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TENSILE, IMPACT AND NON-DESTRUCTIVE ANALYSIS OF 316 L STAINLESS STEEL FOR MARINE APPLICATIONS

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ABSTRACT

Welding is an age-old method used for joining the metals permanently. The marine industry significantly uses sheet metal components that benefit from custom welded blanks (TWBs). These advantages encompass weight, cost, noise savings, increased crash safety, improved efficacy, and oxidation resistance. However, machinability issues are prevalent as a result of the welding process. These benefits and drawbacks and TWB forming techniques, welding procedures, and materials utilized in the marine sector are explored. In this study, two different thicknesses of 316L stainless steel grade plates were welded using manual and automatic TIG welding processes. The process parameters chosen for this study are welding current, voltage, welding speed, shielding gas, and filler diameter. The manual TIG welded specimen was then compared with the automatic TIG welded model in terms of Liquid Penetration test tensile and impact test. The result and discussion are briefly explored.

Keywords: *Tailor welded blanks, 316L Stainless steel, Tig Welding*

1. Introduction

The welding process is essential in the engineering field. In many mechanical industries, welding is vital in the materials joining process. Various types of welding are used in welding industries, such as TIG, MIG, ARC, Gas, Submerged and Laser beam welding. Any metal sheets or alloys can be welded in particular applications. Aluminium alloys, stainless steel grade metal sheets, iron materials, and so on [1-2]. Karpagaraj investigated the fabrication of tailor-welded blanks (TWB) with thicknesses of 1.6 mm and 2 mm for aluminium-based alloy utilizing the GTAW method with specified parameters. This research assessed the machinability limitations of TWB and tensile testing to determine the influence of the GTAW process. The GTAW-fabricated joint had a maximum strength of 982 MPa, 3.58% higher than the 1.6 mm and 1.10% lower than the 2 mm thin base material. [3]. J.Rojek et al. Different techniques have been carried out, including metallographic analyses, Uni axial tension studies, measures of microhardness, indentation tests and laser welding numerical simulation. The stress-strain curves obtained with various approaches display variations, while the stress intensity is comparable [4]. Yan Qi et.al. Car weight can be significantly reduced using tailor-made welded blanks in the body-in-white structural sections. Lower vehicle weight means better fuel economy, critical in today's energy shortages. In addition, materials will now be best used in stamping, and scraps in the car workshop can be minimized. The inevitability of tailor-made welded blanks used by car manufacturers in the automobile industry [5].

Buste et al. use the dynamic analysis finite element algorithm LS-DYNA to create aluminium alloy sheet TWB welds. The limitation dome height test, which is in short said as LDH, is modelled using three instrument groupings: 2 mm to 1mm, 2 mm to 1.6 mm, and 1.6 mm to 1mm, as well as several welded configurations comparative to the loading direction utilising two methods of welding: NVEB Welds and Nd: YAG Weld. However, the model needs to be more cautious for better results. Nd: YAG-welded blanks often fail in the thinner parent metal distant from the fusion zone. For the lowest thickness ratio, failure invariably happens by weld fracture (2:1.6) [6].

B. L. Kinsey et al. TWBs have attracted the automobile industry's attention because of their reduced component weight, lower cost, lower noise, excellent crash safety, and increased dimensional precision.

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Typical welding process and procedure adjustments are used to solve relevant formability difficulties caused by differences in the material characteristics of the welding zone [7]. Vinoth analysed the microstructure behaviour of 316L stainless steel fabricated by wire in additive manufacturing. The process parameters chosen were welding speed, current, voltage, gas flow rate, macro examination, surface roughness, and surface textures using a scanning electron microscope [8-10]. Vinoth studied the mechanical properties of TIG welded 316 Stainless steel using Taguchi-based grey relational analysis. The perfect parameters were optimized, such as current 150A, welding speed 190 mm/min and gas flow rate 15L/min [11]. The friction stir welding process is a solid-state welding process. The advantages of friction stir processing for aluminium composites include advanced research in aluminium alloy Friction Stir Welding. The marine industry and current car production have gained innovative opportunities for simple and better use of the abundant metal on the ground [12-14]. Numerous exploration projects are underway in tailor-welded blanks for the benefits of various welding processes. Because of innovation is given by the application in marine, aerospace, railroad and transport industries [15-17]. Jagathesh et al. investigated the AA2024 and AA6061 dissimilar weld joints using friction stir welding for aerospace, marine and automotive sectors. Using three factorial designs, the Box-Behnken matrix response surface methodology tool used all the experimental works [18]. Chanakya et al., the tool spinning speed, traverse speed, and axial load were chosen to investigate the effect of friction stir bead-on-plate processing on the tensile strength qualities and microhardness in AA5052 [19].

In this investigation process, two different thickness materials can be welded using the tailor welded blanks method and the tensile, impact and non-destructive test analysis in the 316L stainless steel material.

2. Materials and Methods

SAE 316L grade stainless steel is the second most common austenitic stainless steel after 304. Type 316L stainless steel is a low-carbon variation of the alloy 316. The decreased carbon concentration of 316L reduces the possibility of harmful carbide precipitation during welding. As a result, 316L is utilized whenever welding is necessary to achieve optimal resistance to oxidation.

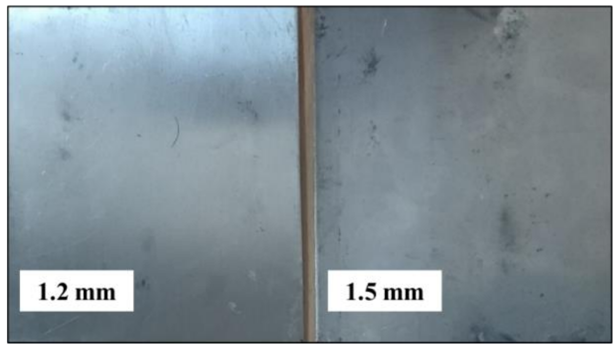

Fig. 1 SAE 316L Stainless steel Plate (1.2 mm & 1.5mm)

2.1 Chemical Composition of 316L stainless steel

The chemical composition of the stainless steel 316L used for welding is described in Table 1. This table shows the differences between the two steel types used in welding.

Table 1 Chemical Composition of 316L stainless steel

Element	Type 316 (%)	Type 316L (%)
Carbon	0.08 max.	0.03 max.
Manganese	2.00 max.	2.00 max.
Phosphorus	0.045 max.	0.045 max.
Sulfur	0.03 max.	0.03 max.
Silicon	0.75 max.	0.75 max.
Chromium	16.00-18.00	16.00-18.00
Nickel	10.00-14.00	10.00-14.00
Molybdenum	2.00-3.00	2.00-3.00
Nitrogen	0.10 max.	0.10 max.
Iron	Balance	Balance

2.2 Tailor Welded Blanks

Tailor-welded blanks are created by individual sheets of steel of varying thickness and strength that can be welded with one another. This method enables the user or the researcher to weld two pieces of steel or any other material with variations in thickness. Also, when the coating on the material differs, this method can be used to weld the metal joints. The schematic sketch of the TWB weld is shown in Figure 2.

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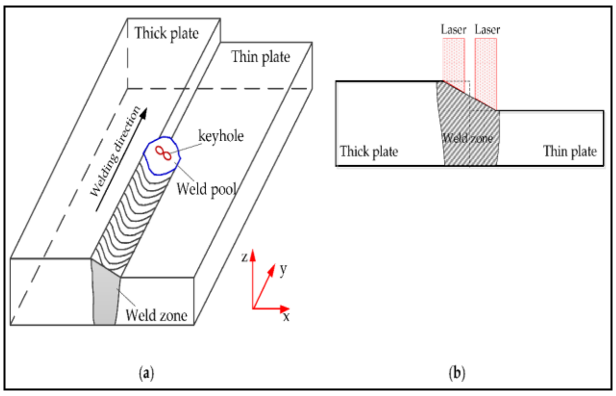

Fig. 2 Tailor welded blanks (TWB)

2.3 TIG welding

TIG welding is also commonly used in automated systems, both autogenously and using filler metal. Furthermore, various 'off the shelf' technologies for orbital welding of pipes used to produce chemical plants or burners are provided. The systems do not require manual manipulation, but the controller must be thoroughly trained. Since the welder has less control over the arc and weld pool characteristics, the welder must pay close attention to edge preparation (machined rather than hand-prepared), joint fit-up, and welding factor management. Taken the similar metal stainless steel (316L) Dimension of (100 x 100 x 1.2) mm and (100 x 100 x 1.5) mm using Tig welding by manual and automatic.

Table 2 Process Parameters

S. No	Method	Manual	Automatic
1	Current	90 amps	90 amps
2	Voltage	16V	16V
3	Speed	Hand speed	25 cm/min
4	Shielding gas	Argon+He	Argon + CO_2

2.4 Liquid Penetration Test

When it comes to non-destructive testing challenges, liquid penetration testing, also called as dye penetrant inspection (DPI) or liquid penetrant inspection (LPI), is one of the most popular and cheapest solutions, as well as one of the earliest. To identify surface-breaking flaws, the approach uses capillary action, which is the capacity of a fluid to stream into tight areas deprived of the support of, or even in obstruction to, other services such as gravity.

Fig. 3 Welded specimen manual

Fig. 4 Welded specimen automatic

After pouring the liquid and allowing it to remain, the surplus is cleaned, and a developer is applied. The developer draws the liquid where it has leaked from surface-breaking faults, showing their existence. A test in welding, after welding, which is cleaned using acetone, we sprayed the penetrant and made it dry for 8 minutes. Then, it is again cleaned with acetone. Then, the developer sprayed on the welded structure.

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Fig. 5 LPT (Penetrate solution)

Fig. 6 LPT (developer solution)

2.5 Tensile Test

This is one of the most often used structural testing techniques because it allows the researcher to evaluate the behaviour of a specimen when an axial extending stress is applied. Increasing the temperature of a substance to determine its tensile qualities can be done under ambient or supervised conditions. Tensile testing is done on various materials, such as metals, polymers, synthetic rubber, cellulose, alloys, rubbers, fabrics, sealants, and sheets. Tensile testing is frequently performed to assess an element's ultimate load. Tensile testing can be done using either a load or a stretch value. After the welding process is done, the material is cut for the tensile testing based on the standard ASTM E8 by using the wire cut EDM, and the tensile test is conducted in the Tinius Olsen instrument. After 10 minutes, the results have been recorded.

Fig. 7 Tinius Olsen

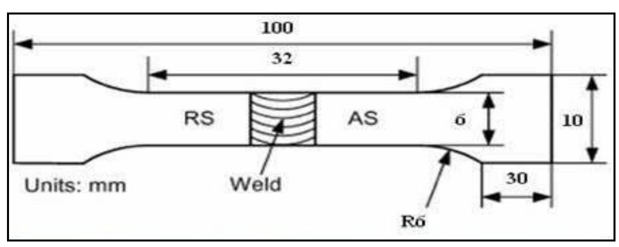

Fig. 8 ASTM E8 Standard Specimen

2.6 Impact test

Impact testing is used to investigate material toughness. The capacity of a substance to absorb energy during plastic deformation is measured by toughness. Brittle materials have poor toughness because they can only endure a limited degree of plastic deformation. The impact value of a material can also be affected by temperature. In general, the impact energy of a substance decreases with decreasing temperature. Because it allows for a different number of faults in the

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material, which can serve as work stress and lower impact energy, the size of the specimen may also influence the result of the Izod impact load. A Charpy Impact test has been taken on the welding plate. The impact specimen was cut into the ASTM D256 dimension. The impact test machine is shown in Figure 9.

Fig. 9 Impact test machine

3. Results and Discussion

After welding, the mechanical testing process is carried out as per the experimental procedure, and the results are discussed. The welding of similar grades of stainless steel was carried out. The non-destructive test was checked in the welding zone, and a tensile test was carried out for each welded sample of TIG welding processes.

3.1 Liquid Penetration Test

The liquid penetration test to find the pores or the cracks in the weld region provided a positive result that is highly approachable for other mechanical tests. No other cracks or scratches in the welded structure were found while testing in the Liquid penetration test.

3.2 Tensile test

After the experiment's successful conduct, the two specimens are subjected to the tensile test and the test results are tabulated in Table 3. The results in Table 3 clearly show that the ultimate tensile strength was 490 MPa, achieved using the automatic welding process, which is higher than that achieved using manual welding. The yield strength, ultimate force, and elongation value increased by 243 MPa, 4090 N, and 51.3%, respectively. The stress-strain curves of both specimens subjected to testing are given in Figures 10 and 11.

Table 3 Tensile strength values

	Manual	Automatic
Ultimate strength	343Mpa	490Mpa
Yield strength	193Mpa	243 Mpa
Ultimate force	4510N	4090N
Elongation	33.3%	51.3%

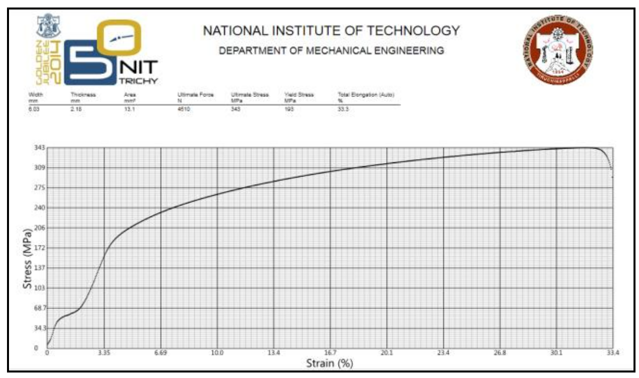

Fig. 10 Stress-strain curve (Manual)

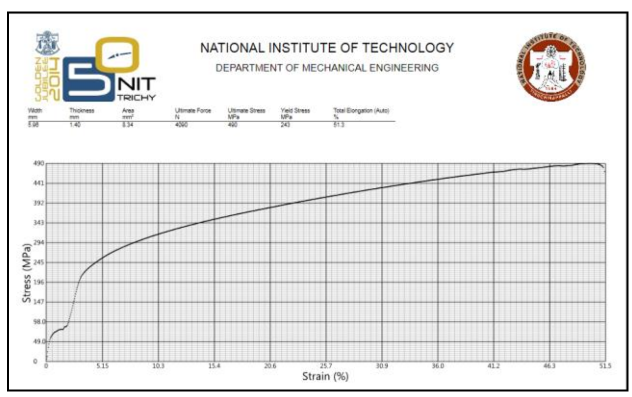

Fig. 11 Stress-strain Curve (Automatic)

3.3 Impact test

Charpy impact tests were performed at room temperature with heat inputs ranging from 2.00 to 2.56 kJ/mm utilizing impact testing equipment. Similar to the other mechanical tests conducted to find the properties of the welded specimens, an impact test is also carried out to find the mechanical characteristics of the manual and automatic welded joints. The results show that the automatic welding specimen's impact strength achieved

105 Joules, which is higher than the manual welding specimen, which is only 93 Joules.

4. Conclusion

In this project, the investigation was carried out on the TIG welding of 316L SS. Two different thicknesses of plate (1.2&1.5) mm were welded using manual and automatic TIG welding. Discuss the liquid penetration and Tensile tests carried out on the welded specimen. Finally, a comparison of the two different thickness materials is done. The observations are as follows,

i. During the liquid penetration test, no cracks occurred on the surface of both weld specimens.
ii. The tensile strength of Automatic is 30 % efficiency higher than manual welding.
iii. The impact strength of the Automatic welding specimen is 11% efficiency higher than the manual welding.

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