Available online at www.sciencedirect.com
ScienceDirect
Physics Procedia 83 (2016) 523 – 531
Physics Procedia

9th International Conference on Photonic Technologies - LANE 2016

Novel approach to increase the energy-related process efficiency and performance of laser brazing

C. Mittelstädt[a],*, T. Seefeld[a], T. Radel[a], F. Vollertsen[b]

[a]*BIAS – Bremer Institut für angewandte Strahltechnik GmbH, Klagenfurter Str. 2, D-28359 Bremen, Germany*
[b]*BIAS – Bremer Institut für angewandte Strahltechnik GmbH and University of Bremen, Klagenfurter Str. 2, D-28359 Bremen, Germany*

Abstract

Although laser brazing is well established, the energy-related efficiency of this joining method is quite low. That is because of low absorptivity of solid-state laser radiation, especially when copper base braze metals are used. Conventionally the laser beam is set close to the vertical axis and the filler wire is delivered under a flat angle. Therefore, the most of the utilized laser power is reflected and thus left unexploited. To address this situation an alternative processing concept for laser brazing, where the laser beam is leading the filler wire, has been investigated intending to make use of reflected shares of the laser radiation. Process monitoring shows, that the reflection of the laser beam can be used purposefully to preheat the substrate which is supporting the wetting and furthermore increasing the efficiency of the process. Experiments address a standard application from the automotive industry joining zinc coated steels using CuSi3Mn1 filler wire. Feasibility of the alternative processing concept is demonstrated, showing that higher processing speeds can be attained, reducing the required energy per unit length while maintaining joint properties.

Peer-review under responsibility of the Bayerisches Laserzentrum GmbH

Keywords: laser brazing; galvanized steel; process monitoring; efficiency

1. Introduction

In recent years efficiency is becoming more and more important for manufacturing in general. In this context laser processing offers great opportunities, but a profound understanding of the respective process is necessary to exploit its potential, as suggested by Bley et al. (2007), who investigated welding of zinc-coated steels. These steel

* Corresponding author. Tel.: +49-421-218-58-030 ; fax: 49-421-218-58-063 .
E-mail address: mittelstaedt@bias.de

Peer-review under responsibility of the Bayerisches Laserzentrum GmbH
doi:10.1016/j.phpro.2016.08.054

grades are widely used in the automotive industry, which motivated further investigations to focus on defect-free welding (cf. Milberg and Trautmann 2009). Wilden et al 2009 pointed out that a substitution of welding by brazing is a step towards resource and energy efficient joining in the product life cycle. Besides pores and spatter are often an issue for laser welding according to Schmidt and Kägeler 2008. Also for this reason laser brazing with copper-base filler wire has become one key joining technology in the modern automotive industry. The technique is widely used for joining zinc-coated parts of the outer bodywork, which are typically exposed to the customer's eye. More specifically Kimpel 2013 examplifies that to be e. g. joining the roof to the side panel, parts of the trunk lid, etc.. In each case the customer exposed parts demand the highest possible surface quality, which is of course including leak-tightness. At best the joint does not appear like a joint after finishing.

Compared to alternative joining techniques, like e. g. arc brazing, laser brazing has dintinct advatages that pay off on the long term, legitimating the higher costs for the technology (see Riedelsberger et al. 2006). Most important benefits are high processing speeds and a low heat input, and the available, more and more upgraded process controls, as it is discussed by Graudenz et al.2012. Due to the minor thermal load of laser brazing the joints demand little rework, and well-engineered system technology significantly enhances the reliability of the technique. The increased reliability of laser brazing can be attributed to a well advanced knowledge of the temperature field (Grimm et al. 2007) and melt dynamics (Grimm et al. 2009).

However there are limits to the state of the art laser brazing. On the one hand the filler metal's high reflectivity of solid-state laser radiation, which can be up to 97 % according to Dausinger 1995, is impacting process efficiency. On the other hand the maximum processing speed applied in series production of up to 3 m/min is comparatively low for laser brazing. That is because in conventional process configuration the laser beam impinges nearly perpendicular and the filler wire is delivered under an angle of 45 degree, as described by Heitmanek et al. 2014. Therefore, the filler wire is shadowing the joining partners to some extent, which is resulting in an insufficient heating at high brazing speeds, which in turn is affecting the wetting and thus the seam quality. Grimm 2012 found that at higher processing speed the wetting takes place in a periodic manner, which is negatively impacting surface quality. To overcome speed and wetting limits two-beam laser brazing was introduced and has been investigated ever since. According to Hoffmann et al. 2004 the principle is to use one high-energy laser beam to melt the filler wire along with a forerunning low-energy laser beam to peheat the sheets in the processing zone and thereby support the wetting. Previously the authors pointed that out, showing the correlation between preheating temperature and wetting length (cf. Mittelstädt et al. 2014). In consequence of the process configuration the filler wire is typically aligned in the middle of the beam axes. Nontheless two-beam laser brazing solutions make a virtue of the necessity to have to deliver the filler wire at a nearly perpendicular angle, advertising that thereby hardly accessable contures can be joined and that a change in process-direction can be easier made (see e. g. Hornig 2006). However there are numerous two-beam processing heads available, but no product has yet established in series production. This is because of enhanced system costs and complexity. Overall two-beam laser brazing features benefits, as far as attainable processing speed and improved wetting is concerned, but has constraints as there are higher costs.

This contribution builds on the situation, that there are well documented benefits for laser brazing with preheating. The drawback of the technology, which is rather attributed to further system costs is addressed by the innovative processing concept that this work is introducing. A novel approach for laser brazing is presented that features a compareably steep filler wire alignment and the laser beam in leading configuration. By that means otherwise unexploited laser radiation that is reflected from the filler wire is directed onto the substrate.

2. Idea and Approach

The novel approach of this contribution is based on the alignment of filler wire axis and beam axis to one another, in which the laser beam is preceeding the the filler wire. The effect, which is intended by this process configuration, is illustrated in Fig. 1. On the left a detailed view of the filler wire tip in contact with the substrate and illuminated by the pilot laser is given. By redirection of the incident laser radiation onto the substrate in process direction, reflected and otherwise unexploited laser radiation shall be utilized. Due to the geometry of the filler wire, the incident laser beam is expanded, illuminating a wider area of the substrate. The sketch on the right in Fig. 1 points out the optical path of the radiation.