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FATIGUE STUDY ON SUPER DUPLEX STAINLES STEEL -A REVIEW

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Abstract: Super duplex stainless steel are widely renowned for their improved strength and resistance to corrosion, and are characterized by stable ferrite/austenite microstructures. It is challenging to combine super duplex stainless steels because fusion weld joints are prone to solidification cracking and have low impact toughness in heat-affected zones (HAZ). To obtain the necessary quality of welded connections, pre-heating must be done, and cooling rates must be regulated**.** The study on connecting super duplex steels welded with arc and non-arc welding procedures that was previously published was examined in this publication. The majority of studies concentrated on microstructure as well as mechanical properties such as hardness, Tensile strength, and fatigue. The influence of different welding techniques on super duplex stainless steels is thoroughly examined in this research.

1 INTRODUCTION:

Stainless steels are often utilized in various industries because of their superior mechanical and corrosion properties. Among them, duplex and super duplex stainless steels have gained significant attention due to its great strength, corrosion resistance, and weldability. However, the fatigue behavior of these materials under different welding conditions is still a major concern for engineers and researchers. Many research has been published in recent years to investigate the varied welded circumstances, the fatigue strength of DSS and SDSS. One such study by Björk et al. (2018) evaluated the fatigue strength of duplex and super duplex stainless steels using the 4R technique [1]. The outcomes of the study suggested that tiredness strength of these materials is influenced by various factors such as the number of cycles tress level, and microstructure. Another study by Cortés-Cervantes et al. (2018) The fatigue life of AL6XN super-austenitic stainless steel welded with low intensity electromagnetic contact during GMAW [2]. The study showed that the use of electromagnetic interaction during weld improves the material's fatigue resistance. In addition to the exhaustion behavior, the microstructure of DSS and SDSS is also an important factor that affects their properties. Hosseini et al. (2016) studied the effects on the microstructure in multi pass TIG welding of DSS [3]. The results showed that the nitrogen loss during welding has a considerable influence on the material's microstructure and characteristics. Recent studies focused on investigating the development of both the microstructure and mechanical characteristics of SDSS joints. Wang et al. (2023) Keyhole plasma arc welding was used to evaluate the microstructure development, mechanical characteristics, and corrosion characteristics of SAF 2507 super duplex stainless steel joints [4]. According to the results. The welding process has a significant influence on the microstructure and material properties. Moreover, Kise and Tepal (2022) investigated the texture, microstructure. and mechanical characteristics of AISI 2507 super stainless steel laser beam welded. The results of the study showed that the laser beam welding process has a considerable impact on the material's texture, microstructure, and mechanical characteristics. [5]

2 Methodology:

This paper is analyzed different welding techniques effected on Super duplex stainless steels and their properties.

2.1 Fatigue testing on SDSS using different welding techniques.

2.1.1Friction Stir Welding:

The researcher [21] used SAF-2507 SDSS 10 mm thick plates. The FSP was performed with a cylindrical tool with 18 mm shoulder dia and 6 mm pin dia. The FSP parameters utilised were 1000 rpm rotating speed, 100 mm/min traverse speed and 2° tool tilt angle. FSP fatigue crack development behaviour was investigated using compact tension (CT) specimens. The trials were carried out utilising a servo-hydraulic testing equipment at a frequency of 10 Hz under cyclic loading circumstances.

Fig.1 Stir zone base metal microstructure [21] **Fig.2** Microstructure of processed metal in Stir zone

Figures 1 and 2 illustrate the transverse distribution of ferrite and austenite grains in the source material and the stir zone, respectively (parallel to the crack tip). Friction stirs processing polished both ferrite and austenite grains, as seen in Fig.2. Due of the tool shoulder's forging power and heat, considerable During FSP, plastic deformation occurs. This action mechanically stirs the material, causing grain refinement by dynamic recrystallization to change its microstructure. The grain sizes were measured using the line intercept method, providing average BM sizes of around 160 m and a range of 2 to 30 m in the stir zone [21]. The results of the study showed that As compared to the base material, the fatigue crack development resistance of the friction stir treated SAF-2507 was greatly enhanced. The researchers [21] also observed that the FSP samples exhibited higher fracture toughness and lower as compared to the base material, crack tip opening displacement (CTOD) values are higher.

Friction stir processing is a good way to improve the fatigue crack development behaviour of SAF-2507 SDSS. The FSP process leads to the refinement of the microstructure, which results in a homogeneous microstructure and improved mechanical properties. The results of this study can be useful in the development of high-performance materials for offshore and marine applications.

2.1.2 PLASMA ARC WELDING (PAW):

Taban,E [8] conducted an experimental study to investigate the welding behavior of duplex and super duplex stainless steels using two different welding processes: laser and plasma arc welding. The study involved preparing welded joints using different welding parameters and analyzing the mechanical properties, microstructure, and corrosion resistance of the welded joints.

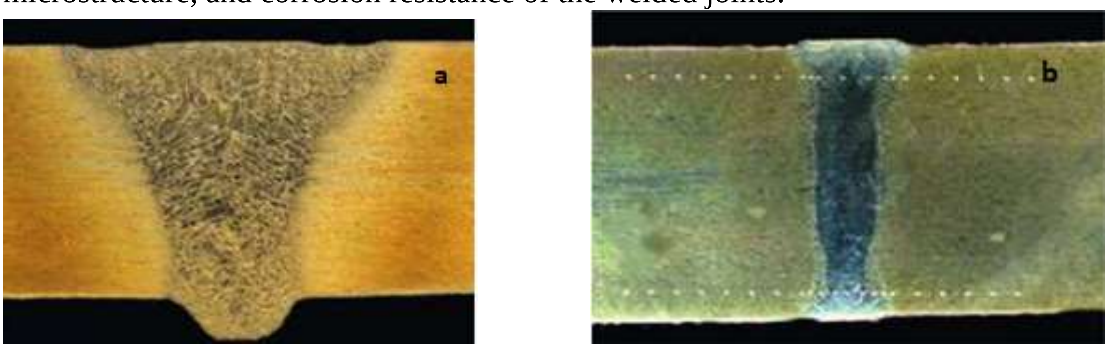

Fig.3 Macrographs of plasma arc weld junctions a) SDSS PAW b) SDSS LASER [8]

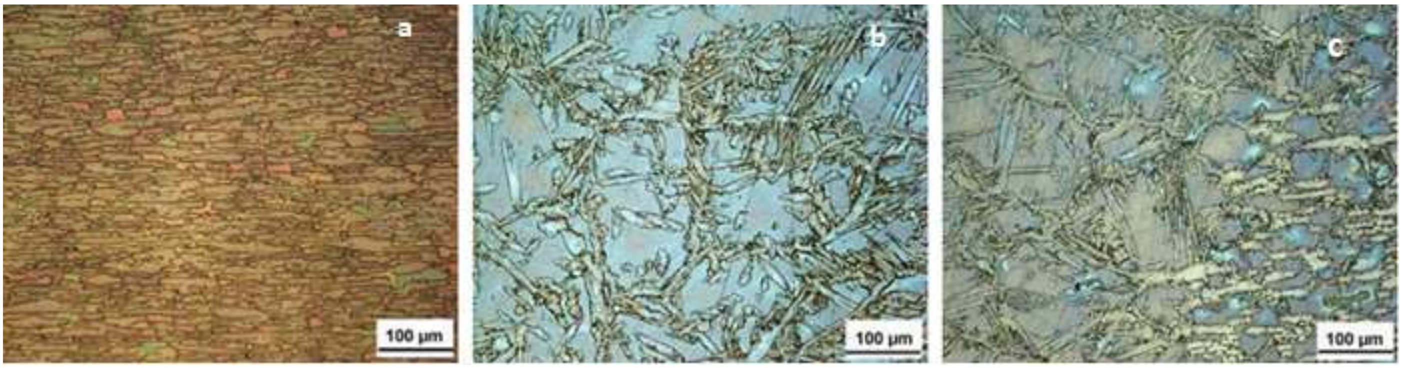

Fig.4 Micrographs of plasma arc weld junctions a) SDSS PAW BM b) SDSS PAW WM c) SDSS PAW+HAZ [8]

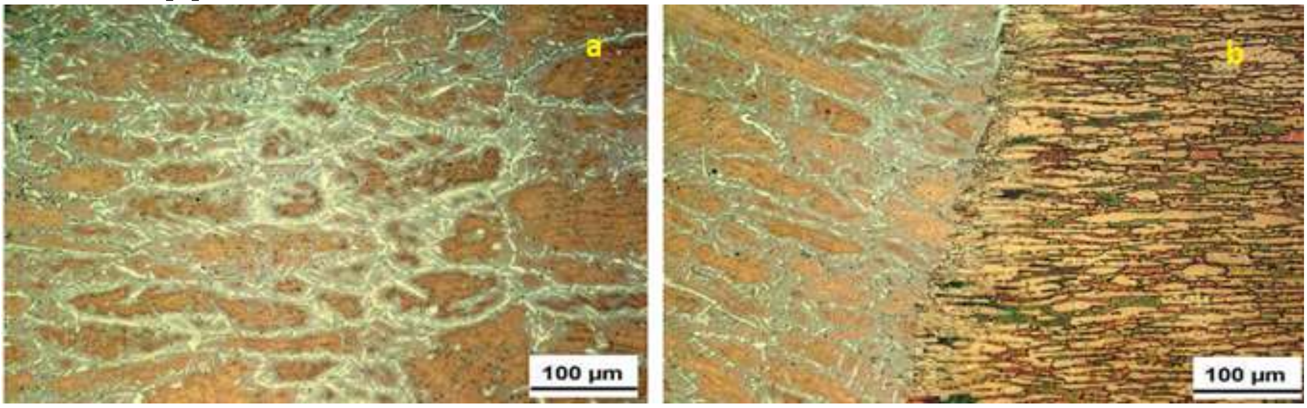

Fig.5 Micrographs of joints from Laser welds a) SDSS LASER WM b) SDSS LASER WM + HAZ [8]

The welds have been explored from BM to WM, in that order. Figure 3 depicts macrographs, whereas Figures 4 and 5 depict microstructures of the corresponding weld zones and base mteal for duplex and super duplex grade PAW and laser welds. According to the findings, both plasma arc and laser welding processes may generate sound, defect-free welds in DSS and SDSS. The authors observed that the choice of welding process depends on the specific application requirements, as each process has its advantages and disadvantages. For instance, laser welding produced narrow and deep welds with a small heat-affected zone, while plasma arc welding produced wider and shallower welds with a larger heat-affected zone. The authors also noted that the welding parameters, such as welding speed and power input, can significantly affect the mechanical properties and the welded joints' microstructure [8].

Similarly, research of Urena et al. [8], Figure 4 shows a very Further Columnar ferrite grain epitaxial development within the fusion pool will be influenced by a narrow Heat affected zone and some grain development. The welded connections' mechanical characteristics, including tensile strength, elongation, and hardness. They found that the welded joints' tensile strength and elongation were comparable to those of the base materials, indicating that the welding process did not have a substantial impact on mechanical characteristics. However, the welded connections have a higher hardness than the foundation materials, this can have an impact on the toughness and ductility of the welded joints. Additionally, Taban, E [8] investigated the microstructure of the welded joints and discovered that both laser and plasma arc welding created a totally austenitic microstructure in the weld metal, with varied levels of ferrite in the HAZ. They also tested the corrosion resistance of the welded junctions and discovered that the welding method had no effect on the materials' corrosion resistance.

2.1.3 Submerged Arc Welding (SAW):

Arun, D., Ramkumar [7] aimed to examine the impact of different welding methods on the mechanical characteristics and microstructure of welds of 12 mm thick SDSS. There are three types of arc welding procedures used: Submerged Arc Welding (SAW), Gas Metal Arc Welding (GMAW) and Gas Tungsten Arc Welding (GTAW). The microstructure, hardness, and tensile characteristics of the welds were all investigated. Moreover, the effects of heat input and interpass temperature on weld microstructure and mechanical characteristics were examined.

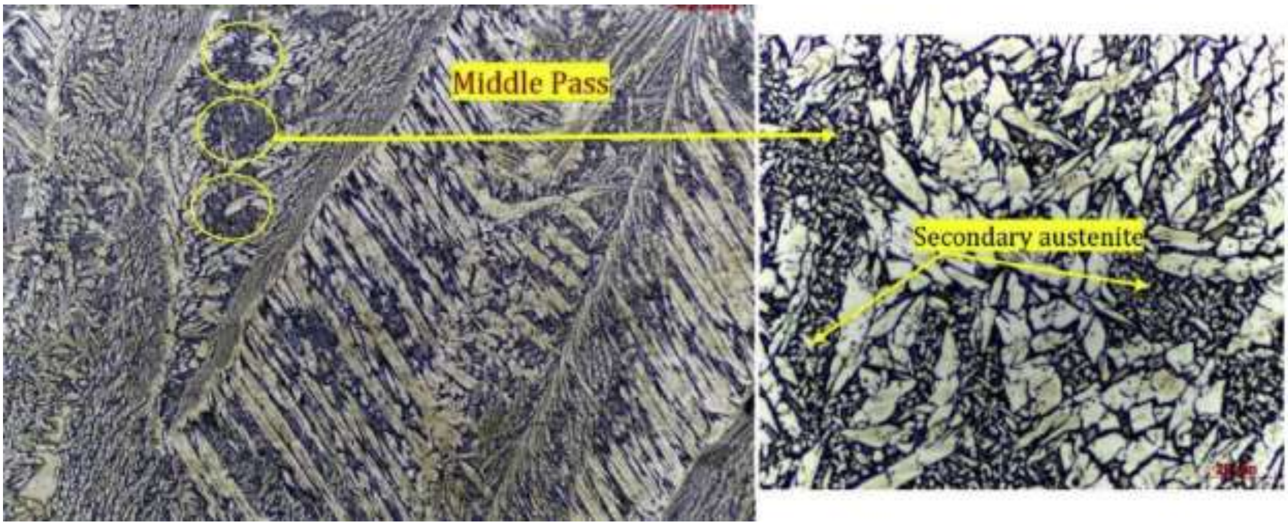

Fig.6 Multi pass, SAW welded UNS S32750 fusion zone microstructure spanning several zones [7]

Almost all forms of austenite, include Widmanstätten austenite, grain boundary allotriomorphic austenite, intragranular, and secondary austenite, develop in the fusion zone microstructures of UNS S32750 FCA welds (Fig. 6). The content of intragranular and secondary austenite (72), which is found in all passes except the cap area, is greater in the GTA and GMA weldments.

However, the SAW technique produced the best results in terms of mechanical properties. The SAW technique produced a greater yield and ultimate tensile strength as compared to the other two techniques. The microstructure of the SAW welds was found to be fine-grained and uniform, with a low amount of ferrite and sigma phase. Arun, D., Ramkumar [7] demonstrated that the SAW technique is a suitable welding technique for 12 mm thick super duplex stainless steel due to its the capacity to make welds with superior mechanical qualities and a fine-grained microstructure

2.1.4 GAS METAL ARC WELDING (GMAW):

Cortés-Cervantes [2] used AL6XN super-austenitic stainless-steel plates to conduct the experiments. The plates were welded using GMAW with and without low-intensity electromagnetic interaction. The electromagnetic interaction was provided using an electromagnetic coil placed close to the welding area. During the trials, welding parameters such as current, voltage, and wire feed rate were held constant. A fatigue testing equipment was used to assess the fatigue resistance of the welded plates. The microstructure of the welded plates was examined using optical and scanning electron microscopy [2].

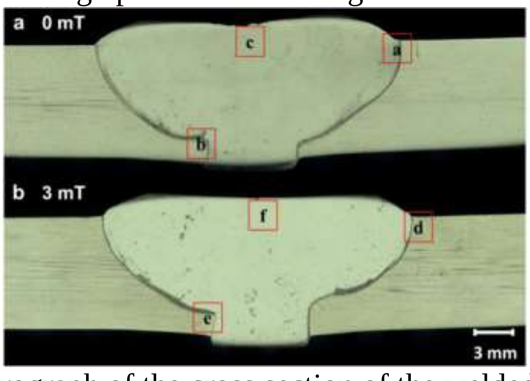

Fig.7 Macrograph of the cross section of the welded joints [2]

Transverse views of the welded joints are shown in Figure 7. These macrographs demonstrate completely penetrated welds with no loss of fusion throughout the weld height and there is no microporosity (The chemical etching left the spots in the WM in both welds) [2]. A profile of weld beads for both welding settings is quite similar, with an estimated dilution of 47% due to the 1.38 kJ/mm heat input.

V. H., Miyashita [2] found the application of low-intensity electromagnetic contact during GMAW considerably increased the fatigue resistance of the welded plates. The welded joint's fatigue life plates increased by about 23% when the electromagnetic interaction was used. The microstructure analysis revealed that the use of electromagnetic interaction improved the weld quality by reducing the total number of defects such as lack of fusion, porosity and fracture.

2.1.5 LASER BEAM WELDING(LBW):

Köse, C., & Topal, C. used a 6-kW fiber laser system to weld the AISI 2507 super duplex stainless Steel plates 3 mm thick [5]. Throughout the research, welding characteristics, such as welding speed, focus position and laser power altered. Optical microscopy was utilised to examine the texture of the welds and microstructure as well as scanning electron microscopy (SEM) and X-ray diffraction (XRD). The mechanical properties of the welds were evaluated using hardness and tensile tests.

According to this study's findings, welds featured columnar dendrites and a dendritic network in the HAZ and equiaxed grains in the FZ [5]. Authors also noticed roughness in the welds, which they ascribed to the heat gradient during the welding process. The welds' mechanical characteristics were found to be identical to those of the base metal. The welds' tensile strength was found to be greater than that of the base metal, but the toughness was found to be somewhat lower than that of the underlying metal. [5].

2.1.6 Tungsten Inert Gas welding (TIG):

welding of super due to their vulnerability to many types of corrosion, duplex stainless steels are difficult to work with weld defects. Among the weld defects, nitrogen loss during welding is a major concern that can affect the microstructure and properties of the weld metal.

Vahid Hosseini [3] conducted a series of experiments using a SAF 2507 super duplex stainless steel grade was welded utilizing multipass TIG welding. A Design of Experiment (DOE) technique was used to optimize the welding settings. The nitrogen concentration of the weld metal was regulated by modifying the shielding gas composition, and Hurtig, Kjell, Karlsson, and Leif studied the microstructure of the welds using SEM, optical microscopy, and energy-dispersive X-ray spectroscopy, among other techniques (EDS).

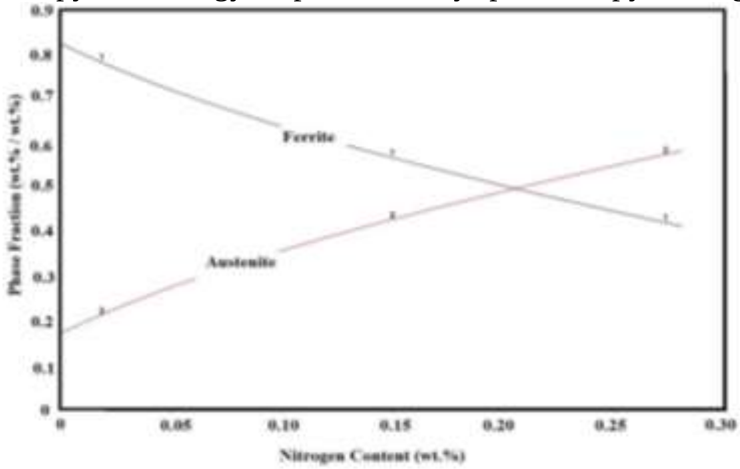

Fig.8 Thermo-Calc computed at 1100 °C, the equilibrium ferrite and austenite content vary with nitrogen concentration. The nitrogen component decreases the austenite concentration [3].

Because the annealing temperature of the base metal is typically 1100 °C, any post-weld heat treatment should be performed at this temperature to have the least impact on the BM [3]. The variability of the ferrite content at 1100 °C was estimated using Thermo-Cale to anticipate the ferrite contents of the welds following likely post-weld heat treatment (Figure 8).

Nitrogen loss was discovered by Hurtig, Kjell, Karlsson, and Leif. during welding as a result of which the weld metal's nitrogen content was dramatically lowered. As a result, coarse ferrite grains formed in the weld metal, reducing the mechanical characteristics of the welds. Hurtig, Kjell, Karlsson, and Leif discovered that welding factors such as welding speed and heat input impact the microstructure of the welds.

2.1.7 Gas Metal Arc Welding (GMAW) and Gas Tungsten Arc Welding (GTAW):

In this work, K. Devendranath Ramkumar assessed the weld strength and impact toughness of super-duplex stainless steel UNS 32750 utilizing various welding methods such as Gas Metal Arc Welding (GMAW) and Gas Tungsten Arc Welding (GTAW) [22]. A variety of testing procedures were also used in the study, including Tensile testing, Charpy V-notch impact testing, and Hardness testing. Welding specifications such as speed, voltage and welding current were also changed to investigate their influence on weld quality.

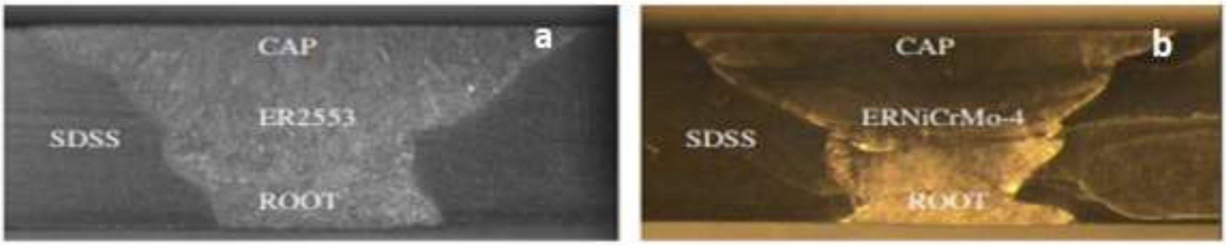

Fig.10 Microstructure of SDSS GTA weldments using (a) ER2553 and (b) ERNICrMo-4.

The visual and microstructure evaluation of the SDSS welded connections (Figs. 10) demonstrated that both filler wires contributed to a superior weld bead by displaying acceptable fusion to the base metals while employing the GTA welding procedure with the specified process parameters.

The results showed that both the GTAW and GMAW techniques produced welds with high tensile strength, good impact toughness, and acceptable hardness. However, the GTAW technique produced better results compared to the GMAW technique. K. Devendranath Ramkumar [22] also showed that increasing the welding current and voltage this resulted in increased tensile strength but decreased impact toughness. The study also emphasizes the necessity of adjusting the welding settings to obtain the required weld quality.

3 CONCLUSIONS:

Based on prior work reported on the welding process of super duplex stainless steel, the following conclusions are derived.

1. The outcomes of this study may be valuable to engineers and researchers working on SDSS welding.
2. The report contains valuable information regarding the fatigue behavior of duplex and super-duplex stainless steels, which may be used to design and optimize components for a wide range of industrial applications.
3. This research may be used to build high-performance materials for offshore and marine applications. Further study is needed to evaluate the FSP samples' long-term fatigue behavior under actual service settings.

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