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Original scientific paper

TESTING THE IMPACT TOUGHNESS OF THE WELDED JOINT OF STEEL S21800

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Abstract

Steel S21800 is an austenitic stainless steel with higher mechanical strength than 316 stainless steel, as well as excellent resistance to corrosion, galling, and wear. Thanks to its specific chemical composition — including elevated levels of manganese, silicon, and nitrogen — this material is increasingly used in industrial applications that demand high reliability and resistance to both mechanical and chemical aggression. Welding such a material requires special attention, as the alloying elements can influence the microstructure and, consequently, the mechanical properties, particularly impact toughness. In this study, the weldability of S21800 steel was evaluated using the TIG welding method, with a focus on assessing the impact toughness of the welded joint. Testing was performed on two types of samples with different chemical compositions. The research included metallographic analysis and impact toughness testing using the Charpy method, targeting the heat-affected zone (HAZ) and the weld metal (WM). The results showed that the chemical composition of both base and filler materials, along with the welding method, plays a crucial role in determining joint quality. The observed differences in toughness between the WM and the HAZ were attributed to variations in delta ferrite content.

Keywords*: austenitic steel, weldability, delta ferrite, impact toughness*

1. INTRODUCTION

UNS S21800 is an austenitic stainless steel specifically designed to offer enhanced wear and galling resistance. It is a nitrogen-strengthened alloy, with increased levels of silicon and manganese. These additions improve its wear resistance and mechanical strength without compromising corrosion resistance at ambient and elevated temperatures. This steel offers better corrosion resistance than type 304 and is nearly comparable to type 316 in many environments, including marine and chloride-exposed conditions. Because of its unique combination of strength, galling resistance and corrosion behavior steel S21800 is used in: automotive valves, fastener galling, pins and marine shafts [1]. In this work, the weldability of S21800 steel was tested with an emphasis on the evaluation of the impact toughness of the welded joint. In order for the weldability of a material to be satisfactory, it is necessary to find the most adequate type of welding and the conditions in which welding will be performed. Weldability of a steel depends on the type of the material (chemical composition, microstructure...), filler material and welding process. Austenitic stainless steels are weldable and can be joined using all fusion and resistance welding processes. The TIG method is the most commonly used welding technique for stainless steels and is therefore considered suitable for this study [2,3].

2. EXPERIMENTAL

The welding process was performed on steel samples with a diameter of 15 mm which have different delta ferrite contents in their initial microstructure. The chemical composition of S21800 steel, according to the ASTM A276 standard [4], along with the delta ferrite content of the tested samples, is given in Table 1. The Ferritoscope MP30E, manufactured by Helmut Fischer GmbH, was used to determine the delta ferrite content. According to the literature [5], for steels used at elevated temperatures and under high stress, such as S21800, it is recommended that the delta ferrite content does not exceed 3%.

Table 1. Chemical composition and the content of delta ferrite for the steel S21800

Standard/ Melts	Chemical composition (wt. %)								Average content of delta ferrite for base metal (%)	Average content of delta ferrite for weld metal (%)
	C	Si	Mn	Cr	Ni	P	S	N		
ASTM A276	≤0.10	3.4-4.5	7-9	16-18	8-9	≤0.006	≤0.03	0.08-0.18		
No.1	0.05	4.5	8.6	16	8	0.007	0.016	0.147	1.95	5.5
No.2	0.05	3.8	8.9	17	9	0.007	0.005	0.161	0.12	2.4

The standard electric arc welding process – TIG in a protective argon atmosphere – was used for welding. The welding conditions were the same for all samples (current strength: 70–80 A, wire feed rate: 0.5 m/min, gas flow rate: 10 l/min), and 316L AISI stainless steel [6] was used as a filler metal. The metal pieces were welded using butt welding, a process in which two pieces of metal are placed end-to-end without overlap and then welded. The impact toughness test was conducted according to the ISO 148 – 1 standard using the Charpy method, targeting the heat-affected zone (HAZ) and the weld metal (WM) [7]. It is important to determine the fracture location and analyze the fracture surface to see if any irregularities are present. Microstructure of the samples are austenitic with the particles of chromium carbides and delta ferrite. The presence of the sigma phase on delta ferrite islands is visible in the base material as well as in the heat affected zone and weld metal. The microstructure of the weld metal is a cast microstructure, Figure 1 [8].

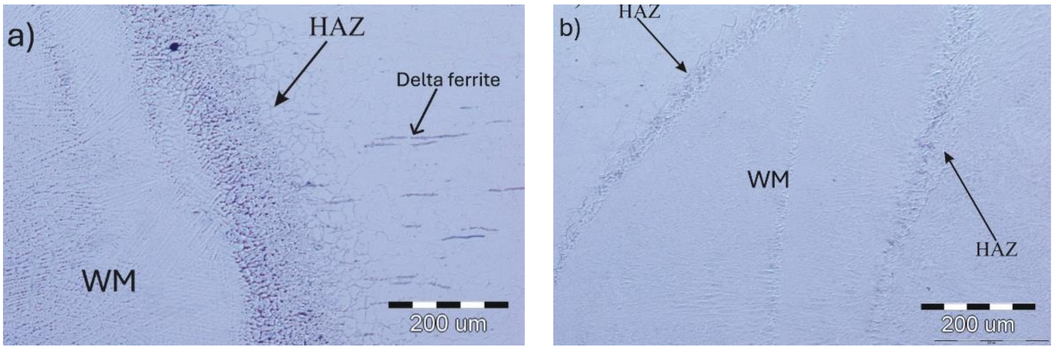

Figure 1. Microstructure of the welded joints: a) sample No1 and b) sample No2 [8]

3. RESULTS AND DISCUSSION

The results of the Charpy pendulum impact test are given in Figure 2. The tests were conducted on three samples for each test and the average absorbed energy value is shown in the figure. can be seen, the highest absorbed energy has sample No2 with a notch in the HAZ. Sample No1 with the same notch location has a much lower absorbed energy, which is influenced by the microstructure. The microstructure in this zone is austenitic but with much more precipitated delta ferrite, carbide and sigma phase [8].

Delta ferrite represents the place where carbide and sigma phase precipitation occurs, Figure3. The absorbed energy value in WM is similar, which was influenced by the welding method. Complete penetration did not occur at the welded joint location for both samples, Figures 4 and 5. According to EN ISO 5817, an imperfection in the form of lack of penetration (402) in a butt joint (partial penetration) is classified as a short imperfection [9].

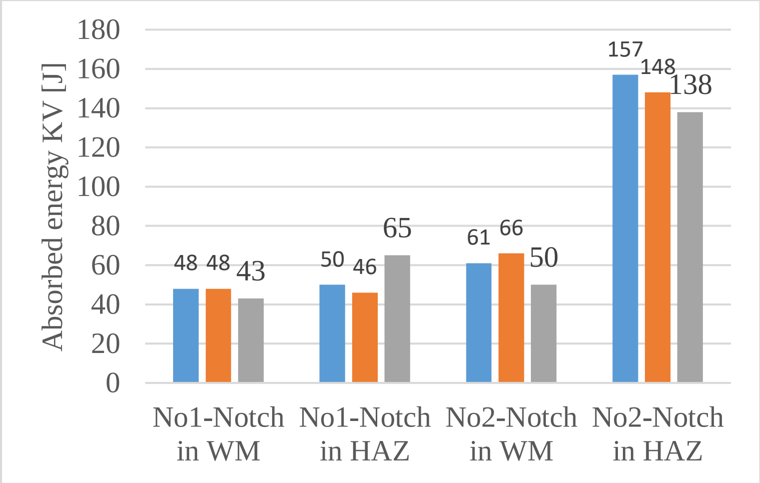

Figure 2. The results of the Charpy pendulum impact test

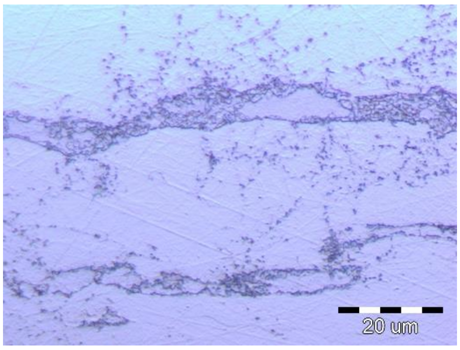

Figure 3. Delta ferrite with precipitated carbides and sigma phase

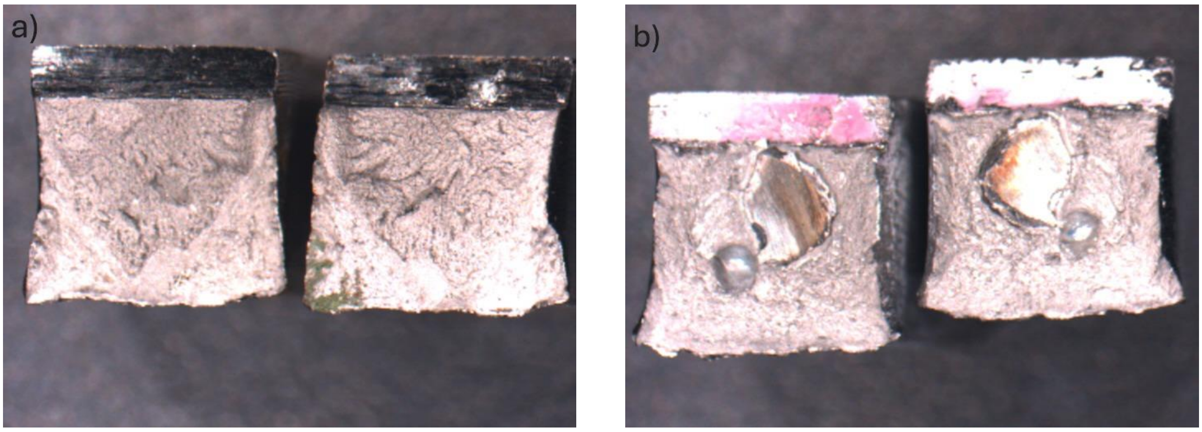

Figure 4. The surface fracture of the No1 sample: a) with a notch in the HAZ and b) with a notch in the WM, 6.3x

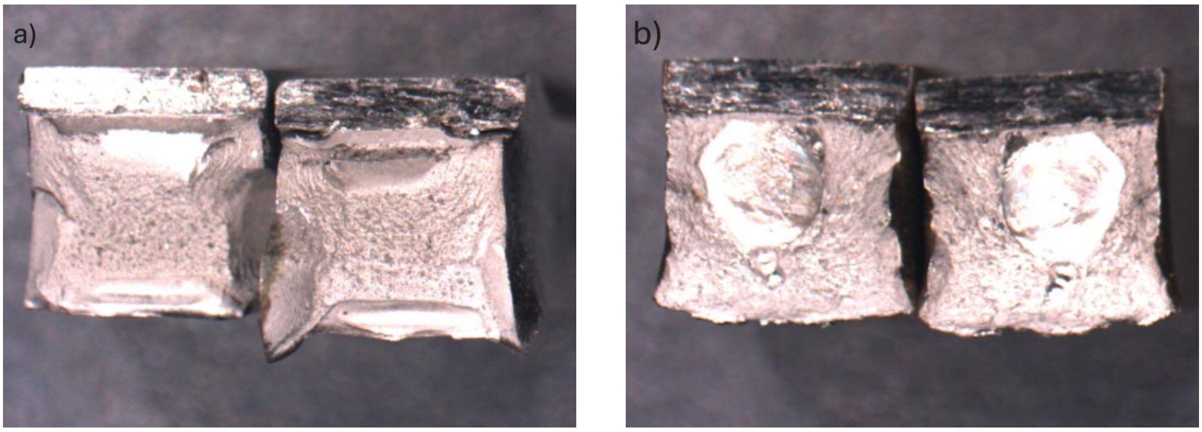

Figure 5. The surface fracture of the No2 sample: a) with a notch in the HAZ and b) with a notch in the WM, 6.3x

4. CONCLUSION

The results of the Charpy pendulum impact test for the sample No1 are generally worse than the results for the No2. It can be concluded that with an increase in the delta ferrite content and the presence of the sigma phase and carbides, the toughness of steel S21800 decreases. Carbides and sigma phase usually participate on the delta ferrite. Fracture analysis showed that brittle fracture dominates in the No1 sample, while in the case of the No2 samples, it is a ductile fracture, especially in the heat-affected zone. When analyzing the fracture surface, it was found that during welding, complete fusion of the metal in the weld metal did not occur, which had a negative impact on the mechanical properties of the welded joints.

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