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Inline repair of blowouts during laser welding

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Abstract

In a current laser welding production process of components of stainless steel, a butt joint configuration may lead to failures in the form of blowouts, causing an unacceptable welding quality. A study to improve the laser welding process was performed with the aim of solving the problem by designing a suitable pattern of multiple small laser spots rather than a single spot in the process zone.
The blowouts in the process are provoked by introducing small amounts of zinc powder in the butt joint. When the laser heats up the zinc, this rapidly evaporates and expands, leaving the melt pool to be blown away locally. Multiple spot pattern designs are tested. Spot patterns are produced by applying diffractive optics to a beam from a single mode fiber laser.
Results from welding while applying spot patterns both with and without trailing spots are presented. Data showing the power ratio between a trailing spot and two main spots as a function of spot distance is also presented.
The results of the study show that applying multiple spots in the welding process may improve the process stability when welding materials with small impurities in the form of zinc particles.

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Keywords: Beam shaping; laser welding; diffractive optical element (DOE); weld geometry, inline repair welding, laser spot pattern;

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1 Introduction

Lasers have been applied to areas in hybrid processes in which the ability to dose energy precisely temporally and spatially has found several applications in many other process areas, including grinding and milling Dubey et al. (2008). Especially hybrid solutions with lasers and traditional fusion welding processes such as Gas Metal Arc Welding (GMAW) have shown significant benefits Olsen (2009). This work focuses on the use of several laser spots generated from a single beam.

In a current laser beam welding (LBW) production process of components in stainless steel in a butt joint configuration, impurities in the form of zinc particles in the joint and other residues may lead to blowouts. These will destroy the final weld and may create parts which are not pressure-tight and may contain highly irregular surfaces.

This is almost similar to the well-known problem of performing overlap welding of zinc coated steel sheets, which results in the evaporation and expansion of zinc in the melt pool, leading to small "explosions" which cause the entire weld pool to be blown away. This generally leads to a weld of poor quality with large surface irregularities Graudenz et al. (2013), Bagger et al. (1992). The explosions are caused by the relatively low boiling temperature of zinc at 907 °C compared to the melting temperature of stainless steel (EN 1.430) at 1450 °C. Due to the rapid increase in temperature during LBW, the zinc is trapped and evaporates in the melt pool, causing local expulsions of the melt pool.

Residues of organic compounds like oil rapidly decompose and evaporate when making contact with liquid metal, as is the case in LBW; this may lead to problems similar to those caused when zinc evaporates Katayama (2013).

This work was carried out as an industrial case in which an edge butt joint between two round discs with a thickness of 2.2 mm was examined. A thin foil of 75 µm, with the same diameter as the discs, was placed between the two discs. The experiment entailed an attempt to weld together the foil and both of the discs. The principle can be seen in figure 1a.

Instead of trying to carry out a repair welding with a spot trailing behind the first spot, a different strategy was applied in this work, in which the high quality of a single mode beam combined with diffractive optics enables the forming of the beam into spot patterns. In this work, spot patterns with multiple trailing spots were examined; two trailing spots were offset slightly towards each side so that they would melt new material after the melt pool had been blown away. The principle is shown in figure 1b.

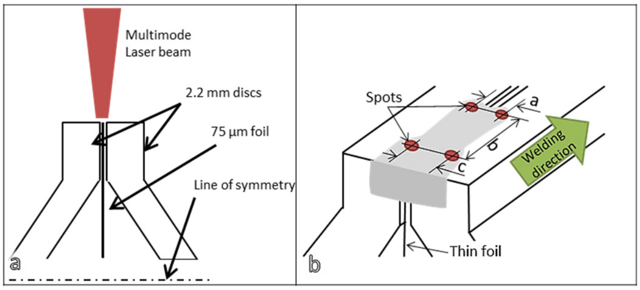

Figure 1 a) Welding principle in current production. b) One of the spot patterns applied to replace the multimode laser beam. Fig 1b from Hansen et al. (2015a)

2 State of the art

LBW with multiple spots has been known for many years and has found some specific niches.

Examples of previous work in which a laser beam has been combined with other laser sources or the laser beam has been reshaped:

- Xie et.al: have shown that using an extra laser spot to reduce the uneven cooling in a weld placed close to the edge of a sheet may prevent the forming of a centerline solidification crack, which would otherwise occur when the extra spot is left out Ploshikhin et al. (2004).