This paper was presented at the 12th Annual Conference of the Society for Structural Integrity and Life 'Prof. Dr Stojan Sedmak' (DIVK12) November 17-19, 2024, Belgrade, Serbia

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INFLUENCE OF WELDING PARAMETERS ON THE GEOMETRIC CHARACTERISTICS OF SURFACE WELD METAL OBTAINED BY HANDHELD LASER WELDING

UTICAJ PARAMETARA NAVARIVANJA NA GEOMETRIJSKE KARAKTERISTIKE NAVARA DOBIJENOG RUČNIM LASERSKIM ZAVARIVANJEM

Originalni naučni rad / Original scientific paper
Rad primljen / Paper received: 1.12.2024
https://doi.org/10.69644/ivk-2025-02-0245

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Keywords

- handheld laser welding
- wire feed rate
- laser oscillation width
- weld metal width
- weld metal reinforcement

Abstract

The handheld laser welding process is the latest innovation in welding technology with an increasingly broad range of applications primarily due to the simplicity of the welder training, the minimal influence of the welder on joint quality, low heat input, high welding speed, and lower equipment costs. In this paper, the influence of selected welding parameters (wire feed rate and laser oscillation width) on the geometric characteristics of surface welds on low-carbon steel P235GH is presented. Additionally, based on the selected optimal parameters, a butt joint is performed by welding plates made of the same base material. The dependence of these parameters on weld metal width and weld metal reinforcement is determined. Furthermore, it is concluded that use of a higher power device would most likely be successful in a complete root penetration during butt welding.

Ključne reči

- ručno lasersko zavarivanje
- brzina dovođenja žice
- širina oscilovanja lasera
- širina navara
- visina nadvišenja navara

Izvod

Postupak ručnog laserskog zavarivanja predstavlja poslednju inovaciju u tehnologiji zavarivanja sa sve širim spektrom primene, pre svega zbog jednostavnosti obuke zavarivača, minimalnog uticaja zavarivača na kvalitet spoja, niskog unosa toplote, velike brzine zavarivanja i nižih troškova opreme. U radu je prikazan uticaj odabranih parametara zavarivanja (brzina dovođenja žice i širina oscilovanja lasera) na geometrijske karakteristike navara na niskougljeničnom čeliku P235GH. Pored toga, na osnovu odabranih optimalnih parametara izveden je sučeoni spoj zavarivanjem ploča od istog osnovnog materijala. Određena je zavisnost ovih parametara od širine navara i nadvišenja. Takođe, zaključeno je da bi zavarivanje korenog prolaza, odnosno, ostvarivanje provara kod sučeonog zavarivanja, verovatno bilo uspešno ako bi se koristio uređaj veće snage.

INTRODUCTION

Traditional welding processes used for maintenance /1-5/ or applying of protective layers on metal parts /6-9/ have been more and more 'suppressed' by new technologies and methods, primarily due to their availability, and secondly, due to relatively low cost. The handheld laser welding system represents the latest innovation in welding technology. Dr. Valentin Gapontsev introduced the idea of a laser processing system in January 2020, aiming for it to be small enough for handheld use, affordable for workshops, and most importantly, safe. Later that year, in November 2020, IPG Photonics (USA) launched the world's first portable air-cooled handheld laser welding system. In 2021, the same company developed a device that, in addition to welding, also has a surface cleaning function /10/. Since the introduction of this welding process, many companies have begun its production and further development, resulting in a wide range of devices with varying power levels, most commonly ranging from 1 to 9 kW.

The handheld laser welding machine is designed for high welding speeds, precise results, and a clean finish, making it especially effective for sheet metal work. It can handle a variety of materials such as stainless steel, mild steel, galvanised steel, Ni alloys, Ti, Al, Cu, brass, etc. The system allows for both direct laser welding and wire filling when used with an automatic wire feeder. It supports various welding configurations like splicing joints, lap joints, internal and external fillet welds, and seam welding. With its ease of use and flexibility, this machine is well-suited for a wide range of industrial applications. Today, the handheld laser welding process finds wide use in many industries for thin metal sheets, up to 2 mm, such as in: automobile manufacture, the kitchenware industry, metal furniture, stainless steel products, door and window guardrails, /11/.

In this paper, the influence of handheld laser welding parameters on the geometric characteristics of the surface weld metal is determined, as well as the feasibility of butt welding the 3 mm thick low-carbon steel.

MATERIALS AND METHODS

The samples are prepared by applying a surface layer, where the parent material is low-carbon steel, designated as P235GH (by EN 10028-2 standard) of dimensions 50×150 mm and thickness of 3 mm. The filler material is a wire that meets the requirements of EN ISO 14341-A standards, designated as G 42 3 M21 3Si1 (or ER70S-6, according to AWS A5.18) which is well-suited for a wide range of applications in boiler and vessel construction, as well as in structural steel engineering, /12/. The chemical compositions of parent and filler materials are given in Table 1.

Table 1. Chemical composition of the parent and filler metals, /11/.

Parent material steel P235GH						
C	Mn	Si	P_{max}	S_{max}	Cu	Fe
≤ 0.16	≤ 1.20	≤ 0.35	0.025	0.015	≤ 0.30	residue
Filler material G 42 3 M21 3Si1						
0.07	1.5	0.85	/	/	/	residue

The surface layer is deposited using a handheld laser welding process with model MAX A1SE40 of 1.5 kW power, manufactured by Maxphotonics,. The device consists of a power source (laser), a wire feeder, and manual welding torch, as shown in Fig. 1. Preparing the base metal (BM) for surfacing consists of grinding the surface to remove impurities and oxides.

Two sets of samples are made. In the first part of the test, the wire feed rate was varied while keeping the other parameters unchanged (Table 2). In the second part of the test, the laser oscillation width (LOW) is varied, while other parameters are kept fixed (Table 3). Six samples are produced in the first part of the test, while five samples are produced in the second part.

The tests are conducted while butt welding the plates (15×500×3 mm) of the same material. A complete series of tests is carried out, changing several parameters, such as groove edge preparation (I and V grooves), root gap (0 to 2 mm), laser oscillation width (0 to 6 mm), wire feed rate, and welding speed.

Figure 1. Handheld laser welding equipment: a) power source; b) wire feeder; c) torch.

Table 2. Handheld laser welding parameters - Part I.

Parameters	Sample no.					
	I	II	III	IV	V	VI
Wire feed rate, cm/min	30	40	50	60	70	80
Recommended thickness range (mm)	3-4					
Power usage rate (%)	100					
Welding speed (cm/min)	40					
Shield gas	Ar					
Shield gas flow (l/min)	16					
Laser oscillation width (LOW)	2					

Table 3. Handheld laser welding parameters - Part II.

Parameters	Sample no.				
	I	II	III	IV	V
Laser oscillation width (LOW)	1.5	2.0	2.5	3.0	3.5
Wire feed rate (cm/min)	40				
Recommended thickness range (mm)	3-4				
Power usage rate (%)	100				
Welding speed (cm/min)	40				
Shield gas	Ar				
Shield gas flow (l/min)	16				

RESULTS AND DISCUSSION

Figure 2 shows the samples obtained by handheld laser welding, where the wire feed rate was varied while keeping the other welding parameters unchanged. The samples show that the appearance of the weld metal did not significantly change with variations in wire feed rate, except in the case when the wire feed rate was at its lowest (V_w = 30 cm/min), where the weld metal surface deviated from a uniform shape. Figure 3 shows the dependence of weld metal width and reinforcement on wire feed rate, clearly indicating that as the wire feed rate increases, the weld metal width decreases, while weld metal reinforcement increases with the change in weld metal width being more pronounced.

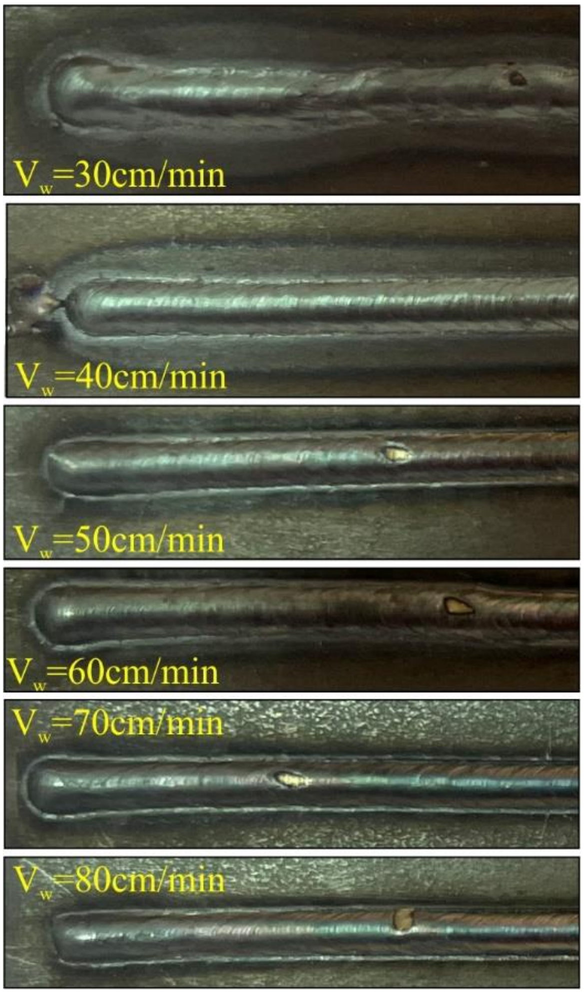

Figure 2. Samples obtained by handheld laser welding with changes in V_w.

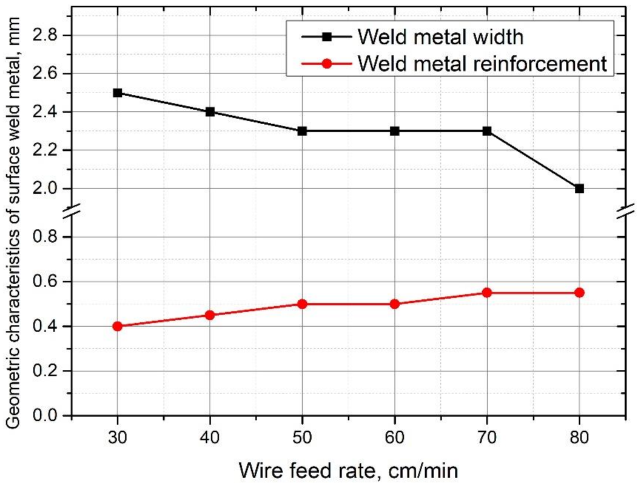

Figure 3. Weld metal width and reinforcement vs. wire feed rate.

Figure 4 shows the samples obtained by the handheld laser welding process, where the laser oscillation width was varied, and the wire feed rate was set at V_w = 40 cm/min.

Dependence of the weld metal width and reinforcement on the laser oscillation width are illustrated in Fig. 5, where it is clearly seen that as the LOW increases, the weld metal width increases while the weld metal reinforcement decreases. These results are in line with expectations, given that the wire feed rate, i.e., the volume of the supplied filler metal, is constant, while the LOW increases, thereby increasing the area over which the material is deposited.

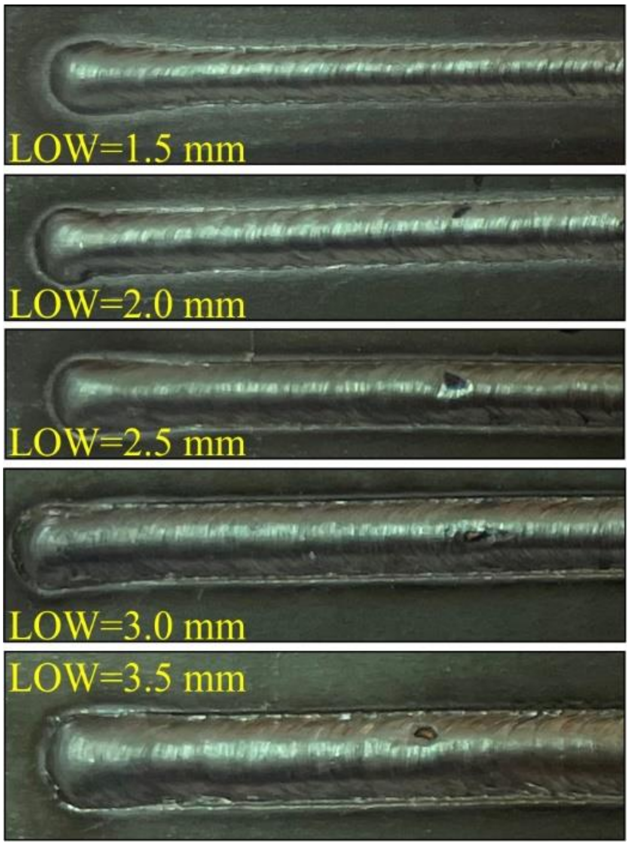

Figure 4. Samples obtained by handheld laser welding with changes in LOW.

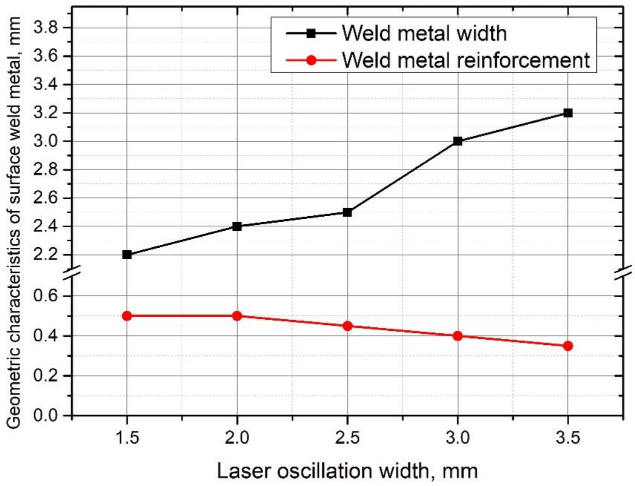

Figure 5. Weld metal width and reinforcement vs. LOW.

In the butt welding of plates, despite to variation of a wide range of parameters, complete root penetration was not achieved in any case. Figure 6 shows the weld face and root from one of numerous tests, where it is clearly evident that complete penetration is not achieved. This finding may indicate that the device is likely not powerful enough or that it is necessary to use base materials of smaller thickness. Additionally, a characteristic of this device is in that the manufacturer recommends welding materials up to 4 mm thick without strictly specifying the type of welded joint being referred to; it is likely that the manufacturer has referred exclusively to fillet joints.

Figure 6. Multilayer butt welding with handheld laser welder: a) weld face; b) root.

Future research will be directed toward the handheld laser welding process using higher-power devices to achieve complete root penetration. Should it be established that complete root penetration cannot be achieved in butt joints, even with devices of higher power, it is highly probable that this type of welding will not find wider industrial applications for the production of critical welded joints.

CONCLUSIONS

Based on the experimental results obtained with samples surfaced using handheld laser welding, where the welding wire G 42 3 M21 3Si1 was used as the filler material, and P235GH steel as the parent metal, it can be concluded:

- due to the increased wire feed rate, the weld metal width decreases while the weld metal reinforcement increases;
- with an increase in laser oscillation width, the weld metal width increases while its reinforcement decreases;
- complete root penetration cannot be achieved in butt welding of low-carbon steel of 3 mm thickness using handheld laser welding process with a device rated at 1.5 kW;
- it is assumed that using a device with higher power would most likely result in complete root penetration during butt welding.

ACKNOWLEDGEMENT

This work is the result of research supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, under Contract 451-03-65/2024-03/200105 dated February 5, 2024.

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