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Welding with high-power lasers: trends and developments

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Abstract

High-power laser beam welding became new stimuli within the last 10 years due to the availability of a new generation of high brightness multi kilowatt solid state lasers. In the welding research new approaches have been developed to establish reliable and praxis oriented welding processes meeting the demands of modern industrial applications during this time. The paper focuses on some of the current scientific and technological aspects in this research field like hybrid laser arc welding, simulation techniques, utilization of electromagnetic fields or reduced pressure environment for laser beam welding processes, which contributed to the further development of this technology or will play a crucial role in its further industrial implementation.

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Keywords: High-power Laserbeam Welding; Electromagnetic Force; Vacuum; Simulation

1. Introduction

During the last decade high-power (> 10 kW, up to 100 kW) solid state lasers with a high brightness (< 15 mm mrad) came into the market, Nielsen (2015). Those lasers are very interesting for a variety of applications, not only on the shop floor, but especially also in the field, Thomy et al. (2006). There are well known applications in shipbuilding (e.g. Meyer, Fincantieri) Seyffahrt (2004), Staufer (2004), Gerritsen (2005), Olschok et al. (2007), Unt et al. (2015) from the early beginning on. Later results from Schneider et al. (2014) showed successful weldings of thick titanium sheets, also for marine applications.

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Further fields with intensive research activities are the longitudinal and orbital welding of pipelines or the welding of off-shore wind energy plants foundations. Typical materials welded are pipeline steels (X65, X80, X120) or very common S355 structural steel, Sokolov et al. (2011).

The interest in these lasers results from the high-power and brightness which facilitate the (single pass) welding of thick sections with minimal distortion, the wavelength which enables the beam delivery via a fibre, the high plug-efficency, and a small footprint which makes an application in field conditions possible.

Nevertheless there are still some major challenges which have to be solved, which are listed here and will be discussed in the following major chapters: To work with a laser normally implies the need to have high-precision parts without any gaps or misalignments which is not possible in most applications. Therefore a lot of research was done in the field of laser hybrid welding. One major aspect here is the hot crack formation when welding thick plates in single-pass, Nielsen (2015). Another big challenge is the hydrostatic pressure which will lead to excessive root-dropping when welding single-pass welds in thicknesses of 15 mm or above. Some interesting works were done, looking into an electromagnetic weld support system, Avilov (2012, 2016), Bachmann (2012, 2013, 2014, 2016). During the last years there were also different research groups looking into laser beam welding under vacuum/reduced pressure, which can have significant advantages. Many of the experiments in the different fields were also accompanied by simulations.

2. Laser hybrid welding

In laser hybrid welding normally an arc welding process e.g. gas metal arc welding process (GMAW) is coupled with a laser in one process zone, but there are also hybrid processes combining laser and submerge arc welding (SAW), (Reisgen 2014, 2016b). The general idea is to combine the advantages of both processes, the deep penetration and high welding speeds from the laser with the good gap bridgeability and the opportunity of a filler metal of the GMAW process. Furthermore it is well known, that the arc is stabilizing the laser and vice versa, so that there is a much more stable hybrid process. A comprehensive review also on the industrial applications can be found e.g. in Ribic et al. (2009).

A main driver for laser hybrid welding processes is the application in the field of huge structuctures with heavy plates like ships, pipes, or off-shore constructions, where edge preparation and misalignment cannot be avoided. To reach deep penetration in combination with low heat input and low distortion the only other suitable welding process would be electron beam welding (EBW). Herewith, the necessary vacuum chamber is a major drawback. During the last decade several research groups worked with laser powers of up to 100 kW to reach single pass welds with high thicknesses, Katayama (2015). Vollertsen et al. (2010) published results of thick plates welding in PA (1G) position with a 17 kW laser power of 16 mm mild steel in square butt joint reaching 2.1 m/min welding speed. 20 mm were joined with edge preparation @ 19 kW laser power. Using a multipass technique Rethmeier et al. (2009) showed results of welding of 32 mm thick pipeline steel (X65) in 5 passes, Fig. 1. To weld even higher thicknesses with less passes, the use of laser SAW hybrid welding can be beneficial. When combining laser and SAW the distance between the two processes is crucial. With a 22 mm distance, synergy effects are reached which will be eliminated for higher distances Reisgen et al. (2016). With optimal parameters a 50 mm joint is possible when welding in double-sided single pass technique.

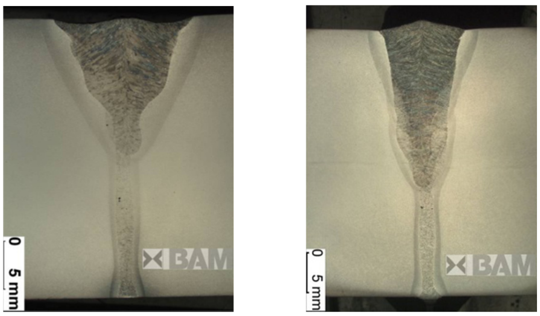

Fig. 1. 28 mm 2 layers (left) and 32 mm 5 layers (right) multi-pass welds.