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ScienceDirect

Physics Procedia 83 (2016) 447 – 454

Physics Procedia

9th International Conference on Photonic Technologies - LANE 2016

Sound welding of copper: laser beam welding in vacuum

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Abstract

Copper is one of the most important metals of modern times. The extensive usage from thin foils up to thick plates leads to a huge amount of welding applications. Basically the Laser Beam Welding is suited well for the welding of copper, because difficulties such as the high thermal conductivity can be overcome by high intensities. However in industrial applications, a sufficient process capability is currently only achieved at high welding speeds. This leads to low penetration depths and high demands in terms of laser power. At low welding speeds weld metal ejections, which cause critical defects occur.

By Laser Beam Welding in Vacuum (LaVa) the process capability can be increased significantly. Weld metal ejections at low welding speeds can be prevented. By applying this process variation, high quality welding of copper at a low power level between 4 kW and 8 kW and a low intensity level between 50 kW/mm² and 80 kW/mm² of a multimode solid state laser becomes possible for penetration depths of 3 to 8 mm.

Peer-review under responsibility of the Bayerisches Laserzentrum GmbH

Keywords: Laser; Welding; Vacuum; reduced Pressure; Copper

1. Introduction

Copper belongs to the most important materials and is simply indispensable in this day and age. The pursued energy revolution or the electrification of cars are unthinkable without the massive use of copper, and copper is applied also in terotechnology and apparatus engineering. The applied material thickness values are within a large range, from very thin foils up to thick plates, as, for example, cooling plates with a thickness of 60 mm. This multitude of application fields offers immediately numerous possibilities for the joining of copper by means of welding. This is, however, due to the specific properties of copper, such as the high heat conductivity, connected with considerable expenditure.

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Peer-review under responsibility of the Bayerisches Laserzentrum GmbH
doi:10.1016/j.phpro.2016.08.046

Due to the high achievable energy density, the beam welding methods Laser Beam and Electron Beam Welding are especially suitable for solving this complex joining task. Electron Beam Welding has, in comparison with Laser Beam Welding, process-related disadvantages (high vacuum required, generation of X-radiation) and the method still has to struggle with acceptance problems and high market introduction barriers. Laser Beam Welding, in contrast, is a wide-spread method and there is a high demand from the industry for the joining of copper with the laser beam. In industrial application, however, only comparatively small penetration depth values can be achieved so far since a sufficient process reliability is mostly only ensured with very high welding speed of more than 10 m/min. At low welding speeds eruption-like weld metal ejections cause critical defects. The necessarity of a high welding velocity leads to a low penetration depth, a high demand of laser power and increases the costs for fast and accurate positioning. Within the framework of current research around the globe, the application of so-called green lasers and of lasers with highest beam quality is subject of research to overcome these difficulties. At the RWTH-Aachen University - Welding and Joining Institute ISF a different approach is used to solve this difficulties by applying the Laser Beam Welding in Vacuum for the welding of copper. The aim of the underlying research project “LaVaCu3+“ (IGF 18.707 N, Forschungsvereinigung DVS) is to qualify the LaVa-process for the welding of copper and copper alloys in the plate thickness range of 3 to 10 mm at comparatively low welding speeds below 2 m/min.

2. Laser Beam Welding In Vacuum (LaVa)

The first investigations in the field of laser beam welding under reduced working pressure “LaVa” date back to the 1980s and the 1990s. The aim of these works was the reduction of the developing plasma plume in welding via CO_2-laser by Arata et al. (1985), Verwaerde and Fabbro (1985) and Katayama et al. (2001). Based on these results, the ISF started in 2010 to work in this field using modern solid-state laser beam generators (single-mode fibre lasers), Longerich (2011). In the subsequent development of the equipment technique and of the application possibilities, remarkable results in the field of thick-plate welding of steel materials have been obtained. By applying the same welding parameter configuration, an enormous change in the inner weld seam geometry can be observed. At low welding speeds, the weld seam becomes much more narrow and the penetration depth is increased more than two times. The amount of weld metal is constant, which means that the thermal efficiency remains unaffected, Fig. 1 (center). For unalloyed steel, single-pass joint welds on a plate thickness of 50 mm are achieved, Fig 1 (right side) and, with the double-sided single-pass welding technique, joint welds for a plate thickness of up to 110 mm are possible, Reisgen et al. #1 (2013). Also in the field of high-alloy steel materials and of nickel-based alloys, single-pass joint welding has been successfully carried out in the plate thickness range of between 30 and 40 mm, Fig 1 (right side) and Reisgen et al. (2016). The implementation of first industrial application is pursued by the ISF and the Forschungs- und Entwicklungsgesellschaft Fügetechnik FEF GmbH, Reisgen et al. #2 (2013).

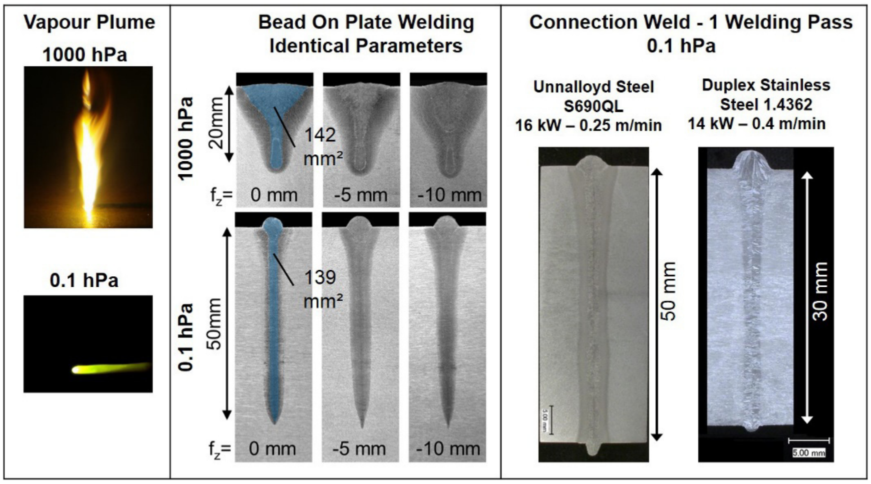

Fig. 1. Benefit of the pressure reduction and potentials of Laser Beam Welding in Vacuum.