Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 4, April : 2023

A STUDY ON THE TENSILE STRENGTH OF PLASMA ARC WELDED SUPER DUPLEX STAINLESS STEEL SHEETS

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ABSTRACT

In this study, super duplex stainless steel sheet with a 0.33mm thickness is butt welded using a micro-plasma arc welding method. Pulse width, and pulse rate, peak current and base current were considered welding input elements, whereas the hardness and tensile strength are known as output characteristics. Super-duplex stainless steels are being utilised more often in applications that call for both corrosion resistance and strong fatigue strength. In comparison to base metal tensile strength (923.16MPa), the tensile strength of welded joints (868.28MPa) is 6.28 percent lower. The welded super duplex stainless steels tensile strength (SDSS) has been correlated closely through microstructure and ANSYS has been used to do FEA analysis at various profiles also studied. In this work, a wide range of welding conditions and their impact on super duplex stainless steel have been thoroughly investigated.

Keywords: *Super duplex stainless steel, Plasma Arc Welding, Tensile strength, ANSYS*

INTRODUCTION

Super duplex stainless steel is extensively used in the offshore and onshore industries, where high mechanical strength, high resistance to corrosion, and excellent fatigue resistance are required. These materials have unique microstructures that combine austenitic and ferritic phases in approximately equal proportions, providing an outstanding balance of properties. The microstructure of these materials, which may be considerably impacted by welding, is a key factor in determining their mechanical characteristics, such as strength, toughness, and fatigue resistance. Hence, the study of welding behaviour, welding processes, and welding parameters is crucial for achieving high-quality welds with optimal properties. Using the 4R technique, the fatigue strength of duplex and super-duplex stainless steel and found that the microstructure significantly affected the fatigue strength of these materials and also observed that the fatigue strength of the super duplex stainless steel was higher than that of the duplex stainless steel due to its finer microstructure [1]. SAF 2507 super duplex stainless steel joints' mechanical and corrosion characteristics were studied, and it was discovered that the microstructure had a substantial impact on these qualities [2]. The effect of heat input on the microstructure and corrosion behaviour of duplex stainless steel shielded metal arc welds was investigated, and it was discovered that as the heat input, the microstructure got finer and the corrosion resistance declined.[3]. The behaviour of laser and plasma arc welding with duplex and super-duplex stainless steels and found that the plasma arc welding process provided better results than the laser welding process in terms of the joints mechanical properties [4]. studied multi-pass arc welding processes and looked at how heat input, the number of passes, and the temperature between passes affected the welds' microstructure, mechanical characteristics, and corrosion resistance [5]. Effect of tensile stress on 2205 duplex stainless steel fatigue crack behaviour and found that tensile overload led to the initiation of secondary cracks and the acceleration of crack growth [6]. The AL6XN super-austenitic stainless steel fatigue resistance was studied using low intensity electromagnetic interaction during gas metal arc welding, and it was discovered that the electromagnetic interaction greatly increased the fatigue resistance of the welded joints [7]. For the ferrite phase in DSS welds, pulsed current flux cored arc welded parameters were optimised and found that the welding speed and pulse frequency significantly affected the ferrite content in the welds [8]. DSS exhibits a unique combination of mechanical properties and corrosion resistance, making them suitable for use in harsh environments [9]. AISI 2507 SDSS steel texture, mechanical properties and microstructure were studied how welding speed, gas flow rate and laser power among other welding variables, had an

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 4, April : 2023

impact on the procedure [10]. Heat input significantly affects the corrosion resistance and microstructure of DSS welds [11]. Fatigue process, which has been modelled under both very high-cycle fatigue (VHCF) and high-cycle fatigue (HCF) loading circumstances, is one of the crucial elements impacting the fatigue behaviour of DSS [12]. Lower heat input was used, which produced a finer microstructure and higher corrosion resistance and in addition to the heat input, the welding process itself can also significantly impact the microstructure and mechanical properties of DSS welds [13]. Compared to pulsed current gas tungsten arc welding, current gas tungsten arc welding produced welds with higher mechanical strength and less distortion [15]. The fatigue crack development behaviour of friction stir treated SDSS(SAF-2507) considerably increases the material's fatigue crack growth resistance while focusing on different areas of the material's characteristics and fatigue performance.[16]. The cyclic deformation behaviour and failure mechanism of S32205 under torsional loadings and found that the DSS failure mechanism under cyclic loading is intricate and comprises several different deformation types.[17]. When electron beam welded DSS joints were evaluated for their metallurgical impact and fatigue performance, it was found that the microstructure and presence of flaws had an influence on the joints fatigue life [18]. Investigating the impact of laser beam welding on the materials fatigue behaviour, tensile strength, and microstructure revealed that the process had a sizable impact on the mechanical characteristics and microstructure of DSS2205 [19]. The behaviour of brief fatigue fractures under extremely high cycle fatigue of DSS was examined, and it was discovered that the processes for fatigue crack initiation and propagation are distinct from those seen under conventional fatigue loading [20].

METHODOLOGY

Using a pulsed current micro plasma arc welding procedure, Thickness of 0.33 mm UNS S32750 super duplex stainless steel sheets were connected for this project. Welding parameters, such as pulse frequency, welding current, and welding speed, were altered to analyse how they affect the welded joints fatigue strength.

Materials and Methods:

The joining of Dimensions of Super Duplex stainless steel sheets UNS S32750 is 200x20x0.33mm is accomplished using an autogenous square butt joint. Table 1 and 2 display the chemical composition and mechanical characteristics of UNS S32750 super duplex stainless steel.

Table 1. UNS S32750 Chemical Composition (weight %)

C	Cr	Mn	Cu	Fe	Ni	Mo
0.03	25.04	1.00	0.45	64.02	6.69	3.25

Table 2. UNS S32750 mechanical characteristics

Elongation (%)	Ultimate Tensile Strength (MPa)	Vickers Hardness (VHN)
21.8	923.160	259.7

Extremely pure (99.99 percent) argon is used as a shielding and following gas during welding to stop oxygen and nitrogen from absorbing into the atmosphere. The welding conditions that were used for the welding are listed in Table 3.

Table 3. Conditions for Welding

Power source	Secheron Micro Plasma ArcMachine (Model: PLASMAFIX 50E)
Polarity	DCEN
Mode of operation	Pulse mode
Electrode Diameter	1 mm
Electrode	2% thoriated tungsten electrode

Industrial Engineering Journal
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Plasma gas flow rate	6 Lpm
Plasma gas	Argon & Hydrogen
Shielding gas	Argon
Shielding gasflow rate	0.6 Lpm
Purging gas flow rate	0.6 Lpm
Purging gas	Argon
Nozzle to plate diameter	1mm
Copper Nozzle distance	1mm
Welding speed	240 mm/min
Operation type	Automatic
Torch Position	Vertical

In, Continuous Stream Peak current, base current, pulse width, and pulse rate are the most crucial factors to consider when evaluating the weld quality, according to MPAW study which is shown in the table 4. To establish the welding parameter ranges, material thickness and trial experiments were used. In response, the limitations on base current, peak current, pulse width, and pulse rate have been determined.

Table 4. Limitations of process parameters

		Multiple Levels				
Input Facto	Units	-2	-1	0	+1	+2
Base Currer	A	8	9	10	11	12
Peak Currer	A	18	19	20	21	22
Pulse width	%	30	40	50	60	70
Pulse rate	Pulses/s	20	30	40	50	60

Following the welding process, the sheets were cut into dog-bone shapes using wire cutting electro discharge machining (EDM). This was done to create tensile welding specimens that adhered to ASTM E8M-04 requirements as depicted in the figure 1.

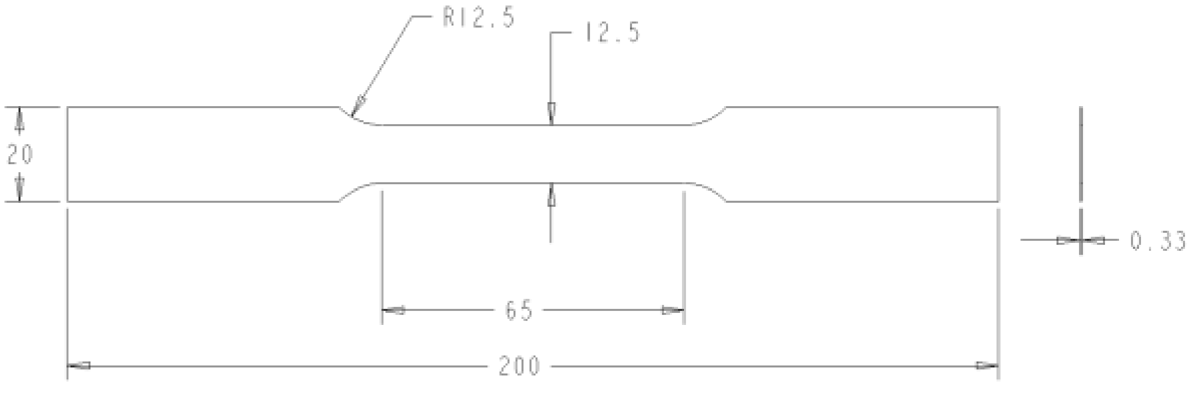

Figure 1. Tensile sample in accordance with ASTM E8M-04

RESULTS AND DISCUSSIONS

Microstructure Analysis

Measurement of the grain size in the fusion zone:

The determination of the fusion zone grain size is an important step in evaluating the quality of a welded joint. The grain size of the fusion zone can affect the strength and toughness of the joint. The sample mounting and preparation procedures adhere to ASTM E 3-1 standards. The samples transverse faces are first polished with emery paper in the mesh sizes are 1/0 (245), 2/0 (425), and 3/0 (515) using a belt grinder.

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ISSN: 0970-2555
Volume : 52, Issue 4, April : 2023

The mechanical characteristics of the weld can be significantly affected by the grain size in this zone. One common method for determining the fusion zone grain is to prepare a cross-section of the welded joint and the surface is then etched to show the microstructure. The grain size can then be measured using a microscope and compared to established standards or criteria. To evaluate the fusion zone and establish the grain size, non-destructive testing methods like ultrasonic or X-ray examination can also be used. These methods can be useful for assessing the quality of the weld without damaging the welded joint.

By adjusting the etching period, reveals the weld zone microstructure and grain size. At 100X magnification. A micrograph showing the Parent metal, heat-affected zone, the fusion zone shown in figure 2, 3 and 4 respectively.

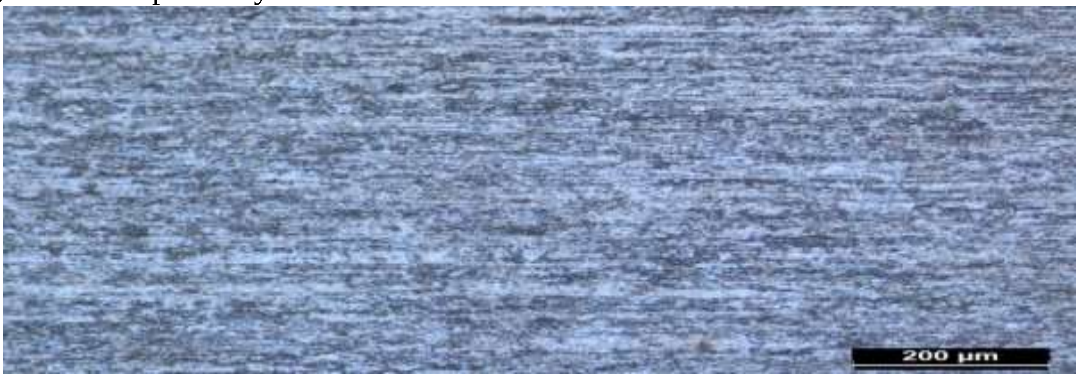
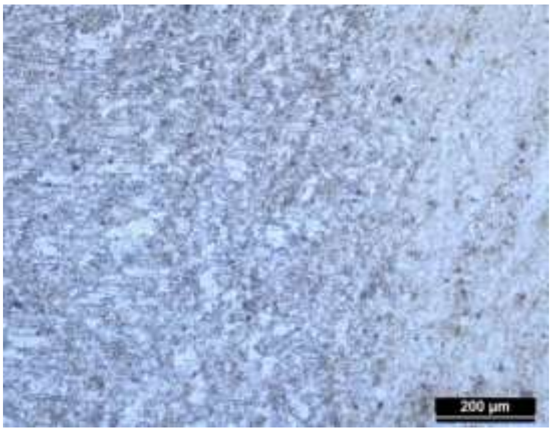


Figure 2 Microsructure of Parent metal of SDSS



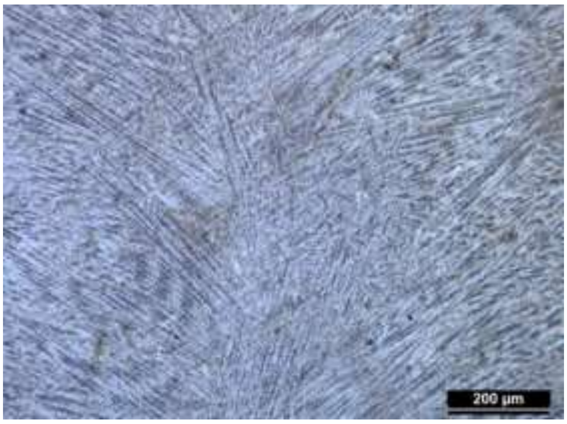


Figure 3 Heat-affected zone

Figure 4 Fusion zone microstructure

Evaluation of the fusion zone hardness:

This is a microhardness testing method that uses a diamond indenter to create an impression in the material. Vickers hardness number is calculated using the indentation's size, which is measured, the material's resistance to indentation. Vickers hardness testing is commonly used for evaluating the hardness of small areas in materials, such as the fusion zone in welded joints.

Vickers' microhardness testing apparatus (Model: VHS 1000, maker: Banbros Engineering Pvt Ltd., India) In accordance with ASTM E384, by leaving a 0.5 kg weight on the fusion zone of welded samples for 10 seconds, it is possible to assess the hardness of the fusion zone. Table 5 displays the three hardness readings average values for each sample.

Measurement of ultimate tensile strength (UTS):

ASTM E8M-04 is a standard test method for conducting tensile tests of metallic materials. This standard specifies the procedure for determining the ultimate tensile strength of metallic materials using a standard test specimen and a universal testing machine. The ASTM E8M-04 standard requires that the test specimen be prepared according to specific dimensions and requirements, including the

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ISSN: 0970-2555
Volume : 52, Issue 4, April : 2023

gauge length and cross-sectional area. The specimen is then secured in the UTM's grips, and a steady stress is applied to it until the specimen breaks.
During the test, the load and the corresponding elongation or deformation of the specimen are measured continuously. This data is used to generate a stress-strain curve, which shows the relationship between stress and strain as the material is loaded. The UTS is determined by identifying the maximum point on the stress-strain curve, which represents the maximum stress that the material can withstand before fracturing. This value is reported in units of pressure, such as psi or MPa. These requirements help ensure that the results obtained from the test are accurate and reliable, and that they can be compared across different laboratories and testing conditions.

Tensile and Hardness test results:
Tensile tests are conducted by using a machine for universal testing with computer assistance with 100kN capacity and a short extensometer attached to it.(Model No. 9036TD, Star Testing Systems, Senior No. STS-522). The specimens are loaded at a steady rate of 1.5kN /min in accordance with ASTM requirements, which results in the tensile specimens deforming. Using the stress-strain curve (Figure 5), it is possible to determine the weld joints' maximum permissible tensile strength. The mean of each sample outcomes shows in Table 5.

Table 5. Experimentation Findings

	Parameters for Welding Input				Values of Experimental Results	
Exp No:	Peak Current (A)	Base Current (A)	Pulse Rate (Pulses/s)	Pulse Width (%)	Hardness (VHN)	Tensile Strength (MPa)
1	19	9	30	40	251.2	846.52
2	21	9	30	40	248.2	860.20
3	19	11	30	40	246.8	854.53
4	21	11	30	40	246.8	850.82
5	19	9	50	40	250.6	860.40
6	**21**	**9**	**50**	**40**	**252.2**	**868.28**
7	19	11	50	40	252.4	862.34
8	21	11	50	40	254.8	854.62
9	19	9	30	60	253.8	850.42
10	21	9	30	60	252.8	852.62
11	19	11	30	60	251.6	846.46
12	21	11	30	60	248.2	848.35
13	19	9	50	60	250.4	838.86
14	21	9	50	60	249.6	842.60
15	19	11	50	60	250.2	840.32
16	21	11	50	60	253.2	828.04
17	18	10	40	50	242.2	838.28
18	22	10	40	50	245.2	842.26
19	20	8	40	50	248.2	848.42
20	20	12	40	50	246.8	836.52
21	20	10	20	50	254.2	858.68
22	20	10	60	50	256.8	855.60
23	20	10	40	30	257.4	870.25
24	20	10	40	70	258.2	858.64
25	20	10	40	50	254.6	853.29

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Volume : 52, Issue 4, April : 2023

26	20	10	40	50	252.4	854.53
27	20	10	40	50	252.1	853.24
28	20	10	40	50	253.8	852.68
29	20	10	40	50	252.2	852.24
30	20	10	40	50	253.8	852.26
31	20	10	40	50	252.3	854.32

Experimentation result number 6 gives the highest hardness strength 252.2 VHN and tensile strength 868.28 MPa. It shows the best welding parameters for welding.

Figure 5 Stress- Strain diagram for Base metal of SDSS

Analysis:

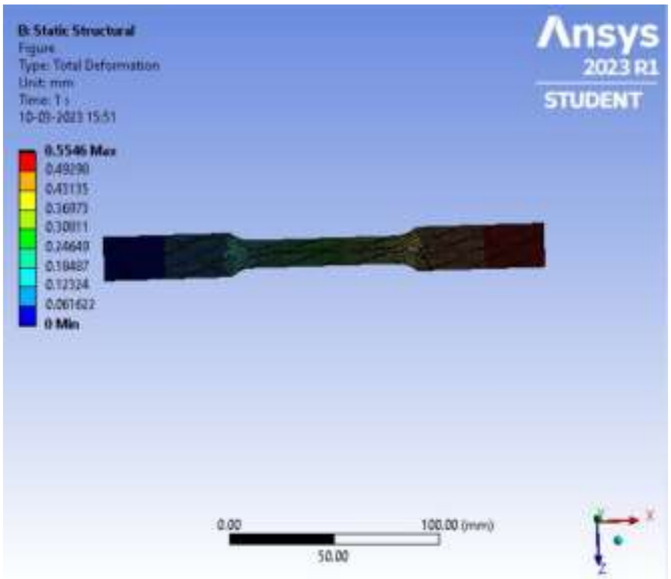

Figure 6. Total Deformation

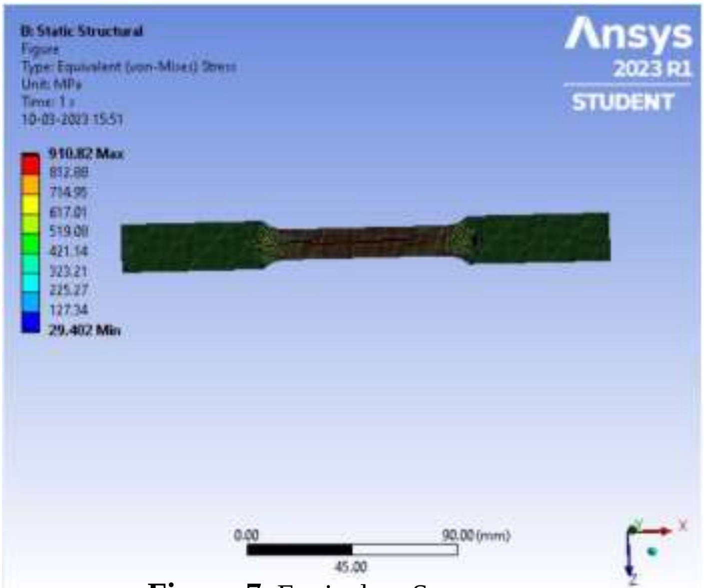

Figure 7. Equivalent Stress

Figures 6 and 7 depict the total deformation and equivalent stress of the super duplex stainless steel

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 4, April : 2023

material after statistical structural analysis was performed using the Ansys workbench.

Table 6. FEA Input parameters

Properties	Standards
Poisson's ratio	0.3
Young's modulus	2E+05 MPa
Yield Strength	655.6 Ma
Tensile Ultimate Strength	868.28 MPa

Table 7. Tensile test results for both welded joints and base metal of SDSS

S.no.	Material	UTS(MPa)
Experiment result		
1	Base Metal	923.160
2	PAW joint	868.28
FEA analysis result		
1	Base Metal	910.82
Error percentage of experiment result and FEA result analysis		
1	Base Metal	1.33

Conclusion:

The following conclusions have been taken from the outcomes of the experiments.

- From the table 5, Experimentation result number 6 gives the highest hardness strength 252.2 VHN and tensile strength 868.28 MPa. Hence those welding parameters are best for super duplex stainless steel sheets using micro plasma arc welding.
- From the FEA analysis, Close agreement in tensile strength numbers for base metal between ANSYS (910.82 Mpa) and experiment values (923.16 Mpa) gives students confidence in this approach before going on to more complicated models.

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