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Experimental Process for Butt Welding and No Gap for AISI 304 Steel with 2 mm Thickby Laser Welding Method

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ABSTRACT: Laser welding is increasingly and rapidly applied in various industrial fields. This paper proposes an experimental process for butt welding and no gap for 2 mm thick AISI 304 steel by laser welding method. The input parameters of the process are laser power (LP) and welding speed (WS). The results show that the weld is well connected through visual and microscopic evaluation, and the tensile strength (TS) value is quite good.

KEYWORDS: laser welding, AISI 304 steel, laser power (LP), welding speed (WS), microstructure, tensile strength.

I. INTRODUCTION

In recent years, the rapid development of laser technology has gradually replaced traditional technologies. Among them, the use of laser welding in various industrial applications has increased rapidly, with unique features such as low and precise heat input, small heat-affected zone, narrow weld width, deep weld penetration, low stress, small deformation, and high welding speed [1-3]. Many studies have shown that the input parameters significantly affect the quality of laser welds.

The automated laser welding process of 2.0 mm thick AISI 304 stainless steel plates was studied by A. Lisiecki et al. [4]. A disc laser with a beam spot diameter of 200 μm was used for bead welding on the plate, followed by welding of autogenous joints. The influence of basic welding parameters such as laser power, welding speed, and focus position on the fusion zone configuration, joint quality, microstructural changes, and microhardness distribution on the joints were analyzed and presented in this paper. The results showed that hardening of 2.0 mm thick plates is crucial for obtaining high-quality and reproducible butt joints in the case of AISI 304 stainless steel due to its relatively low thermal conductivity and concomitant high thermal expansion. A relevant reduction in microhardness was observed in the weld zone. The average value of the microhardness of the base metal was 230 HV0.1, while the microhardness in the fusion zone of the test welds ranged from 130 to 170 HV0.1. In addition, the microstructural changes in the weld metal and the heat-affected zone of the test joints were described. Compared with conventional lasers, fiber laser welding is characterized by high melting efficiency, different keyhole modes, and power density characteristics, which can affect the heat and flow of the molten pool during welding.

The present aim of Khalid M. Hafez et al. [5] was to study the weldability of 5 mm thick AISI 304 austenitic stainless steel sheets by fiber laser. Therefore, plate welding was explored on Type 304 stainless steel plates with different laser powers, welding speeds, eccentric distances with varying gases of shielding, and their effects on the shape and properties of the weld zone and the final solidification microstructure at room temperature. Laser power, welding speed, and focal distance

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greatly influence the grain appearance and shape of the weld zone. Still, they have almost no significant influence on the weld's microstructure and mechanical properties. The microstructure of all laser welds is always austenitic, consisting of about 3~5% ferrite. However, lower laser powers and higher welding speeds result in finer solidification, primary ferrite, or mixed-mode solidification, resulting in crack-free welds.

The aim of the paper by A. Kurc-Lisiecka et al. [6] was to analyze the influence of the basic parameters of laser welding (i.e., laser beam power and welding speed, as well as energy input) of butt joints of 2.0 mm thick AISI 304 stainless steel sheets on the weld shape and quality of the joint. The results showed that providing a suitable weld shape with a fine grain structure and a narrow heat-affected zone is possible. Still, it requires carefully selecting welding parameters, especially low energy input. Microhardness measurements showed that in the case of welding butt joints with a high-power diode laser in the HAZ region, the microhardness slightly increased to approx. 185HV0.2 compared to the base material (160-169HV0.2) decreased the fusion zone (FZ) microhardness to approx. 140-150HV0.2 were observed. All welded specimens broke from the joint during testing at tensile stresses in the range of 585 MPa to 605 MPa with corresponding percentage elongations in the 45-57 % range. It can be seen that the strength of the joint is not less than the strength of the base metal of a 2 mm thick AISI 304 austenitic stainless steel sheet.

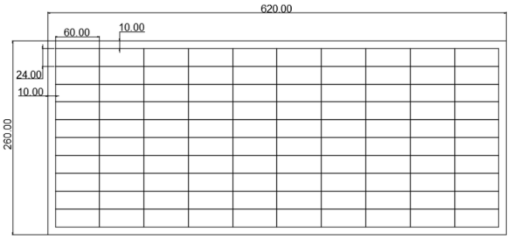
Tsung-Yuan Kuo et al. [7] used the relative tensile strength of the weld and base metal as a quality factor for Taguchi analysis in laser welding of stainless steel. The results showed that the optimum process parameters can be reasonably achieved even in cases where the base metal has a large property variation or the operating setup is not well controlled.

The study by Maddili Praveena Chakravarthy et al. [8] aimed to identify the most important control factors that will help improve the tensile strength of laser-welded Cu-Ni 90/10 alloy joints. Different laser welding process parameters and levels were used to join Cu-Ni alloys. The process parameters such as Laser Power (LP), Shielding Gas (argon) (SG), Focus Position (FP),and Welding Speed (WS) were selected in the experimental study. According to Taguchi's experimental design, welding was carried out on a 4 mm thick sheet of material. The mechanical properties were evaluated, and microstructural observations were made. It was found that the highest tensile strength of 234 MPa and hardness of 83 HV were obtained with 90% and 87% of the base material, respectively. The most influential optimum process parameters were determined using S/N analysis, and each process parameter's percentage contribution was estimated using ANOVA. Laser power was found to be the influential parameter, contributing 64% to achieving the highest strength of laser welded joints. The experimental values and the results of the validation tests were in good agreement.

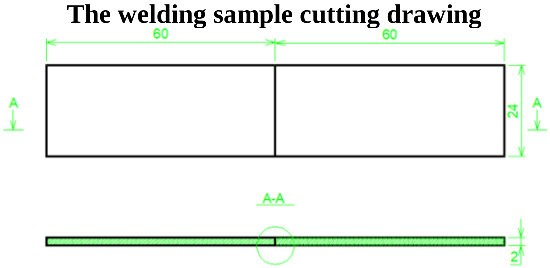
This paper proposes an experimental process for butt welding with no gap for 2 mm thick AISI 304 steel by laser welding method, with the input parameters of the process being laser power and welding speed.

II. MATERIAL AND METHODS

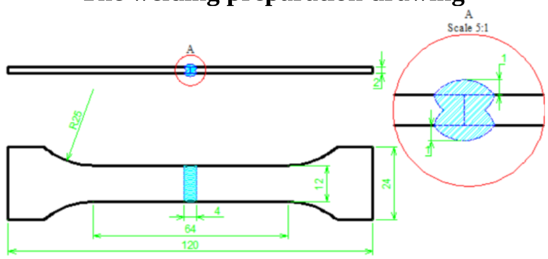
The welded test specimens, which measure 60 mm in length and 24 mm in width, are cut using a laser cutter from a 2 mm thick AISI 304 stainless steel sheet.



The welding sample cutting drawing



The welding preparation drawing



The weld drawing and tensile specimen size after welding

The PG YLR-1070 Series fiber laser welding machine specifications

Central Wavelength, nm	1070±10
Mode of Operation	CW/Modulated
Modulation	0-50

Frequency, kHz	
Maximum Average Power, W	100 to 4000
Power Tunability, %	10-100
Power Stability**, %	± 0.5
Optical Noise***, % RMS	<2, typ.1
Output Fiber Core	Single-mode or 50, 100 and 200 µm diameter
Single-mode Beam Quality, M^2	<1.1 (up to 3 kW)
Beam Parameter Product, mm × mrad	<2 @ 50 µm, <5 @ 100 µm, <10 @ 200 µm

The welding sample symbols and welding process parameters

SAMPLE	LASER POWER LP (kW)	WELDING SPEED WS (m/min)
1	1.2	1.4
2	1.3	1.8

III. RESULTS AND DISCUSSION


Sample 1


Sample 2

The microstructure of the weld area

Image of welded sample after tensile test

The average tensile strength results of the samples

SAMPLE	AVERAGE TENSILESTRENGTH (MPa)
1	454
2	532

The weld is well connected after the tensile test, as evaluated by the visual, microstructure, and sample image. At the same time, the average tensile strength is high.

IV. CONCLUSION

The article presents an experimental process for butt welding with no gap for 2 mm thick AISI 304 steel by laser welding method. The process's input parameter pair (laser power and welding speed) were investigated with two sets of values, respectively 1.2 kW and 1.4 m/min, 1.3 kW and 1.8 m/min. The visual, microstructure, and tensile test resultsshow that the weld is very good. The average tensile strength valuesare high, respectively, 454 MPa and 532 MPa.

ACKNOWLEDGMENT
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