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Mechanical characteristics of welded joints between different stainless steels grades

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Abstract. Investigation of mechanical characteristics of welded joints is one of the most important tasks that allow determining their functional properties. Due to the very high, still rising, cost of some stainless steels it is justified, on economic grounds, welding austenitic stainless steel with steels that are corrosion-resistant like duplex ones. According to forecasts the price of corrosion resistant steels stil can increase by 26 ÷ 30%. For technical reasons welded joints require appropriate mechanical properties such as: tensile strength, bending, ductility, toughness, and resistance to aggressive media. Such joints are applied in the construction of chemical tankers, apparatus and chemical plants and power steam stations. Using the proper binder makes possible the welds directly between the elements of austenitic stainless steels and duplex ones. It causes that such joits behave satisfactorily in service in such areas like maritime constructions and steam and chemical plants. These steels have high mechanical properties such as: the yield strength, the tensile strength and the ductility as well as the resistance to general corrosion media. They are resistant to both pitting and stress corrosions. The relatively low cost of production of duplex steels, in comparison with standard austenitic steels, is inter alia, the result of a reduced amount of scarce and expensive Nickel, which is seen as a further advantage of these steels.

1. Introduction

One of the most important factors of duplex stainless steels (DSS) is its excellent corrosion resistance. They have also enhanced mechanical properties. All these features caused that they are an attractive substitute to austenitic grades. The other characteristic parameter of DSS is the high yield strength. It is higher than 450 MPa. It enables reducing considerably the weight of manufactured constructions [1,2]. This is why these steels are highly recommended for such elements like tanks and pipelines. These elements both should be corrosion resistant and should be light ones [3-5]. The problem arises when currently one must repair older elements made of austenitic stainless steels. To decrease the cost nowadays DSS is applied what results in a specific combination of DSS and austenitic steel. In this way one obtains a dissimilar welded joint. The dissimilarity causes that it could be a weak point of whole construction. To determine the features of the resulting dissimilar joints one should analyse weldabilities of both steel grades [6-9]. Weldability of austenitic steel could be determined as good. To weld such steels one should use consumables electrode allowing obtain up to 10 % of δ ferrite in the material of welded joints. Moreover one should avoid more excessive diluting of the base metal. It allows preventing solidification cracking. In the case of DSS its weldability could be determine as good or even better. Mostly it is related with the chemical composition of DSS. In the table 1 is presented chemical composition of some grades of DSS.

Table 1. Chemical composition of chosen duplex steels [3].

Steel name	C	N	Cr	Ni	Mo	Others
2101	0.03	0.22	21.5	1.5	0.3	5Mn Cu
2304	0.02	0.10	23.0	4.8	0.3	Cu
2205	0.02	0.17	22.0	5.7	3.1	
2507	0.02	0.27	25.0	7.0	4.0	

The objective of chemical composition of each DSS is to obtain approximately equal amounts of ferrite and austenite grains in stable phase of the steel. The ferrite grains content in DSS is strictly related with the annealing temperature. It is a direct relation. The other feature of DSS is its corrosion resistance. The extending the content of molybdenum and nitrogen, increased the stability of their microstructure and allowed for further increasing its properties. Application of steels of austenitic-ferritic structure, mainly for welded constructions, became the reason of particular interest of their weldability. It is widely believed that the duplex steels are relatively easy to weld. However are known examples of serious difficulties occurring especially during welding constructions of large dimensions. These difficulties led to significant financial losses related to the need of repairing and confirmatory testing of re-welded joints.

2. Problems of welding dissimilar joints

As it was stated above some problems with dissimilar austenitic-duplex welds can be observed. They are related with structural changes within the welded joints. The results of these changes are problems with corrosion resistance decreasing. This is why one should investigate the corrosion resistance of weld metal, parent materials, and heat affected zones. From different types of corrosion the stress one is the most serious. In the case of austenitic steels the stress corrosion is induced by water used for cooling. This is why often materials with higher amount of nickel are used. But the influence on Ni is different for austenitic steels and for DSS. The austenitic steel is more resistant to cracking corrosion at the amount of Ni above 25%. DSS is generally more resistant at the Ni level equal to 5%.

The environment influence on cracking corrosion of the analysed dissimilar welded joints could be tested with different corrosion test. One of them is the slow strain rate tests. It allows explaining whether the special conditions of chlorides polarization as well the anodic one could influence the mechanical properties of the analysed joints. It could prove the thesis of material environmental impact. Generally in such tests the braking was observed in the material or weld part with the lowest strength characteristics. To test this impact two grades of steels has been chosen, one from the group of austenitic steels (316L) and one from DSS (2205). From these two steel grades lower strength characteristics are for the first one (316L). In table 2 are presented chemical compositions of both tested steels.

Table 2. Chemical composition of 2205 and 316L stainless steels.

	Content of chemical elements (wt. %)						
	C	**Si**	**Mn**	**Cr**	**Ni**	**Mo**	**N**
2205	0.017	0.40	1.5	21.9	5.7	3.0	0.16
316L	0.019	0.38	1.7	16.0	11.0	2.5	0.04

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The specimens were prepared using steel sheet with 15 mm in thickness in the case of each analysed steel grades. The tested welded joint was performed using the method of submerged arc welding. The welding parameters are listed in table 3.

Table 3. Welding parameters.

Bead	Current	Voltage	Current	Welding	Heat input
1	460-500	32	DC (+)	38-40	2.4
2	560-580	33	DC (+)	30	3.48

In figure 1 is presented the sheet preparation of the welded edge. The both edges of steel sheets were machined identically.

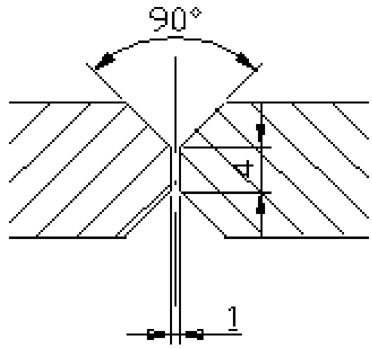

Figure 1. Details of edge preparation.

The weld was performed using the wire of ϕ 3,2 mm made of DSS. It was manufactured from DSS of the 22Cr-9Ni-3Mo grade. The flux utilized in the specimen welding was a non-lloyed agglomerated one of the type ESAB Flux 10.93. Heat inputs parameters were 2.4 and 3.4 kJ/mm. To obtain the proper welded joint two beds needed to be performed. In figure 2 is presented the obtained weld.

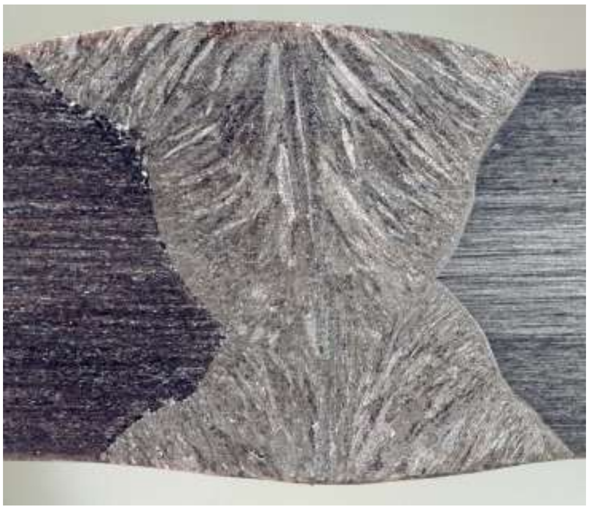

Figure 2. Obtained welded joint.

To obtain a good quality of the performed weld joint the interpass temperature was limited to 100°C maximum. Then each weld was X-rayed.

3. Metallography of the analysed weld

To determine the mechanical properties of the analysed joint the metallographic examinations were conducted. It allows estimating the microstructure of the performed weld. The observations were conducted to determine some characteristics of the analysed weld. Firstly the aim was to determine mutual relationship between ferrite and austenite in the weld. Secondly the aim was to estimate the occurrence of the secondary austenite. Finally it help to state the presence of precipitations of intermetallic phases. The specimen of the welded joint, for the microscopic analysis, was etched in Berah reagent ($HCl + K_2S_2O_4$). In figures 3 and 4 are presented microstructures of different parts of the weld.

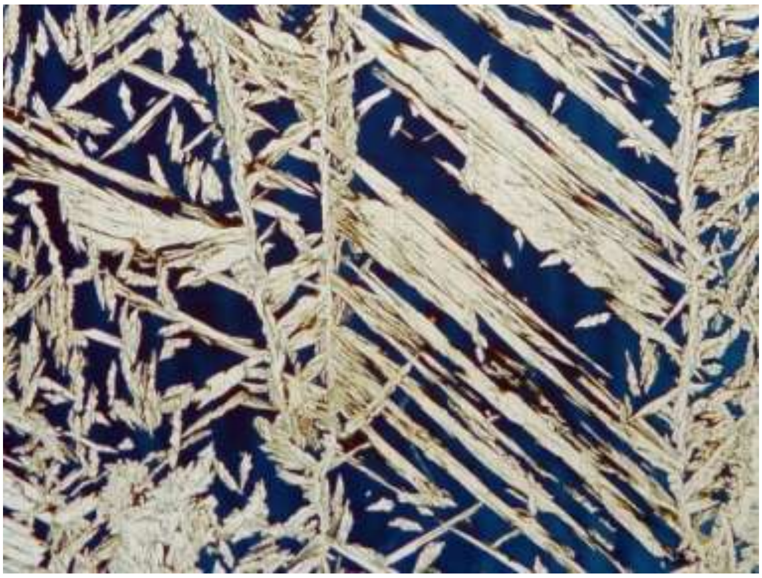

Figure 3. Microstructure of the face of the joint.

Figure 4. Microstructure of the centreline.

Generally it could be stated that the obtained microstructure is rather not uniform. In both figures is visible dendritic microstructure which was developed because of fast cooling conditions. In figure 3 a greater share of ferrite is visible. It could be stated that more globular austenite was observed in root

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area of the first bead. It is related with the temperature acting during the second bed performing what resulting in creating the secondary austenite (figure 4). The other problem is related with the microstructure of the heat affected zone (HAZ). As it is known HAZ and its microstructure are critical for the mechanical properties of the welded joint. So special attention was paid to the analysis of HAZ both from the side of 2205 steel (figure 5) and the side of 316L (figure 6).

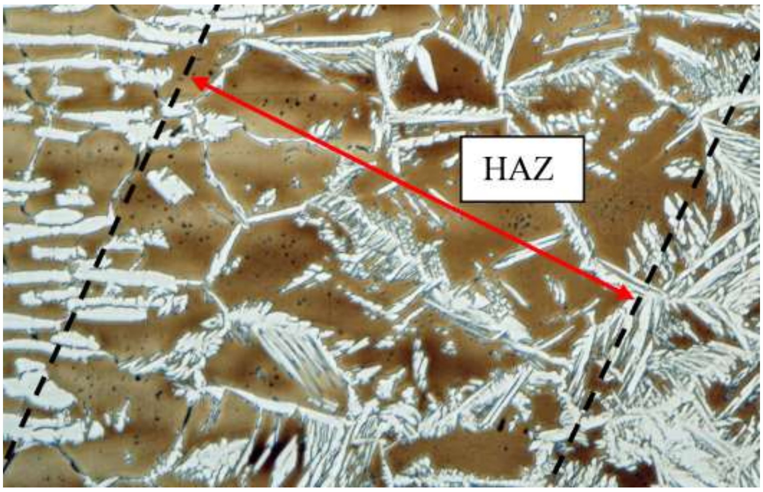

Figure 5. HAZ from the 2205 side (steel on the left).

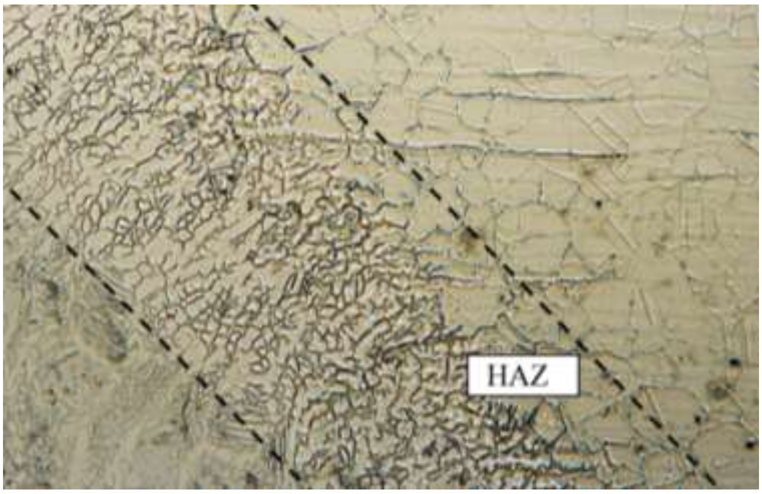

Figure 6. HAZ from the 316L side (steel on the righ).

In the figure 5 is visible HAZ of the width close to 100 μm. The content of ferrite grains in this zone is higher than in 2205 steel. It is estimating as a little higher than 50%. The lamellar austenite precipitates could be observed. Whereas in figure 6 could be observed HAZ between weld and the 316L steel of the width close to 300 μm. The lamellar austenite precipitates could be observed around austenite grains. The ferrite content is half the size of the previous case (25%).

4. Conclusions

The main conclusion of the presented investigation could be ascertainment of the fact that the heat input has the significant influence on decreasing the mechanical properties of dissimilar welded joints obtained on the base of 2205 DSS and 316L austenitic one. This influence has been observed by the microstructure investigation. It must be stated that it affects the corrosion resistance of such dissimilar joints. The observed HAZ-es were of 300 μm in width on the side of 2205 steel and of 100 μm on the side of 316L steel. It should be stated that such widths of HAZ causes the more serious influence of heat inputs on properties of these dissimilar welds. It should be additional stated that after submerged arc welding the 2205 DSS still is two-phase with austenitic and ferritic microstructure. The 316L steel still represent the austenitic structure but some sparse bands of ferrite δ could be observed. For the weld the heterogeneous, dendritic structure is characteristic.

The presented results could be used to improve the constructions manufactured on the base of DSS and austenitic steels according different design approaches [10, 11]. The next investigations should be conducted to analyze the influence of different harmful environment on the properties of investigated dissimilar welded joints.

5. References

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