Seam Guided Laser Remote Welding with Automated Gap Bridging

Increased process windows by online recognition of gap situation

Peter Fixemer, Florian Albert, Pravin Sievi and Tom Graham

Due to high productivity and potential for cycle time reduction, Laser Remote Welding is gaining more and more attention particularly in automotive manufacturing and its tiered supply base. In a typical industrial setup, component tolerances are a major challenge to the usage of laser remote technology. The difference between programmed beam position and the actual component location can only be compensated by complex and thus costly design measures. In addition, a changing gap situation makes it difficult to choose suitable process parameters to reach a bridged weld seam. The presented approach for a laser remote welding system not only detects the correct component location, but furthermore measures the actual gap real time during the process and adapts process parameters according to a process model. The focus will be for fillet type welds of aluminum and steel alloys and their model based parameters.

Fillet welds at lap joints are important joints for body-in-white production. They allow a reduction of both flange widths and mass in addition to high strength connections. In comparison to I-seams at lap joints, a lower laser power is necessary for their realization and false friends are easy to detect. Because of all these advantages, door, bumper or rear panel fillet welds can be seen. In Fig. 1, an example is shown.

Gaps between the parts are the second problem at fillet welds. Without the use of additional material, the possibilities of gap bridging are limited. In addition, the usage of oscillated beam processes have proven their ability to influence gap bridging capabilities for the better [1–3].

For a seam guided remote laser welding process, Scansonic developed a new optic: RLW-A, which has the option of an automated gap bridging technology. In the next few sections, the system approach and process technology implemented for the welding of steel and aluminum sheets will be discussed.
System technology

The principle of the remote laser welding optic RLW-A is shown in Fig. 2. It contains an integrated seam tracking system based on the principle of laser triangulation. Three seam tracking laser lines are projected (1) 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 (2). With the calculated offset position between focus and seam position an automatic beam positioning (seam guiding) takes place by the pivoted deflection mirror ($P_d$). Two additional oscillation scanners ($M_x; M_y$) are integrated to create one- or two-dimensional oscillation profiles superimposed to the welding direction.

The laser triangulation feature also provides information about the gap height between the sheets and sets the angles of the optics in reference to the work piece. Should there be a gap between the parts, bridging strategies will then be implemented. Dependent upon the gap size, laser power, beam defocusing, and beam offset orthogonal to the welding direction, the beam oscillation amplitude and frequency will be varied based on an integrated process model. In Fig. 3, the principle of automated gap bridging can be seen.

With respect to this optic configuration, the optical path of the optic has an aperture of 46 mm, its scanners are synchronized to each other’s movement, and the beam guiding system has a focal length of 500 mm. Due to the post objective scanning setup, the active working distance is 326 mm.

Process technology

Experimental setup

Regarding process investigation, described in this chapter, a 5 kW disk laser with a beam parameter product of 4 mm mrad and a fiber of 100 µm or 200 µm core diameter were used. The resulting focus diameter with RLW-A are $d_{\text{Foc}} = 290$ µm or $d_{\text{Foc}} = 580$ µm. The focus position was set to the lower sheet surface and kept constant by an automatic focusing module.

2D metal sheets of $L = 300$ mm × $B = 100$ mm were used as work pieces for the basic investigation. Fig. 4 shows the clamping situation and gives some further details of the setup.

In Table 1, the main aspects of the used alloys are described.

Accuracy of seam guiding

As previously noted, the position of the beam relative to the joining zone is very important in welding fillet style joints. This is especially true with crack-sensitive alloys, such as aluminum AW6xxx or AW5xxx. Small misalignments can be the deciding factor between crack-free and crack-affected seams. The reason for cracking is typically related to thermo-mechanical stresses which will be induced during the welding process. For tracking, the higher the accuracy of the seam guiding system is, the lower the resulting risk of bad or cracked weld seams. Measurements of seam guiding accuracy are presented in Fig. 5.

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accuracy with the RLW-A show nearly the same values for steel and aluminum sheets. In all cases the accuracy is lower than 50 µm. An influence to the formation of the weld seam geometry and position will be not expected.

**Gap bridging at steel sheets**

Depending on the size of the gap between the sheets, the parameters of laser power, beam offset and amplitude of beam oscillation have to be varied. Information about the necessary values are provided via a theoretic model which considers the necessary S-value of the weld seam cross section. As the gap size increases, more molten material is required. Due to the lack of filler material with remote welding processes, this material needs to be acquired from the upper joining partner. Thus, the laser beam has to be moved more in the direction of the upper sheet. This is done in conjunction with an increase in the amplitude of beam oscillation and laser power. Fig. 5 shows an example of the automated change of process parameters for the welding of DC05 ZE50/50 with \( v = 2.5 \text{ m/min} \) and spot size of \( d_{\text{foc}} = 0.29 \text{ mm} \).

The corresponding welding result is shown in Fig. 6. The complete fillet weld is closed. Gaps up to the sheet thickness can be bridged without the use of additional material.

### Table 1 Used samples for welding investigation.

<table>
<thead>
<tr>
<th>Material</th>
<th>Dimension</th>
<th>Coating</th>
</tr>
</thead>
<tbody>
<tr>
<td>H260LAD</td>
<td>300 mm × 100 mm × 0.8 mm</td>
<td>Z100</td>
</tr>
<tr>
<td>DC05</td>
<td>300 mm × 100 mm × 0.8 mm</td>
<td>ZE50/50</td>
</tr>
<tr>
<td>AlMg0.6SiV</td>
<td>300 mm × 80 mm × 1.2 mm</td>
<td>–</td>
</tr>
<tr>
<td>AlMg4.5Mn0.4</td>
<td>300 mm × 80 mm × 1.5 mm</td>
<td>–</td>
</tr>
</tbody>
</table>

### Table 2 Cross sections at welded H260LAD sheets with automated gap bridging [1].

<table>
<thead>
<tr>
<th>Gap</th>
<th>Oscillation strategy</th>
<th>Front and back side of sample</th>
<th>Cross-section view</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.05 mm</td>
<td>Non-oscillated &amp; longitudinal</td>
<td><img src="image1" alt="Image" /></td>
<td><img src="image2" alt="Image" /></td>
</tr>
<tr>
<td>0.05 mm– 0.2 mm</td>
<td>Non-oscillated &amp; transversal</td>
<td><img src="image3" alt="Image" /></td>
<td><img src="image4" alt="Image" /></td>
</tr>
<tr>
<td>0.2 mm – 0.4 mm</td>
<td>Transversal</td>
<td><img src="image5" alt="Image" /></td>
<td><img src="image6" alt="Image" /></td>
</tr>
<tr>
<td>0.4 mm– 0.6 mm</td>
<td>Transversal</td>
<td><img src="image7" alt="Image" /></td>
<td><img src="image8" alt="Image" /></td>
</tr>
<tr>
<td>0.6 mm– 0.7 mm</td>
<td>Transversal</td>
<td><img src="image9" alt="Image" /></td>
<td><img src="image10" alt="Image" /></td>
</tr>
<tr>
<td>&gt; 0.7 mm</td>
<td>Transversal</td>
<td><img src="image11" alt="Image" /></td>
<td><img src="image12" alt="Image" /></td>
</tr>
</tbody>
</table>
Similar results can be seen for H260LAD sheets. In Table 2, some cross sections of welded sheets are shown. In all cases, the necessary S-value is correct and the weld seams have a closed surface.

Gap bridging at aluminum sheets
When welding aluminum, the fast oxide layer formation is leading to a different beam offset and a bigger oscillation amplitude in comparison to the welding of steel. The laser beam must crack the oxide layer of the bottom sheet for a good wetting of the molten aluminum from the upper work piece. An adapted amplitude is necessary.

The automated variation of laser power, beam offset, and oscillation amplitude allows stable welding results for aluminum with good gap bridging up to ~ 0.5 × sheet thickness. In Fig. 7 an example at AW5182 is given.

Conclusion
The new laser optic Scansonic RLW-A provides fast welding processes with seam guiding and gap bridging. This leads to the possibility to realize fillet welds using remote technology due to the fact that during the welding process, gaps between the work pieces will be measured in-process. The information about the gap size is used for an automated gap bridging by laser beam oscillation using a model based on the necessary S-value. This system can process and bridge gaps in steel materials with gaps up to the sheet thickness and aluminum up to rd. 0.5 × sheet thickness.

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