The replacement of resistance welding with laser beam welding

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Keywords

Laser welding, resistance welding, spot welding.

1. Introduction

Laser beam welding is gaining ground in a wide range of industries. The reason for its spread is in its favourable technological parameters:

- precision, accurate control of the technological parameters;
- high machining speed;
- excellent machining quality (after-processing needs are reduced or fallen below);
- no force affects the workpiece;
- wide range of selectable, and precisely controllable energy density in machining;
- small specific thermal stress on the workpiece;
- the machining tool is abrasion-free and irrespective of the direction of machining (light);
- excellent automation;
- economical production;
- great manufacturing flexibility;
- good combination with other technologies [1].

However, there are a number of challenges in laser beam welding:

1) Steel sheets are usually coated with zinc layer (especially for car body plates) to increase corrosion resistance. Due to the low boiling point of zinc, the steel vaporizes intensively because it has a high vapour pressure. Thus, it makes the keyhole unstable and it is able to create such vapour pressure over the weld seam so that the molten metal splashes out of the plasma channel (sputtering weld). Zinc bubbles may also be incorporated into the seam, causing a continuity shortage. As a result, the seam strength significantly decreases.

2) According to the literature, several methods have been tried in the research to eliminate the zinc vapour problem [2-24]. However, they were either ineffective or would increase the cost of production above marketable levels. According to our idea, with a plastic forming, small bumps can be created on the surface of the plate, which serve as spacers between the two disks during the welding process. The experiments were carried out with spacer sheet solution, since the two solutions are the same, but the bumpy version is also in place during manufacturing and industrial applications.

2. Materials and Methods

The welding experiments were performed using a Trumpf TruLaser Cell 7020 5D Laser Machining Centre with Trumpf TruDisk 4001 laser radiation source. First, blind welds were made, then steel sheet pairs were welded. Sheet pairs have been made using spacer sheets, and also made sheet pairs with no gap in between them. The most important welding parameters were the following; laser power 1,000 W, welding speed 3 m / min. The focal point of the laser beam was set to 3 and 4 mm (defocus) relative to the surface of the upper sheet.

The plates to be welded are cold rolled, with a thickness of 0.6 mm (defined by the norm EN 10346: 2015), and have galvanized zinc coating. The zinc coating of the sheets was made with the so-called “galvannealed” technology, resulting in 45 grams per square meter of Zn layer on both sides and diffused 7-11% Fe. Its European equivalent is the DX54D + ZF plate. The thickness of the spacer sheets was 0.1 mm. During the welding, the plates were clamped together with the spacer sheets placed between them.

For the metallographic examination, the plates were cut with a water-cooled disc cutter, then grinded, polished and finally etched with 3% nital solution. VHX J20 Keyence digital light microscope was used to examine the welds and to take images.

The tensile strength of the sheets is between 260-350 MPa.

The chemical composition of the steel sheets is shown in Table 1.

Table 1. The chemical composition of the steel sheets.

Chemical compounds [%]					
C_{max}	Si_{max}	Mn_{max}	P_{max}	S_{max}	Ti_{max}
0.12	0.5	0.6	0.1	0.045	0.3

3. Results and Discussion

Figures 1 to 3 show light microscopic images of the welds welded with a 4 mm defocus, and figures 4 to 6 show images with 3 mm defocus. The most important dimensions of the seams are shown in Table 2.

Table 2. Dimensions of the welds.

Introduce number	Defocus [mm]	Type	Weld depth [mm]	Face width [mm]
1.	4	blind weld	2.56	0.21
2.	4	without gap	1.52	3.51
3.	4	with spacer sheets	1.57	0.69
4.	3	blind weld	2.67	1.38
5.	3	without gap	1.29	0.90
6.	3	with spacer sheets	1.91	0.85

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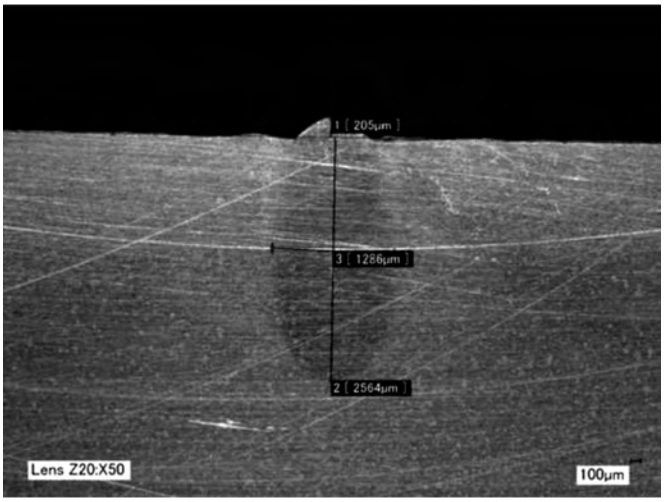

Figure 1. Picture of blind weld (bead on the plate), with 4 mm defocus.

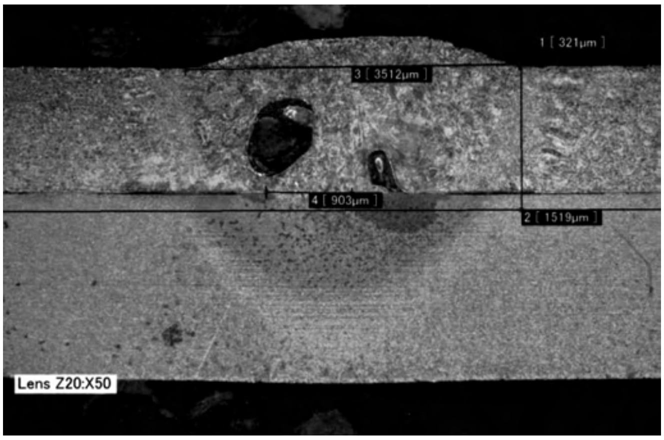

Figure 2. Picture of weld without gap, with 4 mm defocus.

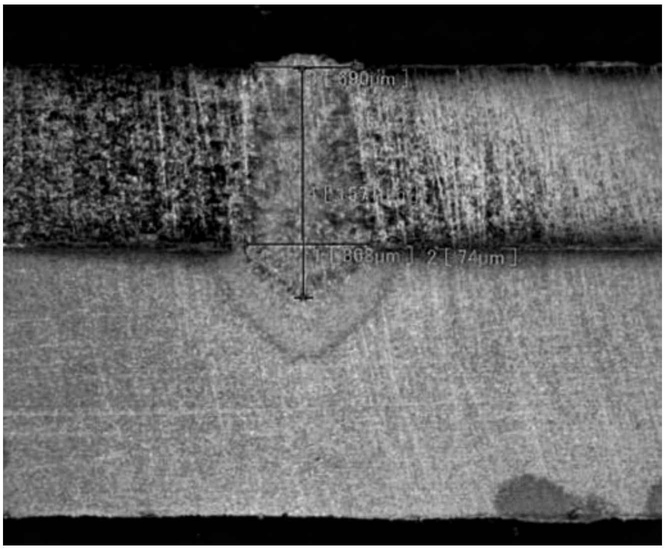

Figure 3. Picture of weld with spacer sheets, with 4 mm defocus.

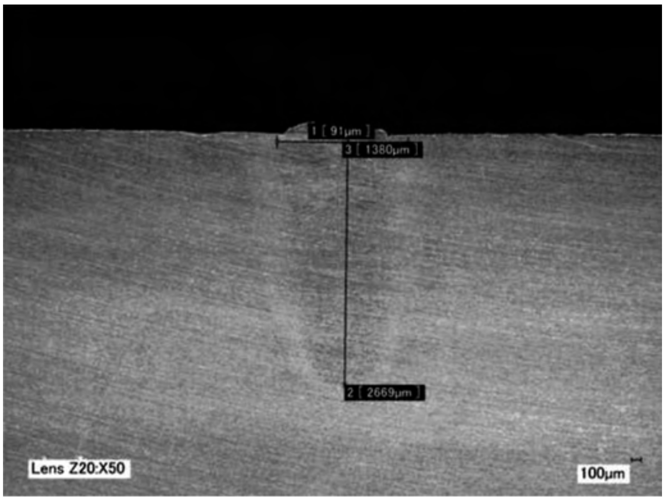

Figure 4. Picture of blind weld, with 3 mm defocus.

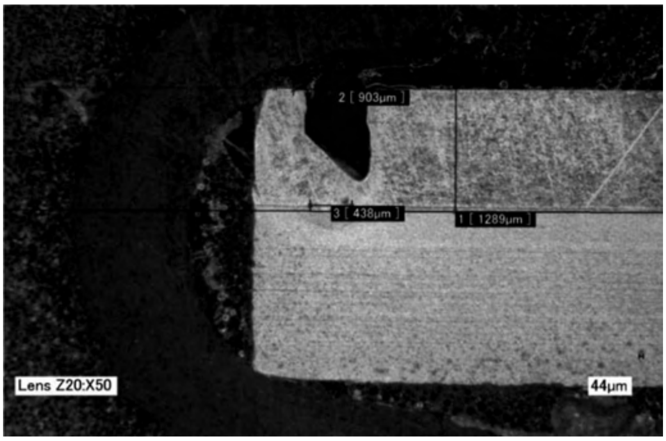

Figure 5. Picture of weld without gap, with 3 mm defocus.

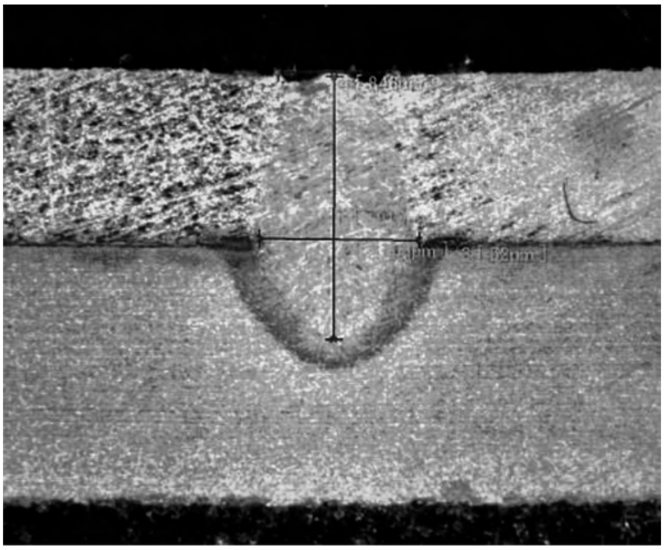

Figure 6. Picture of weld with spacer sheets, with 3 mm defocus.

On metallographic images, it is apparent that the 3 mm defocus value gives better results for this type of steel because in this case the weld penetrates deeper.

The gap between the plates is generally slightly smaller than the thickness of the gap plate, i.e. 0.1 mm. There are a number of reasons for this: the clamping force, the distance of the welding apparatus used (the plate clamping device), the spacing of the spacer sheets from the weld, etc. However, such a small decrease in plate spacing or possibly increase does not reduce the efficiency of the method, this has also been revealed in literature research.

It is well-observed that the plates without gape solution have led to splashes and pores, while the spacer sheet solution has a solid weld.

Conclusion

Laser welding (especially in the case of remote welding) has a high machining speed, is highly automated, combines well with other technologies, and has high manufacturing flexibility.

Steels are usually coated with a zinc coating for corrosion resistance, but this zinc coating causes serious problems during welding.

During welding, zinc vapour is formed, which incorporates into the weld and makes it porous.

In any case, the high vapour pressure makes the keyhole unstable and it is able to create such vapour pressure over the weld so that the molten metal splashes out of the keyhole (sputtering weld). As a result, the weld strength is greatly reduced.

This problem has been solved by installing 0.1 mm thick spacer sheets between the plates so that the zinc vapour could escape. During the conventional "without gap" solution test weldings splashes and pores were found, while using spacer sheets the welds were solid.

In addition, the appropriate laser parameters have been experimented with for the plate thickness and type of material to be used.

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