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Industrial Paper

Laser Remote Welding of Fillet, Square Butt and Spiral Welds with Automated Gap Bridging

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Abstract

At body-in-white production different kinds of weld connections can be found. Typical are fillet, square butt or spiral (spot) welds in PA, PB, PF or PG orientation. In dependence of the clamping also the gap situation is different in a lot of cases. Thus, for robust laser welding processes new remote welding optics need implemented welding know how and strategies for the realization of gap-bridged connections. Oscillated beam processes have proven their ability to influence the gap bridging and their effect will be presented in this paper for different kinds of materials, weld spots and seams in different welding positions. The gap bridging results refer to typical materials and thicknesses for body-in-white production.

Keywords: *Laser Welding; Remote Welding; Spiral Welding; Gap Bridging; Beam Oscillation*

1. Introduction

Remote laser welded fillet, square butt and spiral welds at overlapped metal sheets are important joints for body-in-white production. Under ideal conditions such joints can be created in a welding-friendly PA position with a zero-gap between the parts. In figure 1 an example of a fillet welding process incl. a cross section of a typical weld seam at an aluminum door is shown.

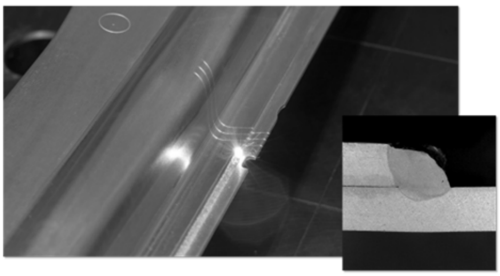

Fig. 1. Example of a fillet weld at a window frame of an aluminum door with zero-gap in PA welding position

As is the case with many applications such as underbodies, door openings or roof beams, it's often not possible to weld under very good conditions. The orientation of the parts is often different, clamping situations change, gaps between sheets vary, etc. The seams have to be welded in PA but also in out-of-position (e.g. PF or PG orientations), which result in different challenges:

- The laser beam is required to hit the joining zone without (for fillet welds) or with a defined beam offset (for square butt or spiral welds) to the edge of the upper sheet. Thus, a seam guided process is necessary in most cases to realize a sound, stable connection or achieve crack-free weld seams.

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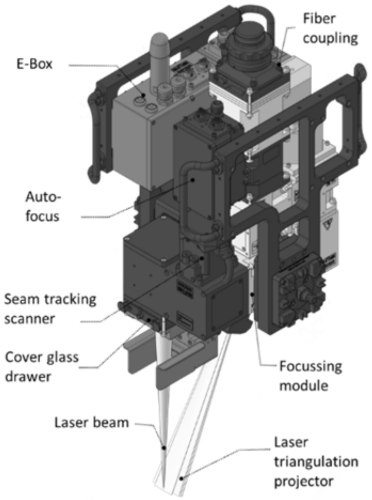
- Gaps between the parts are the second challenge. Especially with remote laser welding, the lack of additional material limits the possibilities of gap bridging. Oscillated beam processes have proven their ability to influence gap bridging [1], [2], [3] and their effect will be presented in this paper.

2. System technology for remote laser welding with beam oscillation for gap bridging

For a seam guided remote laser welding process with the option of an automated gap bridging by beam oscillation, the Scansonic MI GmbH developed the optic: RLW-A. Reference **Fehler! Verweisquelle konnte nicht gefunden werden.**2 for the principle details of this solution. It possesses an integrated seam tracking system based on the principle of laser triangulation. Three seam tracking laser lines are projected to the work piece joint, whose reflections are then detected and processed by a camera, installed behind a semi-transparent mirror inside of the optical path. With the calculated offset position between the focus and the seam position, an automatic beam positioning (seam guiding) takes place by the pivoted deflection mirrors. It's possible to create fillet welds at the correct position as well as square butt or spiral joints (state of actual work) in a defined distance to the edge. Two additional fast oscillation scanners are integrated to create one- or two-dimensional oscillation profiles superimposed to the welding direction.



Remote Laser Welding Optic „RLW-A"
- Magnification M = 2.9
- Optical seam tracking by laser triangulation
- Laser beam deflection in X and Y for seam tracking and welding „X-On-The-Fly"
- Laser beam oscillation in X and Y up to f = 1 kHz

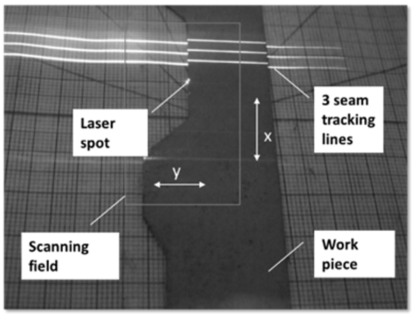


Fig. 2. Schematic overview of the laser optic RLW-A with integrated joint tracking and beam oscillation

The laser triangulation feature also gives information about the gap height between the sheets and setting angles of the optics in reference to the work piece. If there is a gap between the parts, automated bridging strategies by beam oscillation and/or beam defocusing will be applied. Depending on the size of the gap, the laser power, focus position, beam-offset orthogonal to the welding direction, beam oscillation amplitude, and frequency will be varied based on an integrated process model [4]. The optical path of the optic has an aperture of 46 mm with scanners that are synchronized to each other's movement. The beam guiding system has a focal length of 500 mm at an optical magnification of 2.9 providing an active working distance of 326 mm resulting from the use of post objective scanning. By the use of this magnification, no new requirements on laser cell safety are typically necessary which can be critical especially at optics with higher values of optical magnification.

3. Process technology for remote laser welding of fillet, square butt and spiral welds with gap bridging

3.1. Experimental setup

As part of the process investigation to bridge gaps - described in this chapter - a 5 kW disk laser with a min. beam parameter product of 4 mm × mrad and a fiber of 200 µm core diameter was used. The resulting focus diameter of the RLW-A with M = 2.9 is d_{Foc} = 580 µm. The focus position was set to the lower sheets surface and kept constant by an automatic focusing module of the optic RLW-A. The optic allows a fast beam oscillation up to f = 1 kHz. 2D metal sheets of L = 300 mm x B = 80 mm were used as work pieces for the basic investigation. In table 1 the main aspects of the used alloys are described.

Table 1. Used samples for welding investigation

Material	Dimension	Coating
22MnB5 AS 150	300 mm x 80 mm x 1.2…1.5 mm	AlSi 150 g/m²
DC06 ZE50/50	300 mm x 80 mm x 0.8… 1.0 mm	Galv. Zn 50 g/m²
HX220+ZF100	300 mm x 80 mm x 1.2 mm	Zn 100 g/m²
AW6082 / AW5083	300 mm x 80 mm x 1.0…1.5 mm	-

3.2. Gap bridging at fillet and square butt welds

Dependent on the in-process measured gap size between the sheets by laser triangulation, the parameters "laser power, beam offset (at fillet welds) and amplitude / frequency of beam oscillation" will be varied. Information about the necessary values are given by a theoretic gap bridging model which considers the necessary S-value and seam dimension for different materials. As the gap size increases, more material has to be molten. Because of the missing filler wire at remote welding processes this material has to get from the upper joining partner to the lower. In figures 3 and 4, bridged gaps at different cross sections of steel and aluminum fillet welds in different welding positions can be seen.

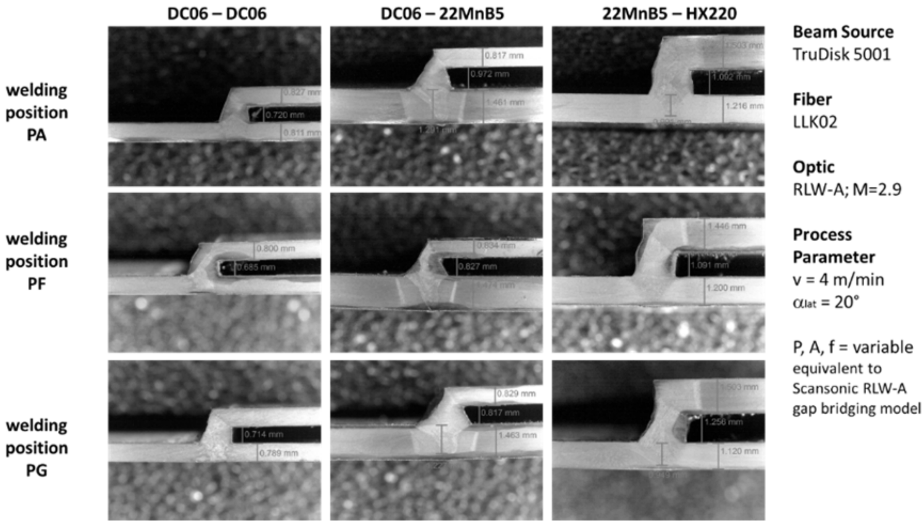


Fig. 3. Cross sections of different kinds of steel in different welding positions with bridged gaps by fast beam oscillation

Thin steel sheet gaps, nearly up to the material thickness of the upper sheet, can be bridged. The welding position PA, PF, PG has less relevance regarding the weld seam formation and quality. A different picture can be seen with Aluminum fillet welds. In PA position it's possible to bridge gaps up to 50…60 % of the thinnest sheet thickness by the usage of a gap-dependent beam oscillation strategy for aluminum. In PF or PG position, bridging is feasible when gaps are roughly 20…30 % of the thinner sheet thickness. Possible reasons for that are the lower viscosity of the Aluminum weld pool in comparison to steel as well as the surface tension of the molten puddle. When processing at upward or falling welding positions, when gap size increases, the molten aluminum has greater tendency to drop out of the weld seam.

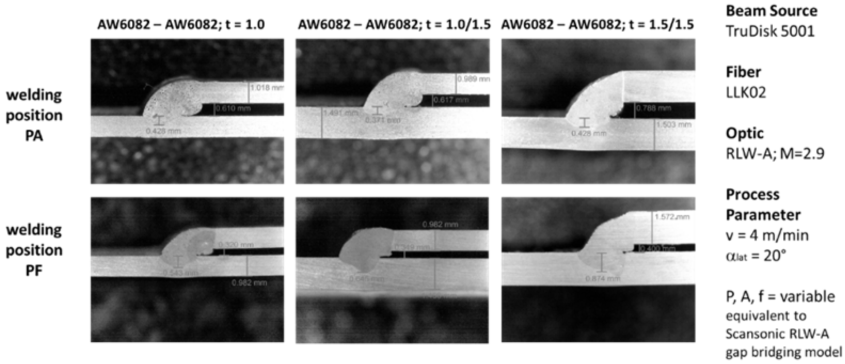


Fig. 4. Cross sections of AW6082 in different welding positions with bridged gaps by fast beam oscillation

The realized gap bridging model is also working for square butt welds at overlapped sheets. However, the weld seam has to be maximum y ~ 6 mm beside the upper sheet edge to get reliable information about the gap size by the triangulation measurement and the parameter laser power, oscillation form and frequency have to be different to fillet welds. In figure 5 a top view and a cross section of a square butt seam at a lap joint of AW6082 can be seen.

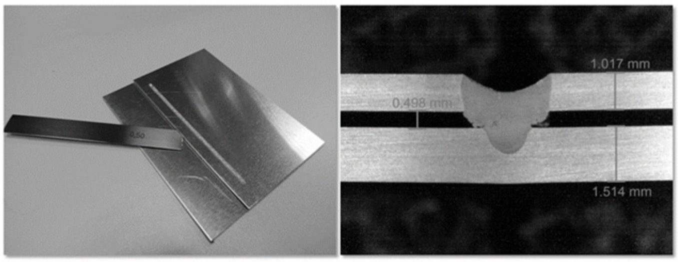


Fig. 5. Top view and cross section of a square butt weld at two overlapped AW6082 sheets; t = 1.0 mm / 1.5 mm

3.3. Gap bridging at spiral welds

A similar procedure can be used for spiral welds closed to the sheet edge. The measurement of the gap size allows the use of the correct welding parameter to realize good results. Especially at zinc coated steel sheets in a zero gap condition it’s necessary to work with process parameter which helps to avoid spatter due to the vaporization of the zinc coating. In figure 6 a spiral weld at zinc coated steel sheets of DC06 in a zero gap condition can be seen.

Furthermore, gaps up to 50% of the sheet thickness can be bridged. Again, at steel the welding position PA, PF, PG has less relevance regarding the weld seam formation and quality.

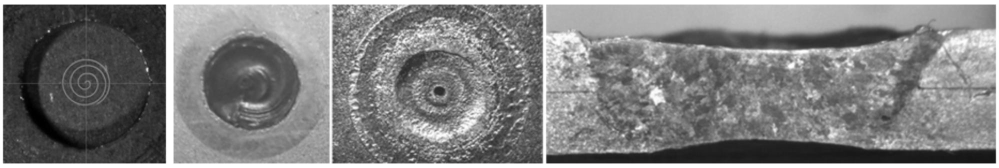


Fig. 6. Left: Spiral welding strategy; left middle: top view of a spiral weld; right middle: vaporized zinc between the sheets; right: cross section of a spiral weld at zero gap (material DC06 zinc-coated, t = 1.0 mm)

Laser spiral welding of aluminum AW5083 is also possible. Gaps can be bridged up to ~ 40% of the lowest sheet thickness in a horizontal as well as vertical position of the sheets. In a vertical sheet position the weld pool geometry is asymmetric. More material is at the lower side of the weld spot. In figure 7 some top views and cross sections in different welding positions can be seen.

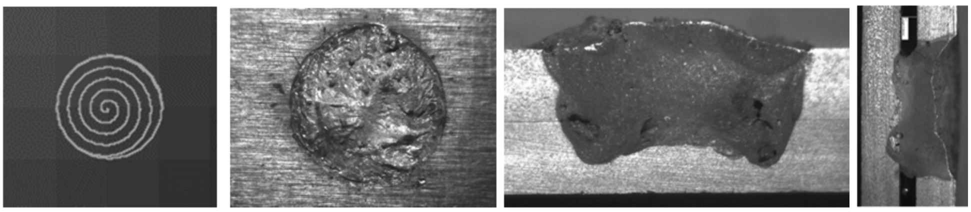


Fig. 7. Left: Spiral welding strategy; left middle: top view of a spiral weld; right middle: cross section of a spiral weld at zero gap condition in horizontal sheet position; right: cross section of a spiral weld with 0.6 mm gap in vertical sheet position (material AW5083, t = 1.5 mm)

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