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Single pass laser welding with multiple spots to join four sheets in a butt-joint configuration

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Abstract

Laser keyhole welding is widely used in industry due to its large welding depth and low heat input. For some industrial cases it is necessary to widen the beam to cover the joint configuration, which instead results in a lower intensity and surface conduction welds. The introduction of the high-power single mode fiber laser makes it possible to deal with this problem, because the beam can be shaped into a pre-defined pattern of multiple spots shaped to the actual joint configuration. The intensity of each spot is sufficient to make a keyhole. A case with four sheets in a butt-joint configuration is used to demonstrate the principle of how to design a spot pattern which ensures weld quality in case of a single pass laser weld.

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1. Introduction

For many industrial applications laser welding is a suitable technique for joining metal parts because of the low heat input, good controllability, high repeatability and high precision of the process. Traditional laser welding performs a narrow deep keyhole, and with the introduction of the high power single mode fiber laser, the keyholes can be even

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narrower. For some applications, a wider weld is required to cover a gap and to join more parts at the same time. A wider weld can be achieved by defocusing the laser beam, which will cause the welding process to change from at keyhole weld to a conduction weld. By defocusing the laser beam, the weld width and depth can only be partially controlled. A higher degree of freedom to control the shape of the weld can be achieved by splitting the laser beam up into a number of sub-beams in a pattern required for the weld geometry.

Different methods for shaping the weld profile have been investigated, and the state of the art for instance shows the achieved results. Abt (2007) and Verhaeghe (2005) have shown how the adjustment of the focus and the beam quality achieved by different lasers affect the weld quality for a single beam weld. Salminen et. al. (2012) tested the effect of dynamic beam forming of single beams by oscillation the beam when welding. Trautmann et. al. (2004) demonstrated the weld result when applying more lasers at the same time in the weld pool using a bifocal laser system. Brian et. al. (2009), Hansen et. al. (2014) and Sundqvist et. al. (2016) have worked with various types of beam shaping and have demonstrated how these affect the laser welding process.

In this experiment a single mode fiber laser was used with a diffractive optical element to split the laser beam into spots, as illustrated in Fig. 4. This spot pattern was chosen to weld the geometry, see Fig. 1, containing four stainless steel sheets which must be joined in a round seam weld. The current joining method is plasma arc welding (PAW), which takes 44 seconds with a travel speed of about 600 mm/minute. Experiments with single beam conduction welding were also conducted in order to measure the efficiency of this process with different spot sizes.

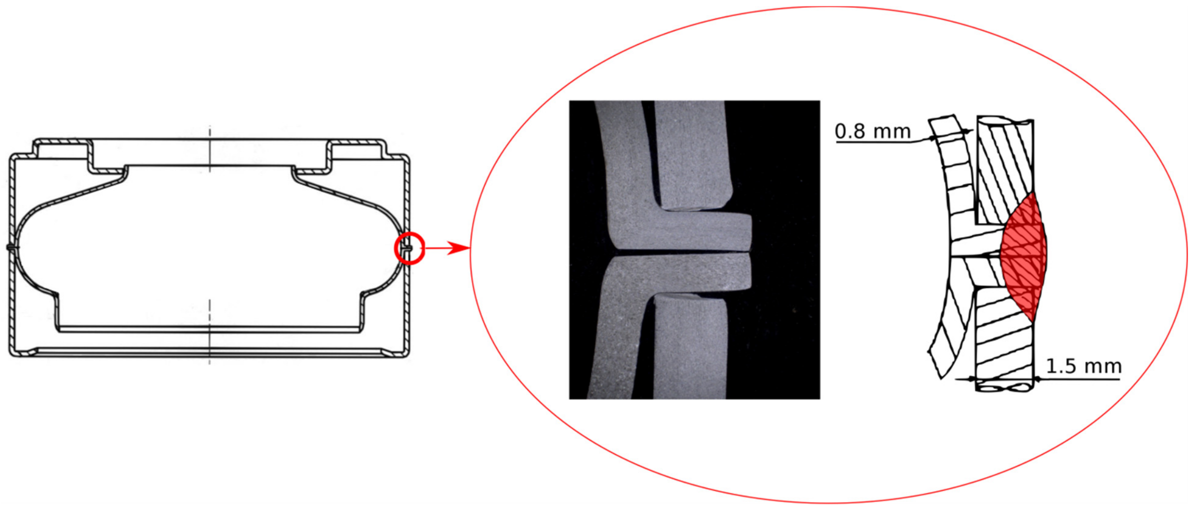

Fig. 1. Cross section of the four sheets to be joined and a magnification of the weld and the physical joining.

The process and considerations for designing a spot pattern to fulfill the welding requirements will be explored in this paper. The chosen spot pattern design will serve as a foundation to investigate the following hypotheses:

- Can the designed multispot pattern achieve the desired weld geometry and process reliability?
- Does multispot laser welding improve the process performance, thus making it possible for this to substitute the existing PAW process?

2. Spot pattern design

Design of the spot pattern must ensure that a certain weld geometry and quality are achieved for the constraints given by the sheet geometry, the available equipment and the available range of the given process variables. The spot pattern design can be based on different types of knowledge, ranging from empirical experiments to more formalised design knowledge and analytical models. Analytical models of the spot pattern effect on the weld geometry have been studied intensively for single laser beams, He X., (2012), whereas work on multispot laser, e.g. Yu-Ning Liu, (1995), is not frequently found. The design process in this work is highly based on experience from previous experiments