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Investigation on microstructure evolution and properties of duplex stainless steel joint multi-pass welded by using different methods

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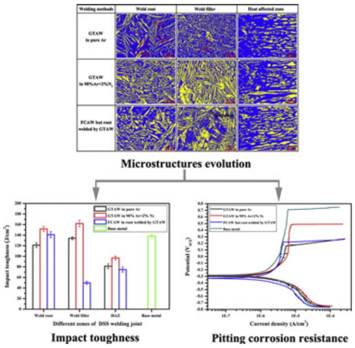
HIGHLIGHTS

- 2% N_2-supplemented shielding gas improved toughness and pitting resistance.
- Different duplex stainless steel welds exhibited various fracture mechanisms.
- Cr_2N and σ precipitation reduced toughness of heat-affected zone.
- Inclusions had adverse effect on toughness and pitting resistance of weld metal.
- Pitting corrosion occurred at γ_2 and Cr-depleted region around Cr_2N and σ phases.

GRAPHICAL ABSTRACT



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ABSTRACT

We investigated the microstructure, impact toughness, and pitting corrosion resistance of duplex stainless steel (DSS) welding joints fabricated by using gas tungsten arc welding (GTAW) and flux-cored arc welding (FCAW) with different shielding gas compositions. N_2-supplemented shielding gas during the GTAW process significantly facilitated austenite formation and reduced amounts of chromium nitride (Cr_2N) precipitation tendency, thereby resulting in an improvement in impact toughness. The heat-affected zone (HAZ) had relatively low toughness because of an insufficient austenite content and Cr_2N and σ-phase precipitation. Dimple fracture was the main fracture mode of the weld metal. Large irregular inclusions resulting in discontinuous dimple fractures mainly contributed to the lowest level of toughness in the FCAW weld metal. The HAZ fracture mode was dominated by the ferrite quasi-cleavage fracture. The base metal exhibited a mixed fracture mode of alternating dimple and quasi-cleavage. Furthermore, the pitting resistance of the whole joint was predominated by the HAZ. The N_2-supplemented shielding gas significantly improved the pitting resistance of the GTAW joint. The pits were prone to form in the secondary austenite and around Cr_2N. Moreover, an abundance of inclusions in the FCAW weld metal resulted in adverse effects on the pitting resistance.

1. Introduction

Duplex stainless steel (DSS) is increasingly used in marine constructions, oil and gas industries, and chemical and petrochemical industries due to the attractive combination of its mechanical properties and

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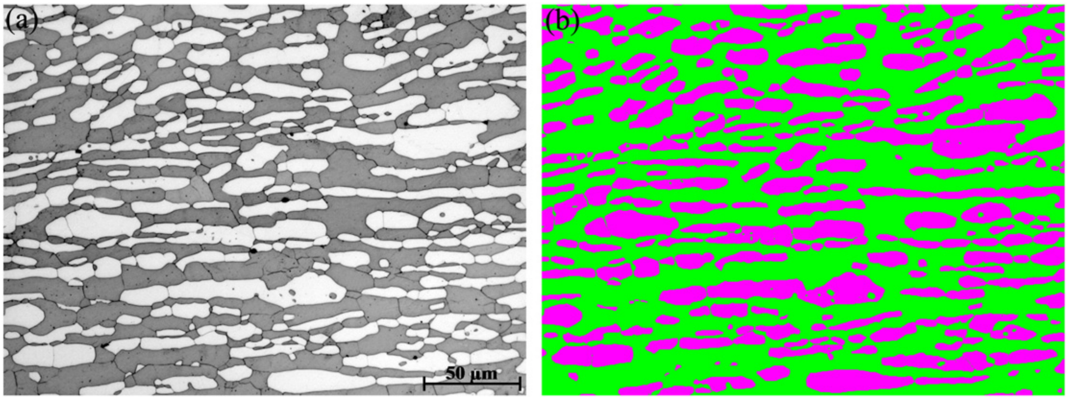

Fig. 1. The comparison of a before and after image processed by Pro-Image software for the phase content calculation: (a) original image and (b) processed image.

Table 1
The chemical compositions of the base material and different wires.

Materials	Chemical composition (wt.%)										
	C	Si	Mn	P	S	Ni	N	Cr	Mo	Cu	Fe
Base material (UNS S31803)	0.018	0.54	0.92	0.011	0.003	5.3	0.17	22.9	3.0	0.042	Bal.
Filler wire for GTAW (ER2209)	0.008	0.48	1.54	0.017	0.0006	8.63	0.15	22.94	3.07	0.14	Bal.
Filler wire for FCAW (E2209T_1)	0.04	0.46	1.08	0.017	0.011	8.73	0.146	23.02	3.57	0.10	Bal.

corrosion resistance [1–4]. To attain excellent properties, DSS in-service is generally recommended to maintain a ferrite/austenite (α/γ) ratio close to 1:1 [5–7]. However, this dual-phase balance is disturbed during welding. According to ISO 15156-3, the austenite content in the fusion-welded joint should be within the range of 30%–70% [8].

It is well known that welding is an inevitable fabrication process in most of applications of DSS. Gas tungsten arc welding (GTAW) is one of the most popular technologies for welding DSS because it produces high-quality welds that meet service requirements, although its low welding efficiency restricts its applications to some extent [9–13]. In

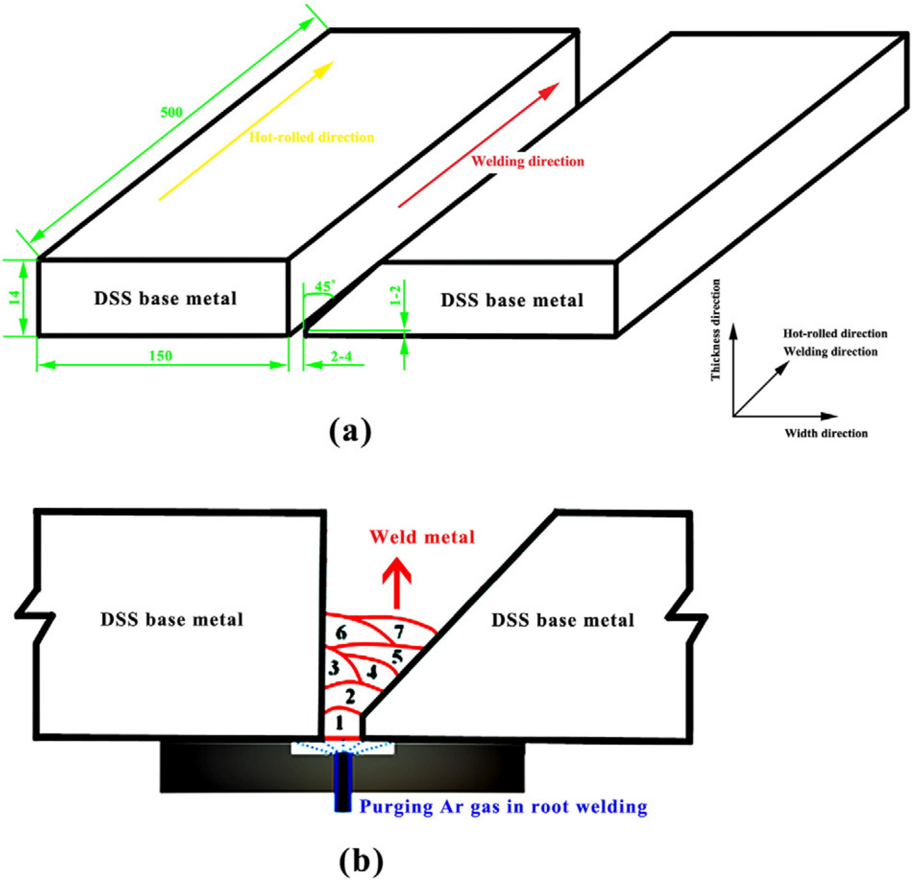

Fig. 2. The schematic diagram of the welding process.