



The Effects of Laser Power and Travel Speed on Weld Geometry in the case of Manual Laser Welding

Virág SIMON,¹ Balázs VARBAI,² Károly ABAFFY,³ László GYURA⁴

¹ Budapest University of Technology and Economics, Faculty of Mechanical Engineering, Department of Materials Science and Engineering, Budapest, Hungary, simon.virag240@gmail.com

² Budapest University of Technology and Economics, Faculty of Mechanical Engineering, Department of Materials Science and Engineering, Budapest, Hungary, varbai.balazs@gpk.bme.hu

³ Linde Gáz Magyarország Zrt. Budapest, Hungary, karoly.abaffy@linde.com

⁴ Linde Gáz Magyarország Zrt. Budapest, Hungary, laszlo.gyura@linde.com

Abstract

In our research, we investigated the effects of laser power and travel speed on the weld geometry in case of manual laser welding. Our experiments revealed that a characteristic two-part weld geometry is obtained under our experimental parameters. It was also found that increasing the laser power leads to a nearly linear increase in the weld width, while increasing the travel speed leads to a decrease in the weld width. The penetration depth does not increase further above a certain power level. A decrease in travel speed results in an increase in penetration depth. At the travel speeds tested, a narrow and deep weld geometry was obtained at the 70-80 % power level and a wider but shallower weld at the 90-100 % laser power level.

Keywords: manual laser beam welding, laser power, travel speed, weld geometry.

1. Introduction

Laser beam welding, after laser beam cutting, is the most widely used laser material processing technology, and its mechanised version is widely used in industry due to its many advantages [1]. The advantages of laser welding are the very low heat-affected zone created by the highly concentrated laser beam focused over a small area and the much lower heat input compared to conventional fusion welding processes, which minimises deformation of the workpiece by internal stresses [2, 3]. Its cost-effectiveness also makes it popular in industrial applications, as the high initial investment cost is quickly recovered due to its high processing speed and thus high productivity [4]. In recent years, hand-held laser welding equipment has also appeared on the market, offering user-friendly operation with a lightweight welding gun and working cable, and a small, easily movable beam source [5]. A growing number of companies are selling and using such equipment in Hungary, but due to its novelty, there is currently very little experience with this process.

In the present study, we investigated the effects of laser power and travel speed on the weld geometry in the case of manual laser beam welding of austenitic stainless steel.

2. Welding and evaluation procedure

In our research, two series of experiments, each consisting of 10 welds, were carried out on 2.7 mm wall thickness, 42 mm outer diameter, 1.4301 grade austenitic stainless steel tubes by manual laser beam welding without the addition of any welding filler metal.

In general, the chemical composition of the steel used is shown in **Table 1**.

Table 1. The chemical composition of the 1.4301 grade austenitic stainless steel [6]

C	Si	Mn	P	S
≤0.07	≤1.00	≤2.00	≤0.045	≤0.03
N	Cr	Ni	Fe	
≤0.10	17.5–19.5	8.0–10.5	rest.	

It should be highlighted that, in order to ensure the reproducibility of the welds during the experiments, the hand-held laser beam welding gun was enclosed in a device to ensure its stability, thus eliminating errors due to the unproven human hand. To ensure a uniform travel speed, the tube material was rotated by means of a rotating device.

Welding of the experimental series was carried out using an XTW-1000 type optical fibre hand-held laser beam welding machine manufactured by Jinan Xintian Technology Co. of China. The machine produces a laser beam with a wavelength of 1080 nm and can deliver a maximum power of 1000 W. The machine's control panel allows the laser power output to be set in percentage form. The first set of experiments was welded at 24 cm/min and the second set of experiments at 40 cm/min, with the laser power varied from 100% to 20% in 10% steps. Based on the experiences of our preliminary experiments, no weld is formed at 10% laser power, so the 10% power level was skipped from the present study. In addition to the power delivered, it is possible to select the wobbling mode of the laser beam within the gun and to adjust the frequency and amplitude of this movement. The laser beam is swung inside the welding gun by optically guiding the laser beam [7]. Our welds were made without swinging the laser beam. The shielding gas used was nitrogen of 4.6 purity at 2.5 bar.

To ensure that the position of the cross-sections tested was the same for all bead-on-plate welds, the specimens were cut in the same position along their longitudinal axis using a Struers Discotom-10 water-cooled disc cutter. The specimens

were then embedded and metallographic grindings were made. Starting with P600 sandpaper and moving to progressively finer grain-size paper, we arrived at P2500 sandpaper. To remove the fine scratches, the samples were polished using a suspension of 3 μm diamond grains. The seam geometry was developed by etching. The etching of the grindings was performed using Adler etchant with the following composition:

- 9 g copper ammonium chloride;
- 150 ml hydrochloric acid;
- 45 g ferric chloride 6-hydrate;
- 75 ml distilled water.

Using the etchant, the geometry of the welds was developed by etching the samples for 2-3 seconds at room temperature and then examining them under an Olympus SZX 16 stereo-microscope. Finally, photographs of the welds were taken using Stream Essentials software to measure the seam width and fusion depth values required for the evaluation. From these values, diagrams were drawn, with some microscopic images plotted as examples to illustrate the resulting weld geometries.

3. Results and evaluation

By observing the microscopic images shown in figures 1–2, it can be observed that the pointwise wobbling mode results in an interesting seam geometry consisting of two parts, a wider and shallower heat conducting part and a narrower and deeper deep seam part.

Figure 1. shows the resulting seam width as a function of laser power and travel speed. The graph shows that the seam width increases with increasing power at both speeds, but to dif-

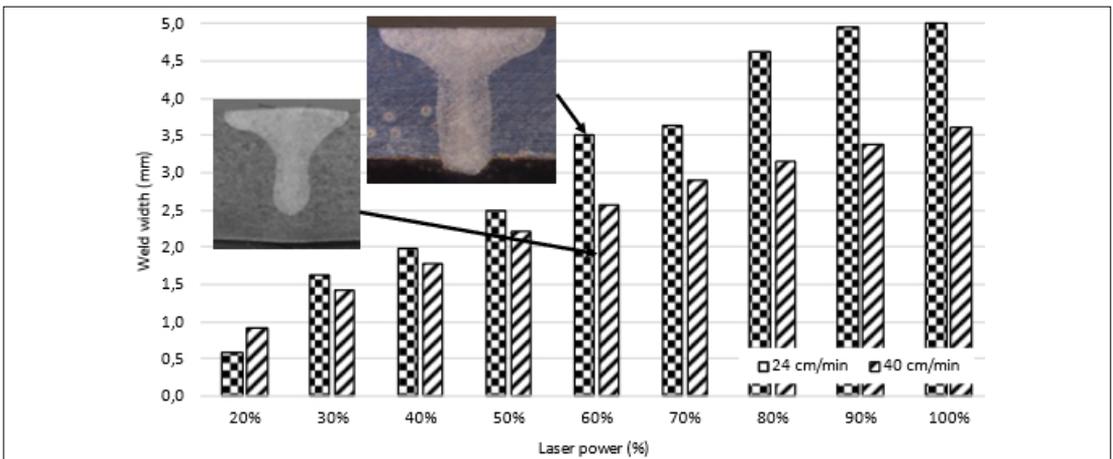


Fig. 1. Weld width as a function of laser power and travel speed.

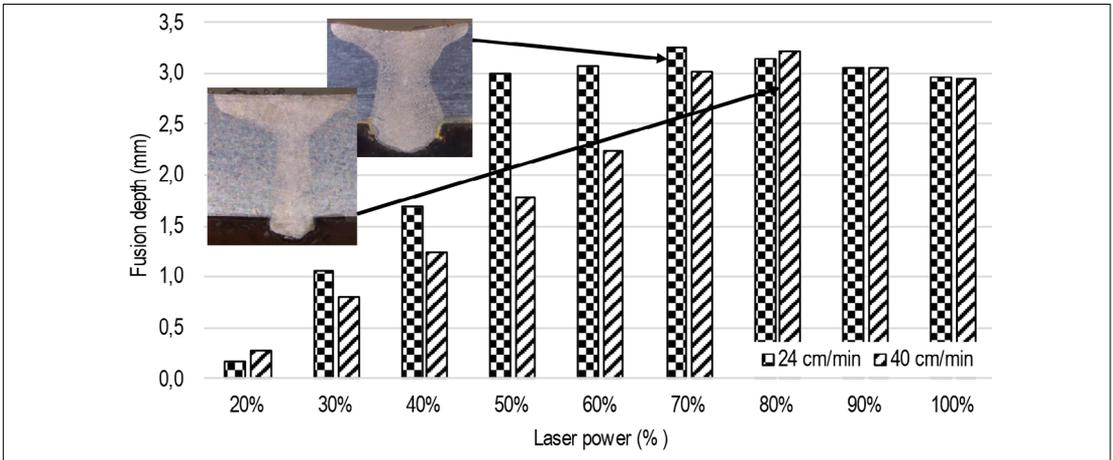


Fig.2. Fusion depth as a function of laser power and travel speed.

ferent extents, with a steeper - almost linear - curve at 24 cm/min and a flatter curve at 40 cm/min.

It can be concluded that both increasing the laser power and decreasing the travel speed will result in an increase of the seam width.

The inset micrographs clearly show that at the same power level, a higher travel speed leads to a smaller weld width.

Figure 2. plots the fusion depth as a function of laser power and travel speed. It can be said that the fusion depth is maximum at power levels of 70-80%, increases gradually at lower power levels and decreases again above 80%. It is interesting to observe that in the 70-80% power range, the welds with a much greater fusion depth were produced at 40 cm/min than at 24 cm/min, the former achieving a fusion depth of 5.91 mm, while the latter only achieved a fusion depth of 3.14 mm. Looking at the inset microscopic images and the data from the diagrams, it can be concluded that the weld geometries are slender and deep at 70-80% laser power and wider and shallower at 90-100%.

4. Conclusions

In the present study, bead-on-plate welds were welded by manual laser beam welding on austenitic stainless steel tubes to investigate the effects of laser power and travel speed on the weld geometry. Based on our results, the following conclusions can be drawn:

- by using a pointwise wobbling mode, two parts of the weld shape - a wider and shallower heat conducting part, and a narrower and deeper deep seam part - are formed;

- as the laser power is increased, the weld width increases almost linearly;
- increasing the travel speed leads to a decrease in the seam width;
- in the 70-80% power range, the fusion depth of a weld made at a travel speed of 40 cm/min exceeded that welded at a travel speed of 24 cm/min;
- at the test speeds, a slender and deep weld geometry was obtained at the 70-80% power level and a wider and shallower weld geometry at the 90-100% power level.

Acknowledgement

Linde Gáz Magyarország Zrt. provided us the necessary raw material and equipment for the experiments, which we would like to thank them for. The project was funded by the National Research, Development and Innovation Office - NKFIH (OTKA PD 138729).

References

- [1] Buza G.: *Lézersugaras technológiák I.* Edutus Főiskola, Tatabánya, 2012. 75.
- [2] Bitay E.: *Hegesztési alapismeretek.* Erdélyi Múzeum-Egyesület, Kolozsvár, 2021. 58. <https://doi.org/10.36242/mtf-16>
- [3] M. Reis, E. Şerifağaoğlu: *A Smart Handheld Welding Torch Device for Manual Spot Laser Welding.* Smart Manufacturing and Materials, II. (2022) 1.
- [4] ESAB Kft., Lézersugaras hegesztés. https://esab.com/hu/eur_hu/esab-university/blogs/what-is-laser-welding-and-how-does-the-technique-work/ (accessed on: 2024. febr. 26.).
- [5] V. Gapontsev, F. Stukalin, A. Pinard, O. Shkurikhin, Y. Grapov, I. Markushov: *Handheld laser welding and cleaning system for typical metal fabrication*

using 1.5 kW fiber laser source. Proceedings Volume 11981, Fiber Lasers XIX: Technology and Systems (2022) 1.

<https://doi.org/10.1117/12.2616585>

- [6] AGST Draht & Biegetechnik GmbH., Rozsdamentes acél 1.4301 adatlap.

<https://www.agst.de/4301?lang=hu> (accessed on: 2024. febr. 26.).

- [7] C. Yuce: *The Effect of Laser Beam Wobbling Mode on Weld Bead Geometry of Tailor Welded Blanks*. Published in 8th International Symposium on Innovative Technologies in Engineering and Science, (2020) 2.