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Structure and properties of the heat affected zone of duplex steels welded joints

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Abstract: Influence of the secondary austenite γ_2 precipitation in a heat-affected zone of a welded joints of duplex steels on hardness and corrosion resistance have been analysed. The secondary austenite was created as a product of ferrite decomposition $\alpha \rightarrow \gamma_2$ as an effect of the welding thermal cycle and an aging following the welding process. Correlation of the thermal cycle, γ_2 phase morphology, kind of precipitations, and hardness, as well as a corrosion resistance were described. Thermal cycle has a significant influence on the transformation $\alpha \rightarrow \gamma_2$, and morphology of the created γ_2 phases. The main mechanism of the secondary austenite creation is the diffusive transformation, as a result of which the Widmanstätten structure is formed. The increase of the γ_2 phase quantity in the tested steel heat affected zone causes an essential influence of the joint hardness and corrosion resistance.

Keywords: Duplex steel; Heat affected zone; Secondary austenite; Hardness; Corrosion resistance

1. INTRODUCTION

The application of duplex steels in a construction of chemical tankers has led to the elaboration of the quality criteria for steel and welded joints in the ships construction that concern to the macro and microstructure, mechanical properties and corrosion resistance. Special attention has been paid to the ferrite - austenite fraction ratio, the presence of carbides on grain boundaries and intermediate phases precipitations in the weld metal and the heat-affected zone (HAZ). The completion of these criteria requires appropriate control over the procedure of carrying of structure transformation processes, which are essentially subjected to the character of the heat cycle during the welding process. So far the utilize quality assessment criteria do not refer to the secondary austenite presence in the weld and in the heat-affected zone. The data concerning to the influence of thermal cycle on the transformation of the ferrite to secondary austenite ratio in HAZ has been explained fragmentarily so far. Short durations of the high temperature impact and high temperature gradients in the the heat-affected zone determine the specificity of the diffusion processes and the ferrite (α) - austenite (γ), and secondary austenite (γ_2) transformation.

The γ_2 secondary austenite in duplex steel is formed as the result of the $\alpha + \gamma \rightarrow \alpha + \gamma + \gamma_2$ transformation in the austenitic - ferritic structure following the heating to temperature below the A - B line in the phase equilibrium diagram of Fe-Cr-Ni. As the result of cooling down from the temperature above the A – B line the γ primary austenite creates as a product of $\alpha \rightarrow \gamma$ transformation.

The secondary austenite formation in the duplex steels is the outcome of thermodynamic equilibrium breach of the alloy during heat treatment, or an effect of the welding heat impact, whose magnitude depends on the value of the heat input.

The secondary austenite in the duplex steel may emerge as a result of the following transformations: eutectoid: $\alpha \rightarrow \sigma + \gamma_2$ in the temperatures 973 – 1173K, diffusion transformation in the temperatures above 923K which results is the Widmanstätten structures, and the isothermal conversion in the temperatures below 923K that proceeds similarly to the martensite transformation. The nucleation and growth of the γ_2 phase may occur on the α - γ phase grain boundaries, or inside the ferrite grains. The presence of the secondary austenite in duplex steels, in respect of the chemical composition, distribution, location, and morphology of the phase, causes the loss of chemical balance between ferrite and austenite, and the local decline of corrosion resistance of the alloy, particularly of the pitting corrosion. The influence of the welding heat cycle and postweld treatment on the HAZ properties is the subject of this paper.

2. MATERIALS AND EXPERIMENTAL PROCEDURE

The decomposition of the primary phases (α, γ) in the duplex steel plates of thickness of 16 mm butt weld joint. The heat-affected zone was analysed on an example of UNS S31803 steel (Table 1) as welded, and after post weld treatment. Avesta Sheffield FCW 2205-H flux cored wire was used as a filler material (Table 1).

3. RESULTS

The heat-affected zone structure after heat treatment consisted of primary ferrite grains with primary austenite precipitated on the grain boundaries, and with secondary austenite growing as a Widmanstätten type from the grain boundary austenite into the ferrite grains.

Secondary austenite formed in the ferrite and at ferrite/austenite phase boundaries during all post weld heat treatments. Two morphologies of secondary austenite precipitates have been created. Huge needles of the secondary austenite dominated after aging at 1273 – 1473 K temperature and duration of it: 30, and 90s. Small secondary austenite precipitates, that replaced in the ferrite grains at temperatures: 1273-1473 K, and aging period of time: 60s. The secondary austenite precipitations behaviour was similar for all aging samples. Volume fraction of ferrite (α) austenite (γ) and secondary austenite (γ_2) are strongly influenced by welding and aging parameters.

Chromium and nickel constitution in the ferrite, austenite and the secondary austenite in HAZ, for every heat treatment temperature is similar. The difference of nickel constitution in HAZ in the austenite and secondary austenite is larger for 1273 K temperature.

The pitting corrosion rate is bigger for the welded joint formed by 1.6 kJ/mm heat input than for the ones produced by 2.2 kJ/mm heat input. The maximum lost of weight was observed for heat treatment: 1273 K/30s. Generally post weld heat treatment decreases the pitting corrosion resistance.

Table1.
Chemical composition of UNS S31803 steel, and FCW 2205-H flux cored wire

Chemical composition [% by weight]	Material	
	UNS S31803	FCW2205-H
C	≤0.03	0.032
Cr	21-23	23.17
Ni	4.5–6.5	9.29
Mo	2.75-3.5	3.48
Mn	≤2.0	0.95
Si	≤1.0	0.7
N	0.15-0.19	0.16
P	≤0.03	0.017
S	≤0.02	0.006
Cu	-	0.11

The heat affected zone HV5 hardness from the root of the weld had higher value than hardness from the face of the weld. Higher hardness of the secondary austenite compared with the ferrite and primary austenite was observed. The secondary austenite hardness is strongly influenced by silica content changes of the phase.

4. CONCLUSION

Thermal the past of the heat-affected zone has a substantial influence on its structure and properties. Precipitates of γ_2 formed as a result of post weld aging have a most important influence on HAZ hardness.

Pitting corrosion resistance of the welds is strongly influenced by thermal cycle parameters. A different level of Chromium and nickel constitution in the α, γ, and γ_2 phases, as well as a phase volume fraction have a significant influence on corrosion resistance. Generally post weld heat treatment decreases the pitting corrosion resistance.

Primary austenite has a bigger hardness compared with ferrite for the every post weld conditions. The secondary austenite hardness is influenced by chemical composition changes of the phase.

The presence of the intermediate phases, carbides, and nitrides precipitates in a heat-affected zone of a welded joint of duplex steels was not observed in this investigation**.**