Indonesian Journal of Maritime Technology (ISMATECH)
Vol. 2, Issue 1, June 2024
eISSN: 3025-518X
DOI: https://doi.org/10.35718/ismatech.v2i1.1069

Strength Evaluation of Combined New and Old Plates Welded Joint: Case of Anggada XV Tug Boat

Samsu Dlukha Nurcholik[1*], Wahyuda[1], Taufik Hidayat[1], Andi Mursid Nugraha Arifuddin[1], Diniar Mungil Kurniawati[2], Devy Setiorini Saadiyah[2], Jatmoko Awali[3], Fikan Mubarok Rohimsyah[3], Andi Trimulyono[4], Andhi Indira Kusuma[5]

[1]Department of Naval Architecture, Institut Teknologi Kalimantan, Balikpapan, 76127, Indonesia
[2]Department of Mechanical Engineering, Institut Teknologi Kalimantan, Balikpapan, 76127, Indonesia
[3]Department of Material and Metallurgical Engineering, Institut Teknologi Kalimantan, Balikpapan, 76127, Indonesia
[4]Department of Naval Architecture, Universitas Diponegoro, Semarang, 50275, Indonesia
[5]Department of Naval Architecture, Institut Teknologi Adhi Tama Surabaya, Surabaya, 60117, Indonesia

KEYWORDS
Shipbuilding
Welding
Spectroscopy
Mechanical properties

ABSTRACT – The naval plate is designed for shipbuilding because of its strength, durability, and corrosion resistance. Old plates were used at the shipyard due to the surplus of previous projects. However, the mechanical properties of the old plate compared to the new plate have yet to be clarified. This study performed a comparative investigation of shielded metal arc welding (SMAW) of the old and new plates. A spectroscopy test was used to obtain the chemical properties of the old plate and the new plate. Furthermore, tensile and hardness tests were performed to investigate the mechanical properties. It was concluded that the average value of tensile strength of the old-old plate, new-new plate, and new-old plate are 451.3, 487, 454,3 N/mm2, respectively, and the average hardness test of HAZ of the old plate, new plate, and weld metal are 73.2, 78.3, 83.2 HRB, respectively. From the results, it can be concluded that using old plates for shipbuilding is still reliable.

*Corresponding Author | Samsu Dlukha Nurcholik | ✉ dlukha@lecturer.itk.ac.id

INTRODUCTION

Welding is an essential shipbuilding process that directly affects construction and quality. Shielded metal arc welding (SMAW) is commonly used in shipbuilding due to its high efficiency and low production cost [1]. The other advantages of SMAW compared to other welding techniques are low maintenance, no need for shielding gas, simple equipment, and many positions with simple problems. Mechanical properties and residual stress characteristics of welded joint were discussed by Alipooramirabad et al. [2]. The result showed that residual stress affects the microstructural of weld metal and heated affected zone (HAZ). Heat input variables such as ampere and travel speed influenced the mechanical properties of weld joints [3] [4]. Heat input significantly affects grain size, microstructure, and ultimate tensile strength (UTS). On the contrary, heat input also expands the HAZ, decreasing mechanical properties. Kook et al. [5] analyzed the metallurgical and mechanical properties of pre-heating of welding. The result shows that the higher temperature of pre-heating increases impact toughness but decreases tensile strength due to low acicular ferrite formation. Rohit and Jha [6] analyzed the amperage of mild steel joints. The current of 120 A gives the best tensile strength because the grains do not have enough heat, which causes the refined grain to change from ferrite to austenite. Jadoun et al. [7] examined welding variables of plate thickness and electrode diameter. The results show that the proportional plate thickness and electrode diameter influence an optimum of mechanical properties. Mao et al. [8] investigated the effect of additional nickel on bainitic steel welding, transforming the granular bainite into martensite.

While previous research has primarily focused on the strength of new plates, this study takes a novel approach by considering the use of new and old plates. In real-world shipbuilding scenarios, residual plates from previous projects are expected to be used. For instance, in replicating the Anggada XV tug boat, which used plates stored in the warehouse. Therefore, it becomes crucial to investigate the impact of this combined use of new and old plates on the mechanical properties. Moreover, comparable studies that consider the tensile strength of welding joints [9] and the degradation of old plates [10] have been carried out in the shipbuilding industry. However, the former focused on seam welding, while the latter just performed a numerical simulation of a ship hull. In this research, we conducted a spectroscopy test of old and new plates to compare their chemical properties. Subsequently, we performed tensile and hardness tests to evaluate the strength of the welding joint.

METHOD

In this research, the welding plates were taken from the Anggada XV tug boat, which was established in 1987. The shipping line is limited to around Semayang Port Balikpapan. The replating place is the bottom near the forepeak, as shown in Figure 1. The principle dimension of the Anggada XV tug boat is in Table 1.

Figure 1. Replating place of the bottom near forepeak

Table 1. Principle dimension of Anggada XV tug boat

Dimension	Value
LoA	: 26 m
LPP	: 24 m
T	: 3 m
B	: 8.5 m
GT	: 220 Tonnage

Spectroscopy test

The chemical properties of old and new plate plates were examined by spectroscopy. The specimens were 10 mm in thickness and 50 mm in width, respectively. The rust was cleaned by grinding the specimens. The results of the Spectroscopy test are shown in Table 2.

Table 2. Chemical propertties (%) comparison of new plate and old plate

Composition	Fe	C	Si	Mn	P	S	Cr	Mo	Ni	Al
New Plate	98,7	0,123	0,198	0,779	0,009	0,002	0,027	0,001	0,012	0,031
Old Plate	98,8	0,118	0,017	0,795	0,005	0,002	0,017	0,001	0,033	0,029
Difference	0,1	-0,005	-0,180	0,016	-0,004	-	-0,01	-	0,021	-0,002

Specimen of welding

Anggada XV tug boat, which has used the Biro Klasifikasi Indonesia (BKI) standard plate of SS400 with an A grade, was acquired for this study. All specimens were prepared with 30 degrees of bevel and 300 x 200 x 10 mm dimensions, illustrated in Figure 2. The gap was set at 3.2 mm according to the electrode diameter, with the groove at 60 mm and 120-140 amperes current. As illustrated in Figure 3, three combinations of two plates were used: old-old plates, new-new plates, and old-new plates. SMAW was conducted for the welding experiments.

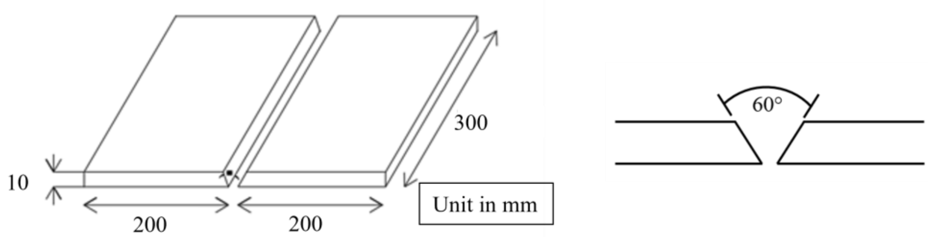

Figure 2. Joint configuration

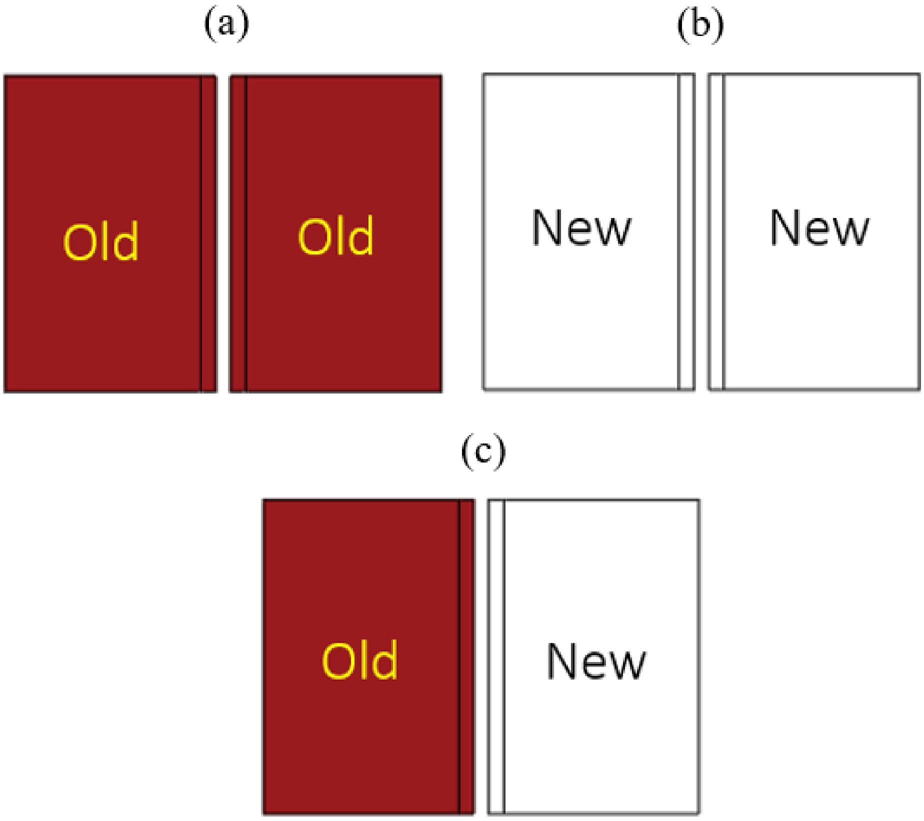

Figure 3. The combination of the joint

Visual Inspection

A visual inspection was conducted to observe the results of the welding joint. Visual inspection is the traditional way to avoid defects resulting in unreliable results.

Tensile test

The tensile test was applied to obtain ultimate strength. The tensile test specimens were met with ASTM E8, as shown in Figure 4. Tile tests were conducted thrice to minimize the errors in the experiments. Then, we get the mean of tensile strength.

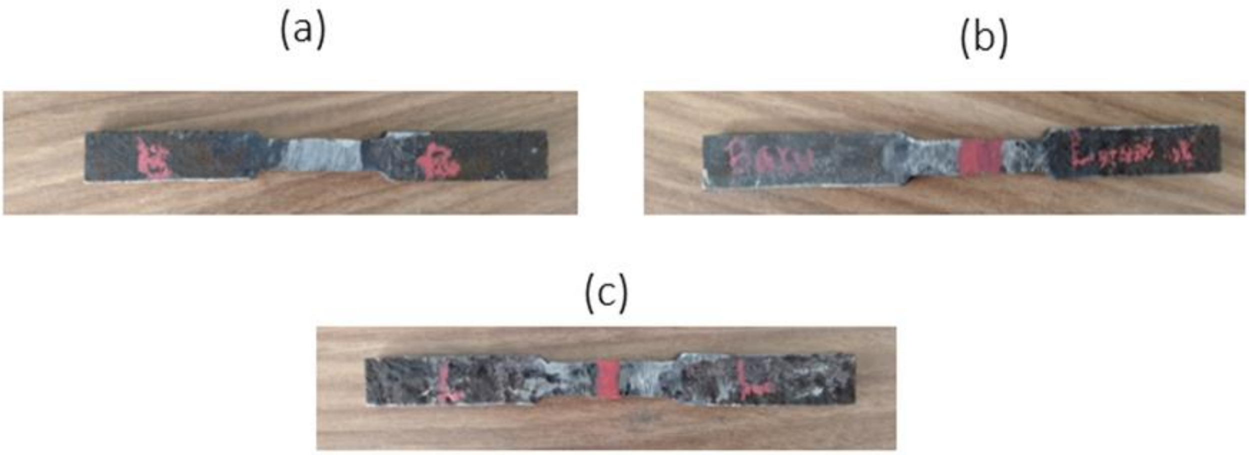

Figure 4. Specimen of tensile test

Hardness Test

A Brinell testing machine was used for the hardness test, emphasizing 100 KgF. The ASTM E10-15 standard was used for the brinnel test. Six times, indentation was applied in each area of the old plate, the affected zone (HAZ) of the new plate was heated, and metal was welded to obtain the mean value of the bridal test.

Figure 5. Specimenn of hardness test

RESULTS AND DISCUSSION

Results of visual Inspection

Figure 6 shows the visual inspection results of old and new plate joints. The joint has two defects, which are spatter and excessive reinforcement. Excessive reinforcement appears because the electrode change is too thick, and the next layer has too much melt weld. For spatter, it is caused by the setting of current and voltage. The humid environment also affects the spatter. Also, contaminants such as dirt and rust affect the spatter. For this experiment, the defects part is used. On the other hand, new-new joints and old-old joints have no defects.

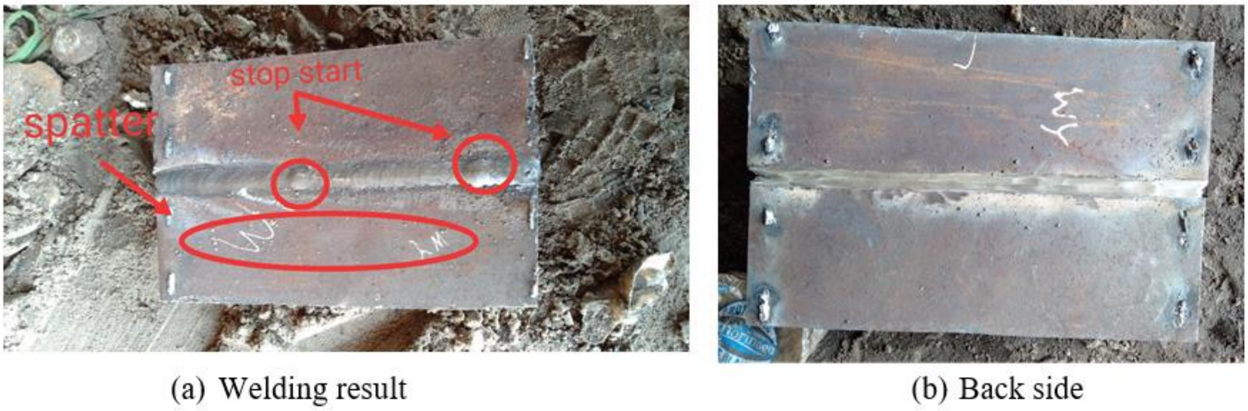

Figure 6. Visual inspection

Results of tensile test

The result of the tensile test is shown in Figure 7. The highest strength value of the tensile test is the new plate, with an average tensile strength of 487 N/mm^2, and the lowest strength of the old specimen is 451.3 N/mm^2. For the old-new plate, the average of the tensile test is 454.3 N/mm^2. From the tensile test, all three combination plates weld joint have a small difference. This results because the differences in chemical properties between the old and new plates is slight as shown in Table 2. With proper plate storage with no chemical contamination, the chemical properties of the old plate remain the same as those of the new plate. The problem with old plates is only the rust, which reduces the plate thickness.

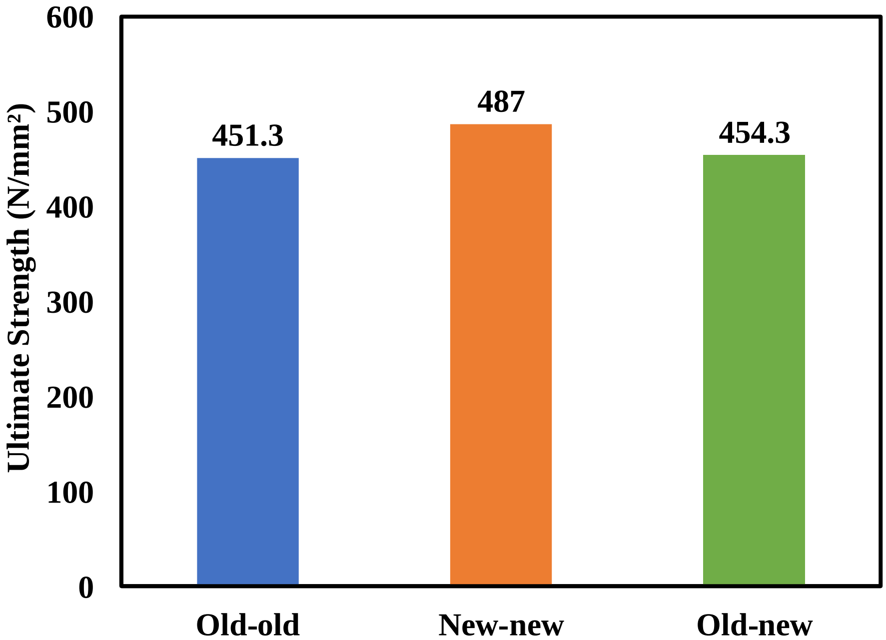

Figure 7. Tensile test results

Results of hardness test

Figure 8 shows the value of the hardness test. The highest value of the hardness test is obtained in the weld metal region with 83.2 HRB. The lowest hardness test is in the HAZ region because this area has a non-uniform microstructure [11]. On the other hand, In the base metal of the new plate, the hardness test value is 78.3 HRB.

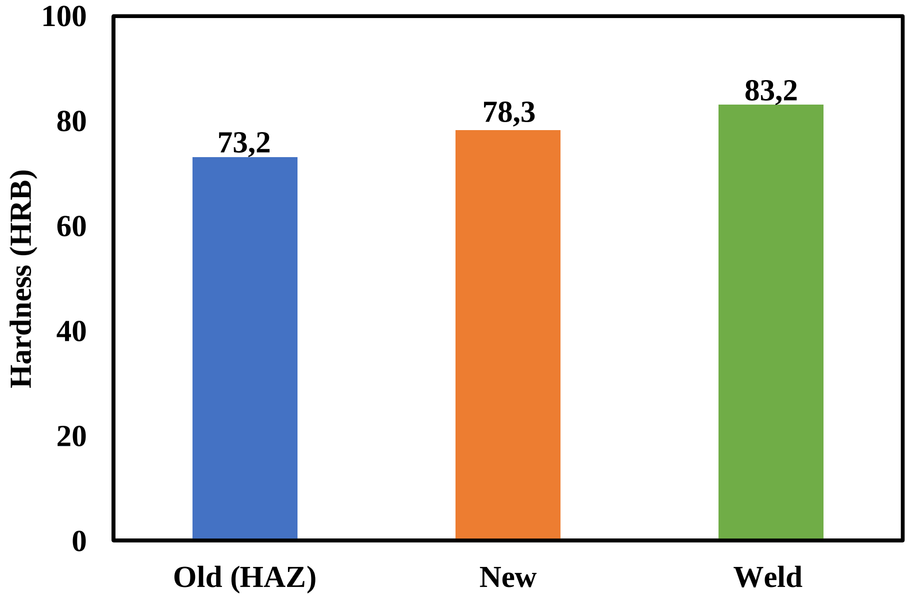

Figure 8. Hardness test results

CONCLUSION

To investigate the use of the old plate to replicate the ship bottom Anggada XV tug boat, a spectroscopy test was carried out to compare the chemical properties of the old plate with those of the new plate. Furthermore, tensile and hardness tests also were carried out to clarify the mechanical properties of using old plates for the welding joint. From this study, the tensile and hardness tests almost have a negligible effect on the mechanical properties of using an old and new plate. The average three times testing of tensile strength of the old-old plate, new-new plate, and the new-old plate is 451.3, 487, 454,3 N/mm^2, respectively. The hardness tests of the old plate, new plate, and weld metal are 73.2, 78.3, and 83.2 HRB, respectively. Using old plates is reliable for replating Anggada XV if they are not contaminated with chemical materials.

ACKNOWLEDGEMENT

The authors would like to express their gratitude to Polteknik Negeri Samarinda for providing ultimate tensile machine test and Politeknik Perkapalan Negeri Surabaya for providing spectroscopy test.

REFERENCES

[1] P. Hariprasath, P. Sivaraj, V. Balasubramanian, S. Pilli, and K. Sridhar, “Effect of the welding technique on mechanical properties and metallurgical characteristics of the naval grade high strength low alloy steel joints produced by SMAW and GMAW,” CIRP J Manuf Sci Technol, vol. 37, pp. 584–595, May 2022.

[2] H. Alipooramirabad, A. Paradowska, R. Ghomashchi, and M. Reid, “Investigating the effects of welding process on residual stresses, microstructure and mechanical properties in HSLA steel welds,” J Manuf Process, vol. 28, pp. 70–81, Aug. 2017.

[3] D. Sumardiyanto and E. Susilowati, “Effect of Welding Parameters on Mechanical Properties of Low Carbon Steel API 5L Shielded Metal Arc Welds”, American Journal of Materials Science, vol. 2019, no. 1, pp. 15–21, 2019.

[4] A. K. Yadav, A. Kumar, C. Pratap, N. Singh, A. K. Singh, and M. S. Nand, “Studies on Impact of Welding Parameters on Angular Distortion and Mechanical Properties of Structural Steel Welded by SMAW”, International Research Journal of Modernization in Engineering Technology and Science. Vol 2, May 2020.

[5] K. Bang, H. Jung, and C. Park, “Effects of Heat Input and Preheat/interpass Temperature on Strength and Impact Toughness of Multipass Welded Low Alloy Steel Weld Metal,” Journal of Ocean Engineering and Technology, vol. 29, no. 6, pp. 481–487, Dec. 2015.

[6] R. Jha and A. K. Jha, “Investigating the Effect of Welding Current on the Tensile Properties of SMAW Welded Mild Steel Joints,” International Journal of Engineering Research & Technology. Vol 3. April 2014.

[7] D. Singh Jadoun, R. Prasad Kori, and D. Kumar Kasdekar, "Optimization of Welding Parameter for Arc Welding of Mild Steel Plate (Grade-40)." Technical Research Organization India, vol 3, 2016.
[8] G. Mao et al., "Effect of Nickel Contents on the Microstructure and Mechanical Properties for Low-Carbon Bainitic Weld Metals," J Mater Eng Perform, vol. 26, no. 5, pp. 2057–2071, May 2017.
[9] Alamsyah, F. . Indah Sari, A. M. N. . Arifuddin, M. U. . Pawara, A. A. Mubarak, and Hijriah, "Experimental Test of Tensile Strength of Barge Deck Plate Welded Joints", Int. J. Metacen., vol. 2, no. 2, pp. 9-17, Dec. 2022.
[10] A M Nugraha A, M. U. Pawara, A. Ardianti, and F. Mahmuddin, "An investigation of strength degradation due to thickness plate reduction on Ferry Ro-Ro Ship's Hull," IOP Conference Series. Earth and Environmental Science, vol. 921, no. 1, p. 012053, Nov. 2021, doi: 10.1088/1755-1315/921/1/012053.
[11] Y. R. A. Pradana, Wahono, D. Tanzila, and A. Lukman, "Hardness analysis of carburized steel weld joint by SMAW using different welding current". International Mechanical and Industrial Engineering Conference. 2018.