Micro structural and mechanical characterization of SS32750 welded using GTAW and CO_2 welding

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Abstract. Stainless steel 32750 (SS32750) is a duplex stainless steel renowned for its exceptional corrosion resistance and mechanical properties, making it ideal for demanding applications, particularly in harsh environments such as offshore and marine industries. This study examines the microstructure and mechanical properties of SS32750 weldments produced using two distinct welding techniques: Gas Tungsten Arc Welding (GTAW) and Laser Welding. The investigation focuses on the effect of various welding parameters, including heat input, welding speed, and shielding gas composition, on the resulting microstructure. Mechanical properties such as tensile strength, surface roughness, distortion, and weld integrity were evaluated using methods like tensile load testing, X-ray radiography, and wire-cut EDM. The study provides critical insights into the relationship between welding techniques, process parameters, and the resulting performance of SS32750 weldments.

1 Introduction

The study of welding conditions (parameters) affects the microstructure and mechanical properties of welds in super-duplex stainless steel UNS S32750. This type of steel is desirable for its strength and toughness, but welding can change its structure. They found that using a specific gas mixture (argon, helium, and nitrogen) and controlling factors like current, voltage, and speed could create welds with minimal defects and a good balance of ferrite and austenite (the two key structures in this steel). This balanced structure led to good mechanical properties, like strength, in the welded material. Overall, optimal weld parameters resulted in strong, high-quality welds in this steel [1].

Weldments made with a specific shielding gas mixture (argon, helium, and nitrogen) achieved the best visual appearance, proper material flow, and minimized weld porosity, Optimal parameters led to a balanced microstructure in the weld zone. This means a good balance between ferrite and austenite, the two important phases in this steel, was achieved, Welds produced with optimal parameters exhibited good mechanical properties, including strength, which is crucial for a strong joint [2]. The study employed a factorial design approach to identify how different welding parameters (current, voltage, travel speed)

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interact and affect the final weld properties. Material used: UNS S32750 super-duplex stainless steel (austenitic-ferritic)., Gas Tungsten Arc Welding (GTAW) Machine. Shielding Gas, Data Acquisition System. Microstructure Analysis, Mechanical Testing, Vickers or Knoop micro hardness testing. Conclusion: The researchers provide to contribute valuable insights into optimizing the GTAW process for welding super-duplex stainless steel UNS S32750.By establishing the relationship between welding parameters, microstructure, and mechanical properties, this research can help achieve high-quality welds with the desired performance characteristics in various marine, chemical processing, and renewable energy applications [3].

The Study Investigates the laser welding process affects the microstructure and corrosion resistance of a joint between two dissimilar metals: X-70 pipeline steel and UNS S32750 super-duplex stainless steel. This combination is desirable for some industrial applications, but laser welding can create unique structures in the joint zone. The study found a relationship between the resulting microstructure and how well the joint resists corrosion. Optimizing the welding process might be crucial for creating strong and corrosion-resistant joints in these materials [4].

The study examined the microstructure of the welded joint, likely using techniques like microscopy. This revealed distinct zones with varying grain sizes and compositions due to the laser welding process. The research investigated how well the joint resisted corrosion, possibly through methods like exposing it to a corrosive environment and measuring deterioration. The findings likely connected the observed corrosion patterns to the specific microstructural features of the joint. A key finding was the connection between the microstructure (grain size, phase composition) and the corrosion behaviour of the joint. Certain micro structural features might have exhibited higher susceptibility to corrosion compared to others. Materials Used:X-70 Pipeline Steel Plate, UNS S32750 Super-Duplex Stainless-Steel Plate, Laser Welding Machine, Shielding Gas System, Metallographic Equipment, Mechanical Testing Equipment, Corrosion Testing Equipment. Conclusion: The research is expected to contribute valuable insights for understanding how laser welding parameters affect the structure, properties, and corrosion resistance of dissimilar joints between X-70 pipeline steel and UNS S32750 super-duplex stainless steel. This knowledge can help optimize welding procedures to achieve reliable and durable joints in various industrial applications [5].

The laser beam's heat input significantly influences the microstructure. Different heat inputs can create variations in the proportions of ferrite and austenite phases, which are crucial for the steel's properties. The optimal heat input is key. Too high of an input can lead to a weaker weld zone due to a coarsened grain structure. Conversely, a very low input might result in incomplete fusion. The research aims to identify the laser parameters that create a balanced microstructure with good distribution of ferrite and austenite. This microstructure is essential for achieving high joint strength, toughness, and maintaining the desired corrosion resistance of the super duplex steel. Weld zone exhibits a distinct microstructure compared to the base metal. Heat-affected zone (HAZ) can also show microstructural changes due to rapid heating and cooling during welding. Tensile strength of the weld zone can be comparable or slightly lower than the base metal, depending on factors like heat input and microstructure. Impact toughness of the weld zone might be lower compared to the base metal. This is an important consideration for applications requiring good low-temperature performance. Microhardness testing might reveal variations in hardness across the weld zone, HAZ, and base metal. Some studies might investigate the effect of PWHT on the microstructure and mechanical properties. PWHT can help refine the microstructure and improve toughness, but it might also slightly decrease hardness and tensile strength. Materials Used: AISI 2507 (UNS S32750) Super Duplex Stainless Steel Plate, Laser Beam Welding Machine, Shielding Gas System

Metallographic Equipment, Cutting and grinding tools, Optical Microscope, Scanning Electron Microscope (SEM), Tensile testing machine, Micro hardness tester (Vickers or Knoop) [6].

2 Materials and methods

Sample Preparation for Microstructure and Mechanical Analysis (by using Wire Cut EDM: Utilize EDM again to extract smaller sections from the welded coupons containing the weld joint, HAZ, and base metal, as shown in Figure 1. Ensure the sections are suitable for metallographic preparation and subsequent testing. Metallographic Preparation: Grind and polish the extracted sections using a sequence of grinding papers and polishing cloths with diamond suspensions to achieve a mirror-like finish. Etch the polished surfaces with a suitable etchant Kaling's reagent for Super Duplex Steel UNSS32750 the micro structure.

Fig. 1. Sample preparation for microstructure and mechanical and mechanical analysis (by using wire cut EDM.

High-performance alloys like Inconel 625 rely on a delicate balance of microstructure (grain size and secondary phases) and macrostructure (weld zones and heat-affected areas) for their exceptional properties and microstructure are shown in Figure 2. Microstructural analysis with optical microscopy and image software reveals grain size, key strengthening precipitates, and potential defects. Macrostructural analysis of welds and surrounding areas explores grain size variations, phase changes due to welding heat, and the overall integrity of the joint. Understanding both micro and macro structures helps ensure the material performs optimally in demanding applications [7].

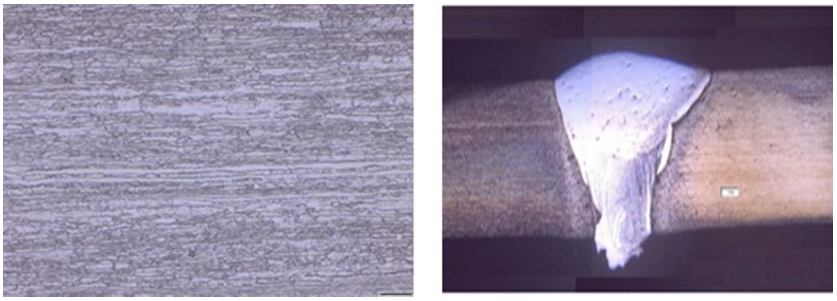
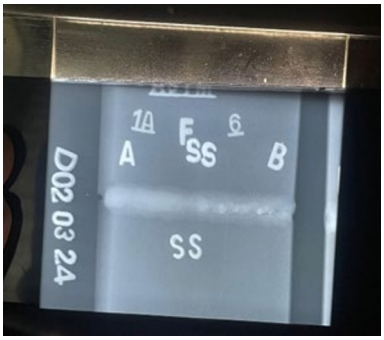
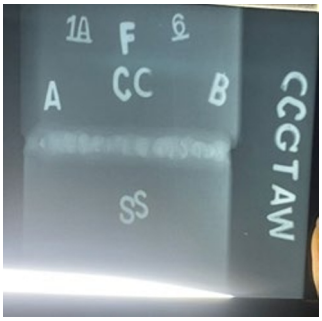
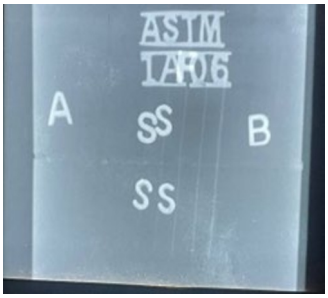
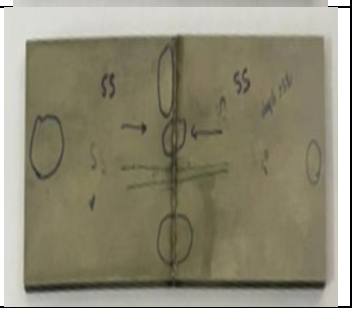


Fig. 2. Microstructure & macro structure of Inconel 625 alloy.

The radiographs (expected to be included) should ideally show defect-free weld zones for both techniques, as shown in Table 1. However, depending on the welding parameters, porosities, cracks, or incomplete fusion might be observed. The presence of such defects can significantly impact the joint's structural integrity X-radiography testing, commonly known as radiography or X-ray testing, is a non-destructive testing method used to inspect the internal structure of materials for defects, voids, cracks, or other discontinuities. The results of X-radiography testing typically include: Detection of defects: X-ray images reveal internal features of the material, allowing inspectors to identify defects such as cracks, inclusions, porosity, or voids. Evaluation of defect size and location: The images produced by X-radiography help determine the size, shape, and location of defects within the material. Assessment of material integrity: By analyzing X-ray images, inspectors can assess the overall integrity of the material and determine whether it meets specified quality standards. Quality control documentation: X-radiography results provide valuable documentation for quality control purposes, including records of inspections performed and any defects found [8].

Table 1. Results of X-Ray radiography.

Weld quality	X-Ray Radiograph	Photograph of Welded Specimen
Not fully welded at the end of weld portion		
No Defect occurred in the weld portion		
No defect occurred in the weld portion		

3 Results and discussions

3.1 Tensile report on UNSS32750 welded on PCGTAW

Tensile properties of the fabricated samples were reported in Table 2. It is observed that maximum stress reached up to nearly 793 MPa with elongation of 18.5% and the corresponding stress-strain curve is shown in Figure 3.

Table 2. Tensile report on UNSS32750 welded on PCGTAW.

Name	YP(YP%)	Max-Stress	Fitted Strain	Reduction
Parameters	0.2%	Calc. at Entire Areas		
Unit	N/mm2	N/mm2	%	%
2	500.051	792.949	18.5600	22.4241

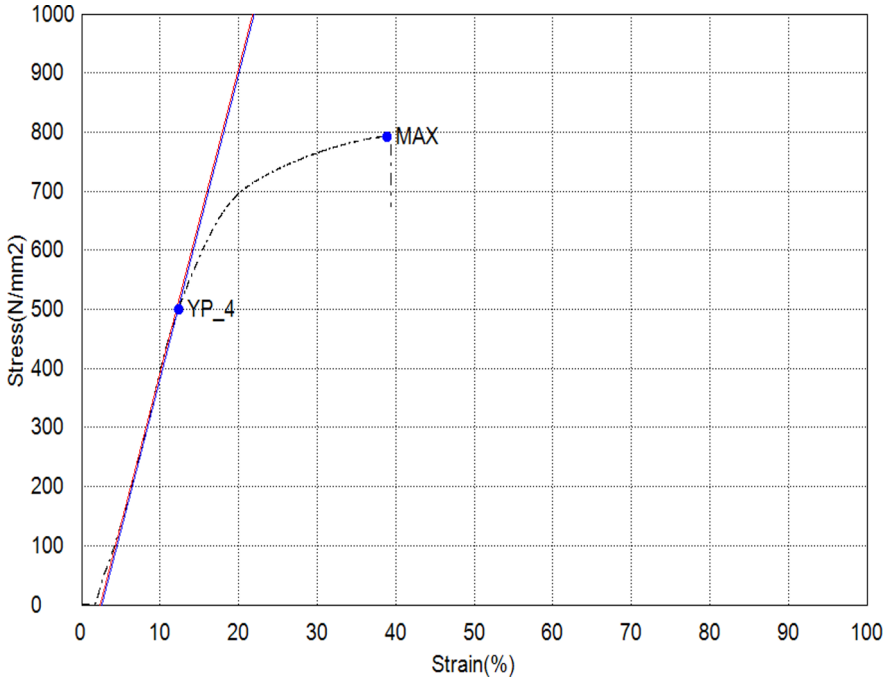


Fig. 3. Tensile report on UNSS32750 welded on PCGTAW.

3.2 Comparison results between CO2 LASER and GTAW

Here the maximum strength is under 792.949 N/mm² to 802.100 N/mm² and then, the yield strength is under 500.051 N/mm² to 568.518 N/mm² and all the failure on the welded portion, Here the laser weld opposes more strength in compare to other welding process, that are shown in Figure 3. A comparative analysis also performed based on the type of source used in this study, Table 3 represents the comparison between carbon dioxide laser and GTAW.

Table 3. Comparison between CO_2 laser and GTAW.

Inconel 625 weldments properties	CC GTAW	PC GTAW	CO_2 laser
Yield strength n/mm²	500.051	568.518	667.918
Maximum strength n/mm²	792.949	802.100	810.780
Failure	weld	weld	Weld

3.3 Results for surface roughness on UNSS32750 welded with laser

Table 4 represents the surface roughness of the joints and the corresponding values were listed. It is observed that surface roughness on the weld part showed very poor values this represents the need of optimization while welding process and the corresponding interpretation also showed in Figure 4.

Table 4. Surface roughness on UNSS32750 welded with laser.

Specimen	UNSS32750 TO UNSS32750		
Experiments	On Surface(µm)	On Welded Portion (µm)	On Opposite Surface (µm)
Ra	0.909	4.278	1.014
Ry	1.149	5.547	1.23
Rz	5.328	24.579	5.317

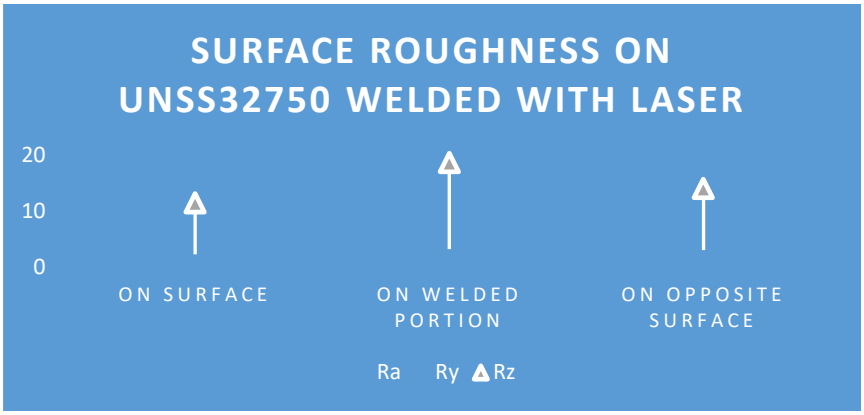


Fig. 4. Surface roughness on UNSS32750 welded with laser.

3.4 Results of distortion

Figure 5 represents a distortion of different weights in that carbon dioxide laser showed least distortion from this we can conclude with carbon dioxide laser assisted building performed better while comparing with other buildings under the corresponding heat affected zones are depicted in Figure 6 in that we can clearly observe the pits on the grades represents high heat conditions.

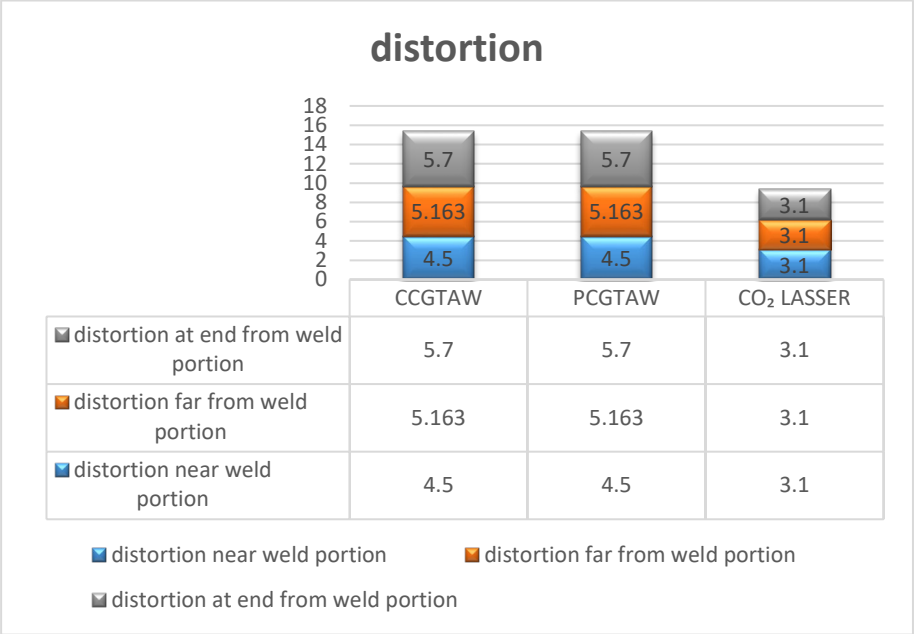


Fig. 5. Results of distortion at different areas of weld jones.

3.5 Results of heat affected zone (HAZ):

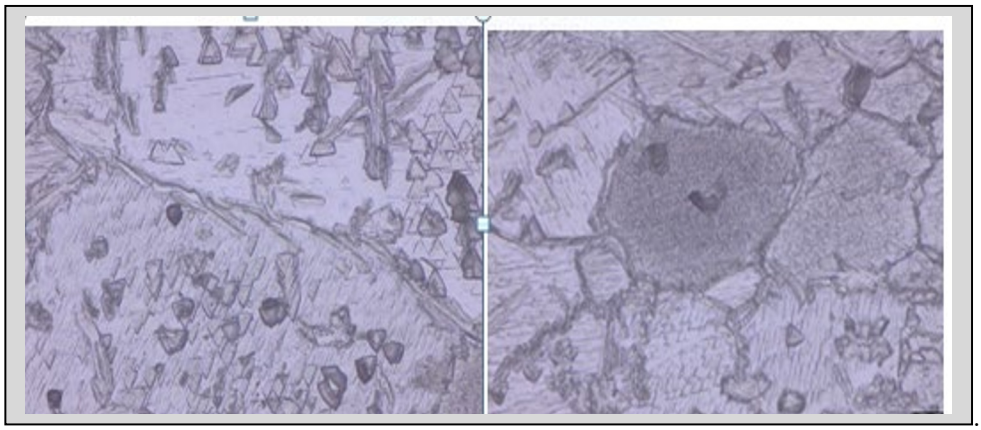


Fig. 6. Heat affected zones in weld regions.

4 Conclusion

In this CCGTAW welding process we experiential observed Coarser grain structure analysis, and the analysis of mechanical Maximum strength is 500.051 N/mm² & reduced strength compared to PCGTAW is 22.4241 N/mm² Surface roughness for the material is 3.393 µm, hence the work piece has slightly rough portion Distortion for the material is 5. 121 degrees

In this PCGTAW welding process we experimentally concluded Finer than CCGTAW grain structure analysis and the analysis of mechanical Maximum strength is 568.518

N/mm² & increased strength compared to CCGTAW is 0.81255 N/mm² Surface roughness for the material is 3.767 μm, hence the work piece has very rough portion Distortion for the material is 5. 121 degrees

In this CO_2 LASER welding process, we finished Very fine than CCGTAW grain structure analysis and the analysis of mechanical Potentially superior strength compared to other techniques that is667.918N/mm² Surface roughness for the material is 2.82 μm, hence the work piece has very smooth portion Distortion for the material is 3.1 degree

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