Lasers in Manufacturing Conference 2017

Reduction of the spatter formation due to the use of superposition of two laser intensities

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Abstract

New developments of laser system technology result in an increased power output at better beam quality. However, available laser power cannot always be transferred to increase the processing speed since imperfections such as the formation of spatter occurs, especially in the range of 5 m/min to 20 m/min for fiber and disk lasers. The appearance of spatter is strongly connected to the conditions in and around the capillary.
This paper shows an experimental approach to reduce the spatter formation by using two laser spots. The experimental trails were executed with austenitic steel (1.4301) sheets using a high power disk laser and a diode laser. The modification of the resulting intensity reduces the loss of mass. High speed camera footage shows a different behavior of the weld pool due to the additional laser spot. Moreover, metallurgical cross-sections demonstrate the influence of the approach on the shape of the melt pool and the resulting weld seam.

Keywords: Spatter formtation; Superposition; Laser intensity; Austenitic tainless steel

1. Introduction

Spatter is an undesirable phenomenon during laser beam welding and names the ejection of droplets of melt from the melt pool. It can lead to the reduction of surface quality of the work piece which results in time consuming rework. Moreover, this appearance causes loss of material in the weld seam, that can lead to underfill and the decrease of mechanical properties of the weld. For this reason, the reduction of spatter is of commercial interest.

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Considering a given focusing setup and laser power, the weld pool behaviour depends mainly on the welding speed (Fabrro et al. 2007). It was observed, that the capillary opening increases with increasing welding speed and therefore the energy coupling takes place at the front of the capillary. The resulting metal vapour transfers its momentum to the melt at the backside of the capillary (Berger et al. 2011). This results in sufficient energy of the fluid in order to exceed the interface energy of the weld pool causing a droplet escape. From the energetic point of view, the droplet escape condition can be described according to Hügel and Graf, 2014 by the following equation (1):

$$\frac{\rho\, V_{dr} |\overrightarrow{v_{Fl}}|^2}{2} > \frac{\rho\, V_{dr} |\overrightarrow{v_{dr}}|^2}{2} + \sigma O_{dr} \qquad (1)$$

Hereby, ρ is the density, V_{dr} the volume of the droplet, v_{Fl} the velocity of the fluid in the weld pool, v_{Fl} the velocity of the droplet, σ the surface tension/interface energy and O_{dr} the area of the surface of the escaped droplet.

The assumption of the presented study is to realize an increased weld pool around the capillary due to the use of a second laser spot, which encloses the main welding spot. This appearance might lead to a decreased fluid velocity around the capillary and according to the equation (1) the droplet escape condition will not be fulfilled and less spatter will occur.

2. Experimental setup

The experimental trails were executed with austenitic stainless steel sheets (1.4301, 150 mm x 35 mm x 2 mm). The sheets were manipulated under the use of an industrial robot (KR 60HA, Kuka). Two laser sources were used. In order to superpose the laser spots, a disk laser (TruDisk 5000, Trumpf) in combination with a BEO D70 optic was used to realize the main spot on the work piece. For the second spot, a diode laser (LDM 3000, Laserline) was applied. The experimental procedure and the properties of the laser sources are summarized in the following paper (Nagel et al. 2016).

3. Results and Discussion

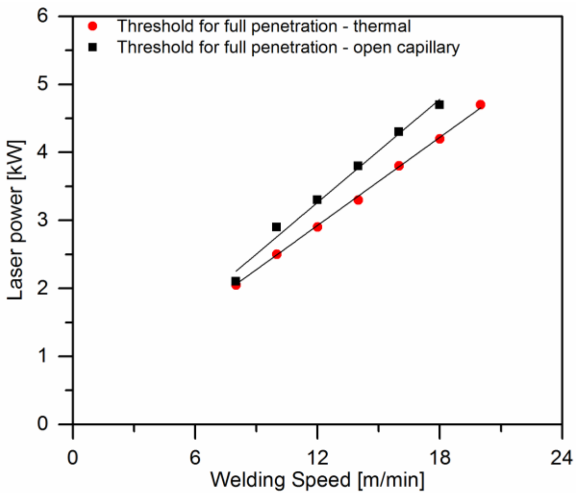

Fig. 1. Required laser power for full penetration welding

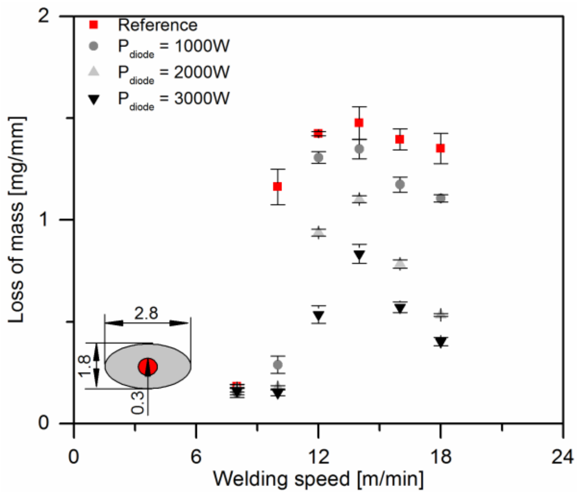

Fig 2. Influence of the laser power of the diode laser on the loss of mass

First, the threshold for full penetration welding was determined for a welding speed range from 8 m/min to 20 m/min. Two thresholds of full penetration were identified and can be characterized as a penetration without an open capillary on the bottom side of the work piece with the formation of a weld root. The second kind of full penetration names the open capillary on the bottom side. In order to ensure the existence of the capillary on the bottom side, the area was observed using a high speed camera. The necessary laser power for the named welding speed range is summarized in Fig. 1. Hereby, the laser power increases linear with increasing welding speed. Considering the same welding speed, a difference of almost 400 W between the two thresholds can be determined. It has to be pointed out, that an open capillary was detected at less laser power. However, the welding process appeared not stable at less laser power which can be ascribed to the interaction of the metal vapour and the laser beam.

Fig. 2 summarizes the influence of the welding speed on the loss of mass. Herby, the loss of mass increases significantly from 8 m/min to 14 m/min. Yet, a further increase of the welding speed leads to a decrease of the loss of mass. Due to the use of the superposition of the second laser spot, a reduction of the loss of mass can be identified. Thereby, the loss of mass can be decreased with higher laser power. It can be assumed, that the fluid dynamics within the melt pool can be reduced due to an increase weld bead resulting in less spatter formation.

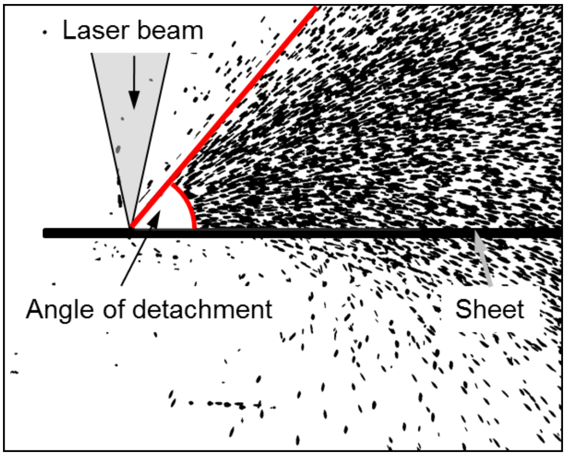

Fig. 3. Schematic illustration of the angle of the detachment (summarized spatters of three frames take with a camera)

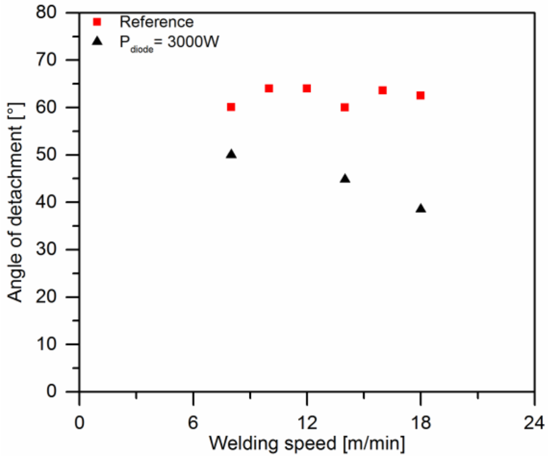

Fig. 4. Influence of the second laser spot on the angel of detachment of the droplets

Further, the influence of the second spot on the angle of detachment of the droplets (see Fig. 3) can be observed in Fig. 4. This angle can be seen as almost constant for the welding speed range from 8 m/min to 18 m/min. Due to the second spot, a reduced angle of detachment can be identified. Moreover, the angle decreases further with increasing welding speed. This observation leads to the assumption, that the vertical component of the fluid behaviour can be manipulated due to the use of the second spot. To put in a nutshell, the use of the second spot results in less spatter formation and a reduced angle of detachment of the droplets during laser welding.

Acknowledgements

The investigations are carried out within the project ”Spatter reduction due to adapted laser intensity for high speed welding” (01.07.2016 - 30.06.2018). The research project (IGF-18582 BR/2) is supported by the Federal Ministry of Economic Affairs and Energy within the Allianz Industrielle Forschung (AIF), which is based on a resolution of the German Parliament. We would like to thank all funding organizations.

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