Marin structure, Chemical plant

Initiation mechanism of pitting corrosion in weld heat affected zone of duplex stainless steel

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Abstract

The pitting corrosion resistance was investigated in duplex stainless steel welds performed by one pass high current gas metal arc welding, it was found that pitting corrosion mainly occurs in high-temperature HAZ (HT-HAZ), where peak temperature is heated to ferrite single phase range. Most of the pitting corrosion in HT-HAZ is initiated from (Ti,Cr)N in the ferrite phase. Even in duplex stainless steel with 50 ppm or less titanium, nitrides containing titanium are precipitated in HT-HAZ, and no clear Cr-depleted zone was confirmed around these nitrides, but it was confirmed that almost no passive film was formed on the surface of (Ti,Cr)N. It is considered that the initiation of pitting corrosion is caused not only by the Cr-depleted zone formed around Cr nitride but also by the vulnerability or lack of passive film on the surface of (Ti,Cr)N.

Background & Results

Duplex stainless steel has a microstructure with a ferrite-to-austenite volume ratio of approximately 1:1, showing excellent corrosion resistance, mechanical properties, workability, and weldability. It has numerous applications in critical areas, such as marine constructions, seawater equipment, and various types of chemical plants. Welding is an extremely important manufacturing technology for duplex stainless steel products. However, in the heat-affected zone (HAZ) of duplex stainless steel welds, excessive ferrite forms owing to the high cooling rate and will easily deteriorate the pitting corrosion resistance. However, the pitting corrosion mechanism in duplex stainless steel welds is still unclear because of the complex microstructural changes caused by the welding thermal cycle. There are very few analyses that consider precipitates as the initiation sites of pitting corrosion. Therefore, it is impossible to fully elucidate the relationship between precipitates and pitting corrosion resistance. In this study, focusing on the HAZ of duplex stainless steel, the initiation mechanism of pitting corrosion was investigated using detailed measurements of the concentration distribution near the pitting corrosion initiation site. As a result, it was originally revealed that trace Ti content in the duplex stainless steel will cause the precipitation of titanium-contained nitrides in the HAZ region during gas metal arc welding (GMAW) of duplex stainless steel. The passive film was vulnerable or lacking on the surface of such nitrides containing titanium. The lack of passive film could hardly protect the duplex stainless steel welds from the initiation of pitting corrosion.

Significance of the research and Future perspective

This research revealed an original mechanism of pitting corrosion caused by precipitates in the HAZ of duplex stainless steel welds. This result provides new prospects and considerations in the chemical compositional design and manufacturing process of the duplex stainless steel to achieve a higher resistance to pitting corrosion. This study will also ensure the safety of duplex stainless steel products for better environmental protection and energy saving.

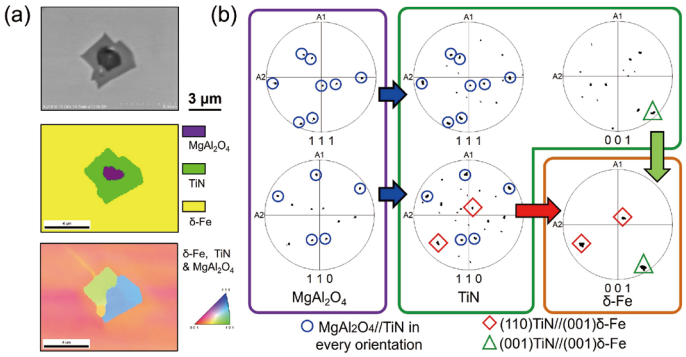

Fig. 1 Identification of oxide accelerating TiN formation for δ-ferrite nucleation to improve mechanical properties of stainless steel welds. (a) Nucleus characterization, (b) phase orientation relationship and nucleation mechanism.

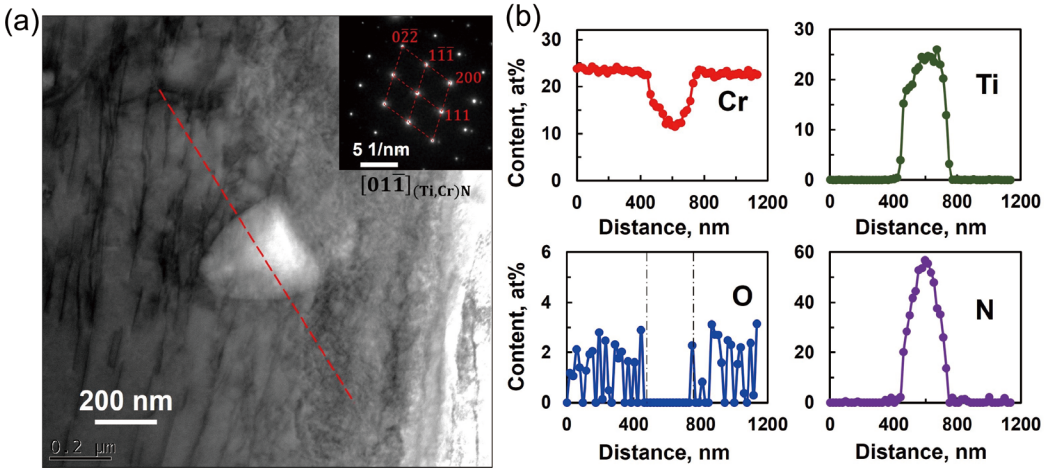

Fig. 2 Initiation mechanism elucidation of pitting corrosion in HT-HAZ of duplex stainless steel welds. (a) Phase identification of (Cr,Ti)N, (b) vulnerability or lack of passive film on (Cr,Ti)N. (TEM-EDS line analysis.)

Patent
Treatise
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