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Impact Fracture Behavior of Duplex Stainless Steel Weldment[†]

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Abstract

Weld simulation has been performed to improve the lowering of the toughness in the heat affected zone of super duplex stainless steel by increasing of austenite volume fraction. The cooling rate of the weld bond region was controlled by varying the cooling time from 1473K to 1073K ($\Delta t_{12.8}$). Austenite content was increased to as much as the base metal by using slow cooling rate ($\Delta t_{12.8} = 114s$). However the toughness was not restored by the increase of austenite. The ferrite grain size also increased by using a slow cooling rate. The apparent size of ferrite grains was almost constant through the cooling rates by the austenite formed intragranularly. It is considered that the toughness of duplex stainless steel is influenced by austenite distribution.

KEY WORDS: (Duplex stainless steel) (Bond region) (Cooling rate) (Toughness)

1. Introduction

Duplex stainless steels (DSSs) are Fe-Ni-Cr alloys with an austenitic-ferritic microstructure at room temperature. The mechanical properties and corrosion resistance of DSSs are generally superior to conventional austenite or ferrite grades. DSSs can have yield strengths twice the austenite grades, while retaining good ductility and toughness properties¹⁾.

The welding process has a great effect on the duplex structure, particularly in the heat affected zone (HAZ), although the microstructure and the properties of weld metals are generally controlled with some success by adjusting the filler material composition. It has been well known that the impact toughness of DSS weldments deteriorate with an increase in volume fraction of δ -ferrite within the HAZ^{2), 3)}. The bond region shows the lowest toughness in the HAZ⁴⁾.

In this study, the volume fraction of austenite in the HAZ of a super duplex stainless steel was controlled by varying the cooling rate from the single phase ferrite region using a weld simulator.

The effectiveness of controlling austenite content with heat input was examined in terms of toughness improvement of the heat affected zone.

2. Experimental Procedures

The material investigated was the super duplex stainless steel, SAF2507 (25.4%Cr, 6.7%Ni, 3.8%Mo, 0.27%N, all wt%). The microstructure of the base metal is a mixture of elongated austenite bands in a ferrite matrix. The volume fraction of ferrite in the base metal was 43% (57% austenite) using the Magne Type Ferrite Scope.

The specimens were cut from the base metal plate along the rolling direction, then subjected to simulated thermal cycles using a resistance heated weld simulator (Gleeb 1500) to simulate the heat affected zone microstructures.

The specimens were heated to the peak temperature of 1673K and then cooled at different rates. The cooling rates were controlled by varying the cooling time from 1473K to 1073K ($\Delta t_{12.8}$). The cooling time ($\Delta t_{12.8}$) was varied from 6s to 114s. The corresponding heat input was in the range from 1 to 6 kJ/mm which was calculated from the relation between cooling time and heat input⁵⁾.

Charpy impact specimens were prepared after applying the thermal cycles and impact tested in the temperature range from 77K and 273K. The fracture surfaces of the specimens after Charpy impact tests were exam-

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ined using a scanning electron microscope (SEM).

The specimens for optical metallography were also prepared by mechanically polishing and then electrically etching in 10 wt.% oxalic acid solution at the condition of 5V for 10s.

3. Results and Discussion

The relation between cooling time from 1473K to 1073K (Δt_{12-8}) and austenite content measured by the point counting method is shown in **Fig. 1**. Austenite is

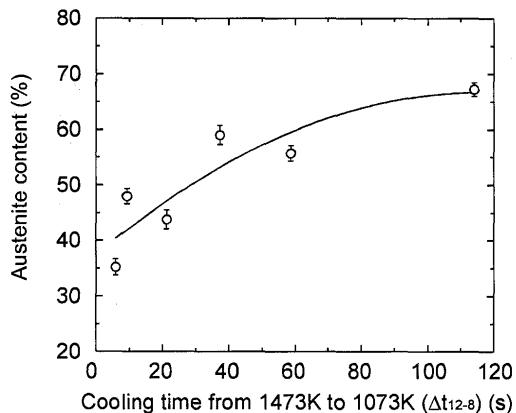


Fig. 1. Relation between cooling time from 1473K to 1073K (Δt_{12-8}) and austenite content within the HAZ of SAF2507 super duplex stainless steel.

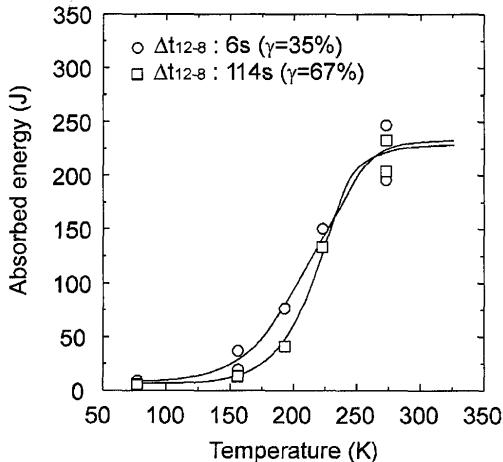


Fig. 2. Charpy impact curves for HAZ of SAF2507 super duplex stainless steel at different cooling rates.

considered to precipitate in this temperature range. As the cooling time increased the austenite content increased.

The volume fraction of austenite was recovered at the same level of base metal when the cooling time of 114s was used.

The impact curves for the specimens of lowest and highest cooling rate are shown in **Fig. 2**. It was found that the impact energy was hardly affected by the cooling rate. Upper shelf energies were almost 230J and ductile brittle transition temperatures ($\sqrt{T_{RE}}$) were 210K.

The size of ferrite grains was also measured using metallographic samples. The size increased from 170 μm to 460 μm as the cooling rate decreased. However, the volume fraction of austenite also increased, which kept the apparent size of ferrite grains constant by forming intragranularly.

This fact shows the impact fracture behavior of duplex stainless steel is more influenced by the austenite distribution rather than the austenite content. The same behavior was observed in previous work⁴⁾ in which the effect of peak temperature on the impact toughness was investigated.

4. Conclusions

- (1) The volume fraction of austenite was increased from 35% to 67% by varying the cooling rate (Δt_{12-8}). However, the impact toughness of the bond region in the heat affected zone was not restored by increasing the ferrite grain size.
- (2) The apparent size of ferrite grains was kept constant by the austenite forming intragranularly, which is considered to result in the same impact behavior at the different cooling rates.

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