



Corrosion Testing of Laser Welded Austenitic Stainless Steel Welds

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Abstract

Laser welding is becoming increasingly common in industrial applications for welding stainless steels. To reduce costs, hot-rolled stainless steel beams can be replaced by laser-welded structures. In our research, the corrosion resistance of laser-welded T-joints made of 1.4301/304 austenitic stainless steel were investigated. The joints were welded one or both sides, with different combinations of travel speed and laser power. Electrochemical corrosion measurements were performed in 3.5% NaCl solution in a standard three-electrode corrosion cell.

Keywords: *laser welding, stainless steel, electrochemical corrosion.*

1. Introduction

Laser welding (52 according to ISO 4063:2023) is becoming increasingly common in industrial applications. Thanks to the high energy density, welding can be performed with lower heat input, low heat-affected area and higher productivity (travel speed) [1, 2]. Due to the low thermal conductivity of stainless steels, there is a significant amount of warping during welding, which can be reduced by the low heat input of laser welding. In laser welding, a distinction is made between solid-state laser welding, gas laser welding and diode laser welding. Thanks to the rapid development of the technology, a fusion depth of up to 15 mm can be achieved when welding stainless steels [3, 4].

Stainless steels are steels containing at least 10.5% chromium and up to 1.2% carbon [5]. Thanks to chromium alloying, a passive oxide layer is formed on their surface, which protects them from environmental effects. Rolled and welded stainless steel beams are increasingly used in structural engineering and interior design. Thanks to their corrosion resistance, maintenance tasks can be reduced. The most commonly used material grades are 1.4301 (AISI 304) and 1.4404 (AISI 316L) austenitic stainless steels [6, 7].

Corrosion is the physico-chemical interaction between a metal and its environment, which results in a change in the properties of the metal and often in a deterioration of the functional properties of the metal, the environment and the engineering system they form [8]. The typical mode of failure for stainless steels is some form of localised corrosion attack. The most common form of localised corrosion is pitting. This form of corrosion is a localised anodic dissolution concentrated in a small area, the rate of which can be extremely rapid. It occurs in the form of pits or holes on the surface, with varying morphologies and depths.

The corrosion resistance of nickel alloys and stainless steels can be determined from their composition by the pitting resistance equivalent (PRE). The most commonly used method for austenitic and duplex steels are:

$$\text{PREN} = \text{Cr} + 3.3 \cdot \text{Mo} + 16 \cdot \text{N}$$

Electrochemical corrosion measurements can be used to determine the pitting corrosion potential of materials with a passive layer, at which voltage the surface passive layer is locally damaged and the metal goes into solution.

2. Test materials and methods

In our research, we used austenitic corrosion resistant steel material grade 1.4301 (AISI 304) with a thickness of 4 mm, the composition of which is shown in Table 1.

The T-joints were made without chamfering and without a joint gap using tack welds.

Table 1. The chemical composition of material grade 1.4301

Symbol	C	Mn	Si	Cr	Ni
1.4301	0.08	2	0.75	18	8

The welds were made with two WSX ND60 welding heads powered by a Raycus RFL-6600S laser source with a nominal power of 6600 W. The two side T-joints were made simultaneously with two fillet welds using two laser welding heads facing each other.

The welds were made with three different parameter combinations: the samples welded from both sides (Figures 1 and 2) at 1.5 m/min with a power of 3630 W and at 2 m/min with a power of 4620 W.

The sample welded from one side (Figure 3) was produced at a speed of 1 m/min and a power of 3960 W.

The laser beam was wobbled along a straight line 0.2 mm wide for each sample. The shielding gas used for welding was grade 4.6 nitrogen.

Electrochemical corrosion measurements were carried out using a standard three-electrode corrosion cell and a Biologic SP-150 potentiostat. The test setup is shown in Figure 4: a platinum mesh was used as a counter electrode, an oversaturated AgCl/KCl electrode as a reference electrode and the welded sample as the working electrode. The electrolyte was a 3,5 % NaCl solution prepared from high purity NaCl and distilled water.

After the corrosion cell was assembled, the system was left to rest for 45 min to stabilize the open circuit potential (OCP). After resting, the voltage was scanned from OCP = -0.2 V to OCP = +1.5 V at a rate of 1 mV/s.

3. Results and discussion

The current density-potential curves recorded by the potentiostat were used to compare the corrosion properties of each joint Figure 5 shows the results of the three test specimens.

The open circuit potentials of the samples are shown in Table 2. The open circuit potential of the hot-rolled plate is -0.07±0.02 V. The open cir-

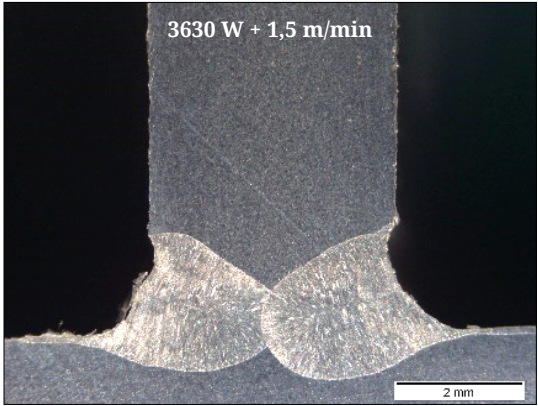


Fig. 1. Cross section of the two sided T-joint, etched with Adler

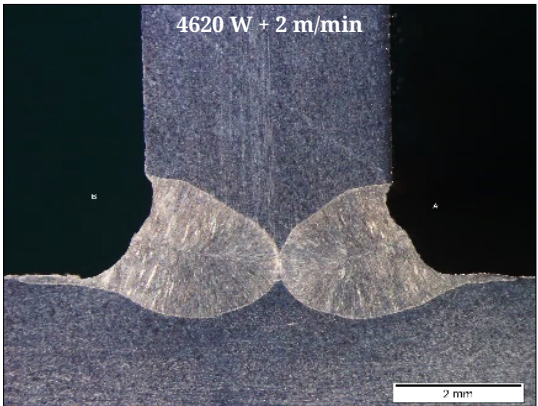


Fig. 2. Cross section of the two sided T-joint, etched with Adler.

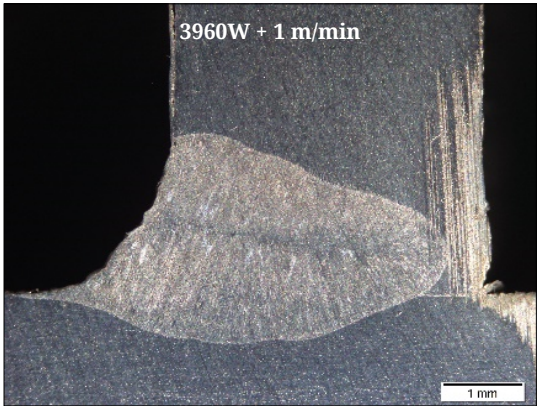


Fig. 3. Cross section of the one sided T-joint, etched with Adler.

cuit potential of the three welded samples is almost the same, no significant difference can be measured between the samples.

Table 2. The open circuit potentials of the samples measured in 3,5% NaCl solution

Sample	OCP
3630 W + 1.5 m/min	-0.11 ± 0.02 V
4620 W + 2 m/min	-0.11 ± 0.03 V
3960 W + 1 m/min	-0.10 ± 0.03 V

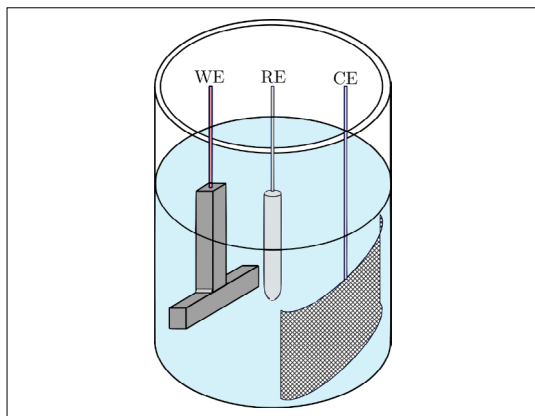


Fig. 4. Standard three electrode corrosion cell setup.

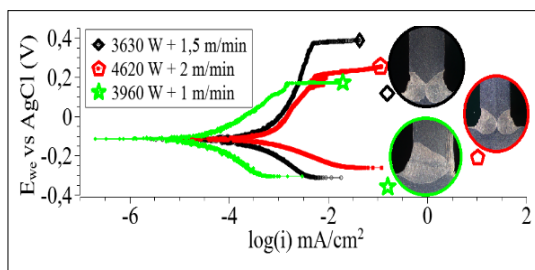


Fig. 5. The results of the electrochemical corrosion measurements conducted in 3,5% NaCl solution.

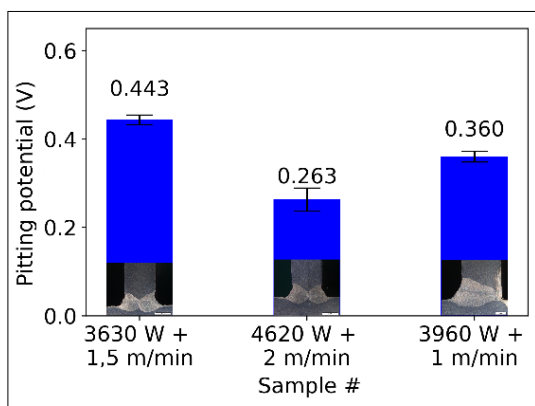


Fig. 6. The pitting potentials of the samples, measured in 3,5% NaCl solution.

The curves shown in **Figure 5** can be divided into three distinct parts: the initial reduction phase, the oxidation phase during the scanning of voltages more positive than the open circuit potential, and the subsequent passive phase. During the passive phase, the current density does not increase, or increases only very slightly, as the voltage increases. When the voltage is increased beyond a certain point, the current density increases rapidly, this voltage is called the pitting potential.

The T-joint welded from both sides at a travel speed of 1.5 m/min shows the highest pitting potential. The pitting potential of each sample is shown in **Figure 6**.

The more negative the pitting potential of a given sample in a given medium, the sooner and easier it is for pitting to occur. A more positive pitting corrosion potential indicates a more noble behaviour and better corrosion properties in the given medium.

4. Conclusions

In our study, we investigated the corrosion properties of single- and double-sided T-joints prepared by laser welding at different power and different travel speeds in a 3.5% NaCl solution. Based on the obtained current density–potential curves, the specimen welded at a speed of 1.5 m/min and a power of 3630 W showed the highest pitting potential. The pitting potential of the sample also welded from both sides at 2 m/min with a power of 4620 W was significantly lower, presumably due to excessive undercut.

The T-joint, made from one side with a power of 3960 W and a travel speed of 1 m/min, was not a full penetration weld, which is likely to have caused crevice corrosion in the joint gap, resulting in increased current density and lowering the measured pitting potential. To confirm this hypothesis, it is necessary to examine the site of pitting corrosion in the welded joint.

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