of 50:50. The distance of the spots was 1.68 mm. Both spots were placed on the aluminum sheet. The center of the laser spots was positioned 2 mm away from the sheet edge, as depicted in Fig. 2(b). The experiments were performed in a fillet weld configuration. The dimensions of the specimen were 45 mm x 105 mm with an overlap of 35 mm in

[1] MatWeb: http://www.matweb.com/search/DataSheet.aspx?MatGUID=8909140a76074049809ad74d536ed606, 06.05.2016, 14.44 CET.
[2] Aluminium Taschenbuch, Kammer, C., 15. Edition, Aluminium-Verlag Düsseldorf, 1995, pp. 61.