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Laser welding of duplex stainless steel with nitrogen as shielding gas

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ABSTRACT

Nitrogen loss from laser welding melts pools and can have a deleterious effect on weld toughness for duplex stainless steels. This effect can be alleviated by using nitrogen as the shielding gas during laser welding. The use of nitrogen results in increased austenite levels in the weld metal and improved toughness levels.

1. Introduction

Duplex stainless steels are a combination of austenite and ferrite, and some grades employ nitrogen as an alloying ingredient which promotes austenite formation in welds and improves toughness. In standard laser welding, using argon as the shield gas, nitrogen can be lost from the weld pool and the austenite content of the weld will be reduced. Kyröläinen and Lukkari (1999) and the Outokumpu welding handbook (Outokumpu, 2010) have noted that a low austenite content can lead to nitride precipitation, which has a negative effect on weld corrosion properties and toughness.

It has been noticed by Keskitalo and Mäntyjärvi (2013) that nitrogen shielded austenitic laser welds have a higher hardness than argon shielded welds. Westin and Serrander (2012) have noted that using nitrogen as the backing gas had a measurable positive effect on the weld metal austenite formation when welding with CO_2 lasers.

This paper investigates the idea that if nitrogen is used as the shield gas some of it would dissolve into the weld pool, compensating for the amount lost by evaporation.

Kyröläinen et al. recommend the WRC-92 diagram for duplex weld material. The presence of nitrogen promotes the formation of austenite in duplex stainless steels according to the following equations (Kyröläinen and Lukkari, 1999):

$$\text{Ni-equivalent}\,(\text{Ni eq}) = \%\text{Ni} + (\%\text{C} \times 35) + (\%\text{N} \times 20) + (\%\text{Cu} \times 0.25) \quad (1)$$

$$\text{Cr-equivalent}\,(\text{Cr eq}) = \%\text{Cr} + \%\text{Mo} + (\%\text{Nb} \times 0.7) \quad (2)$$

According to Sakai et al. (1989) the austenite content of the steel should be higher than 50% in order to achieve high impact toughness, and according to Miura and Ogawa (2000), the lowest pitting corrosion rate is also associated with an austenite content of 50% or more.

In addition to the problem of nitrogen loss from the laser weld, the high solidification rates associated with laser welding tend to suppress austenite formation. Welds were therefore produced at process parameters designed to show the effects of two different solidification rates as well as the effect of nitrogen as a shield gas.

2. Experimental procedure

The test welds were made by using a 4 kW disc laser with 300 mm focusing optics. Shielding gas was blown over the weld using a pipe in front of the keyhole, with a 60 mm shielding gas nozzle behind the keyhole. The root sides of the welds were also gas shielded, see Fig. 1.

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Table 1
The weld parameters used.

Material	Laser power (kW)	Speed (m/min)	Focal point position (mm)	Shielding gas and flow rate	Energy input (J/mm)
LDX	3.0	9.0	−1.0	Argon 30 l/min	20
2101®	3.0	9.0	−1.0	Nitrogen 30 l/min	20
1.5 mm	2.0	1.5	−6.0	Argon 30 l/min	80
	2.0	1.5	−6.0	Nitrogen 30 l/min	80

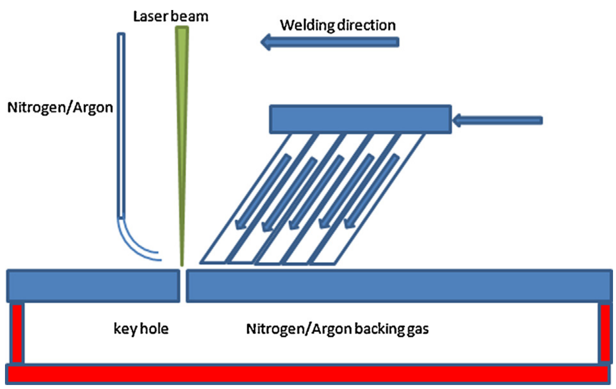

Fig. 1. The shielding gas arrangements.

The welded material was 1.5 mm LDX 2101® duplex stainless steel. The Ni-equivalent was 7.3 and Cr-equivalent was 21.7, which means that the austenite content was 45% (Kyröläinen and Lukkari, 1999).

The laser weld parameters, shown in Table 1, were chosen in order to show the influence of heat input and nitrogen shielding gas on the austenite content of the weld.

Five samples of both argon and nitrogen shielded welds underwent bend testing using a manually operated bending machine.

3. Results

Cross-section macrographs of the four welds are presented in Figs. 2 and 3. There are minor differences in weld shape as a result of changing the shield gas, but the main difference is the increase in weld width between the fast (9 m/min) and slow (1.5 m/min) welds.

This increase in weld width at reduced welding speed is a result of increased lateral thermal conduction associated with longer laser-material interaction times.

The cross sections presented in Fig. 4 were etched in NaOH liquid using a voltage of 2.5 V for 10 s. This etching technique makes the ferrite areas corrode more and become darker. The austenite and ferrite phase contents of the welds were then measured

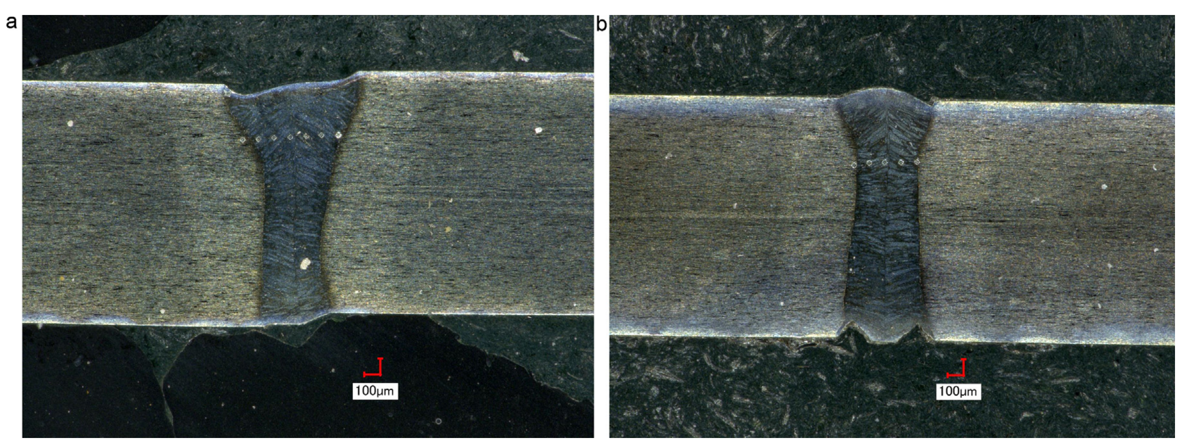

Fig. 2. Cross sections of the 3 kW, 9 m/min welds: (a) argon shield gas, (b) nitrogen shield gas.

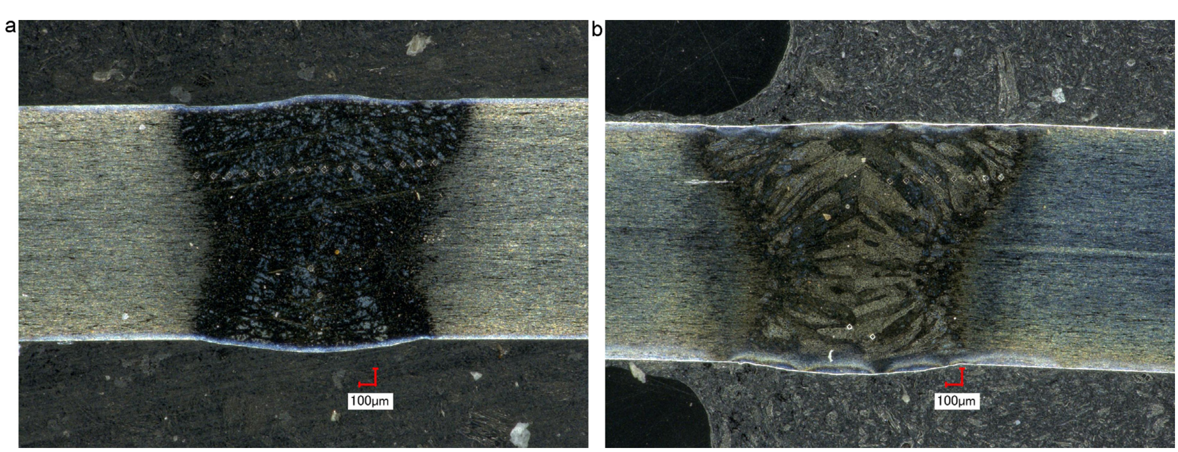

Fig. 3. Cross sections of the 2 kW, 1.5 m/min welds: (a) argon shield, (b) nitrogen shield.