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Influence of SMAW Welding Current Variations on the Tensile Strength of API 5L Grade B Pipe

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ABSTRACT

Welding often fails or rejects weld joints on API 5L Gr.B material, which is a critical problem, because the pipe is a very important part. It will have fatal consequences for the production process. This research is proposed to study the effect of Shielded Metal Arc Welding (SMAW) process current variations on the tensile strength of API 5L Gr. B Pipe material. Results from previous investigations reveal that, single pass welded joint was found to possess adequate strength and meet requirements and the impact toughness for API 5L Gr.B steel pipe oil and gas. The parent material was superior to that of multi-pass weld zone and heat affected zone (HAZ) at all test of temperatures. The ultimate stress with 50 A welding is 295.31 MPa and the yield stress is 216.41 MPa. The tensile stress with a welding current of 140 A produces an ultimate strength of 261.98 MPa and a yield stress of 191.41 MPa so that the SMAW welding process by increasing the current can reduce the tensile strength of the welding results.

KEYWORDS: *Dye penetrant, Radiography, SMAW welding, Tensile strength.*

1. INTRODUCTION

SMAW welding technology has been widely applied in Indonesia, starting from micro (small) industries, medium industries, to national industrial scale. This study aims to test the strength of welding joints on API 5L Gr.B materials using the SMAW welding method by looking at the current that is suitable for welding API 5L Gr.B materials based on the API 1104 standard. One of the most common process is shielded metal arc welding (SMAW) process is widely used for joining of steel plates in the fabrication [1]. In the construction of oil pipelines, one of the constructions is a pipe with API 5L Gr.B material which functions as a fluid distributor from oil wells to the main pipe. During construction work, welding often experiences failure or rejection at the weld joint on API 5L Gr.B material, this is a critical problem, because the pipe is a very important part. Quenched and tempered steel SMAW weldments must be of good quality especially when used for construction of combat vehicles in military applications [2]. A number of welding processes are available to fabricate high strength mining steel structures; however, SMAW is commonly used for joining of thick steel sections due to less cost and easy availability of the equipment [3].

In the construction of the Rokan Block oil pipeline, one of the constructions is a pipe with API 5L Gr.B material which functions as a fluid distributor from oil wells to the main pipe. During construction work, welding often fails or rejects weld joints on API 5L Gr.B material, which is a critical problem, because the pipe is a very important part. If a weld joint fails, it will have fatal consequences for the production process. With an oil production share of 24 percent, the Rokan Block is one of the largest oil producers in SMAW welding technology has been widely applied in Indonesia, starting from micro (small) industries, medium industries, to national industrial scale. This study aims to test the strength of welding joints on API 5L Gr.B materials using the SMAW welding method by looking at the current that is suitable for welding API 5L Gr.B materials based on the API 1104 standard. One of the most common process is shielded metal arc welding (SMAW) process is widely used for joining of steel plates in the fabrication [1].

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In the construction of the Rokan Block oil pipeline, one of the constructions is a pipe with API 5L Gr.B material which functions as a fluid distributor from oil wells to the main pipe. During construction work, welding often fails or rejects weld joints on API 5L Gr.B material, which is a critical problem, because the pipe is a very important part. If a weld joint fails, it will have fatal consequences for the production process. With possess adequate strength, impact toughness and meet requirements and the impact toughness for API 5L Gr.B steel pipe oil and gas. The parent material was superior to that of multi-pass weld zone and heat affected zone (HAZ) at all test temperatures [5-7] revealed in their investigation that, SMAW joint efficiency of filler metal deposits was found to be around 72% of its counterpart high-strength low-alloy steel base metal [6,8]. In addition, the weld deposits exhibited good toughness and better ballistic performance. Lakshminarayanan et al. [7,9,10] studied the effect of SMAW, GMAW and GTAW processes on tensile and impact properties [11,12].

The problem that often arises is how pipeline construction often experiences welding joint failure, how the welding current influences the quality of the strength and toughness of API 5L Gr.B steel SMAW welding with E6010 and E7018 electrodes. Current strength is the main component that determines the quality of the weld joint. Igniting an electric arc becomes more challenging with inadequate current. Therefore, the resulting electric arc becomes unstable. Minimal deep penetration and small and uneven weld losses because the heat generated is not enough to melt the electrode and base material [13,14,15]. Conversely, too high a current causes the electrode to melt too quickly, causing deeper penetration and a wider weld surface. This in turn causes the weld to have poor tensile strength and be more brittle than before.

The problem that often arises is how pipeline construction often experiences welding joint failure; how the welding current influences the quality of the strength and toughness of API 5L Gr.B steel SMAW welding with electrodes. Further, current strength is a major component that determines the quality of a weld. Starting an electric arc becomes more challenging with insufficient current. This paper aims to study the influence of SMAW welding current variations on the tensile strength of API 5L Grade B Pipe material. Understanding this relationship provides insight into why the strength changes, helping to develop better welding consumables and procedures in the future of pipeline construction.

2. METHODS

This study employed the quantitative experimental approach to investigate the relationship between the welding current in the Shielded Metal Arc Welding (SMAW) process and the resulting tensile strength of API 5L Grade B pipe material. The API 5L Grade B pipe sections was prepared according to American Welding Society (AWS) standards, likely involving a single V-groove joint configuration. Test specimens was welded using a consistent electrode type and a fixed welding speed, while systematically varying the welding current across a minimum of three distinct levels, one below, one within, and one above the manufacturer's recommended range. This controlled variation establishes the independent variable. After welding, the pipe was sectioned to extract multiple tensile test specimens following ASTM standards to ensuring the weld metal and the heat-affected zone was included in the gauge length of the specimen.

An investigation into the quality and characteristics of welds in API 5L Grade B steel pipe, a material critical for the oil and gas industry, by systematically varying the Shielded Metal Arc Welding (SMAW) current. The research focuses on how the welding current variation, a key parameter influencing heat input and cooling rate, affects the resultant weld integrity. The evaluation methodology employs both non-destructive testing (NDT), such as penetrant and radiography tests to identify flaws without damaging the specimen, and destructive tests, which typically include mechanical assessments like tensile, and hardness tests, to comprehensively determine the mechanical performance and quality of the welded joints.

Welding API 5L Grade B Sample Preparation

API 5L Grade B is a pipe commonly used for oil and gas pipeline transmission. This pipe is also called L254 referring to ISO 3183 with a diameter of 4 inches and a thickness of 6 mm. The mechanical properties have yield strength of 240 MPa and a tensile strength of 415 MPa. It has a chemical composition of C 0.28%, Mg 1.2%, P 0.03%, S 0.03%, and Cu 0.5%. The electrodes used are E6010 (2.6 mm) root with a welding length of 319 mm and E 7018 (2.6 mm) Filler with a welding length of 319 mm, DCEN and DCEP.

The welding procedure involved four distinct passes: a constant current root pass of 450 A, followed by the hot pass, filler pass, and capping pass. The welding time for each pass was carefully controlled and varied based on the current used. Specifically, a current of 50 A required a welding time of 8.0 minutes, 80 A required 7.2 minutes, and 140 A required 6.0 minutes. This structured approach to the welding process, varying the current and time for specific passes, is critical for controlling the weld bead geometry and the final mechanical properties of the joint.

3. RESULTS AND DISCUSSION

The variation in welding current and time directly influences the heat input delivered to the workpiece, which is a key parameter in determining the metallurgical characteristics and quality of the weld. As demonstrated in Figure 1, the distinct combinations of current and time for the different passes resulted in varying heat input values. This correlation is fundamental because the heat input controls the cooling rate and, consequently, the microstructure, residual stresses, and ultimately the performance of the welded joint. Therefore, the prescribed parameters were selected to achieve an optimal heat input profile across the multi-pass weld.

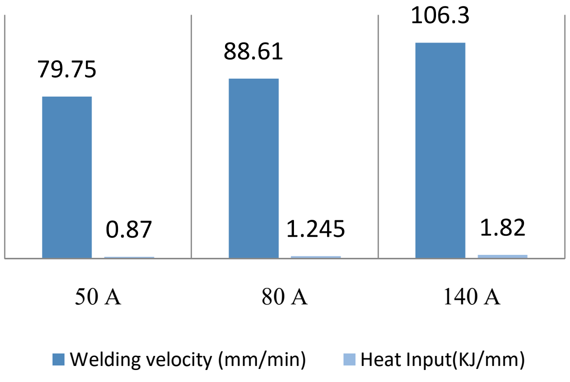

Figure1: Graph welding speed and heat input

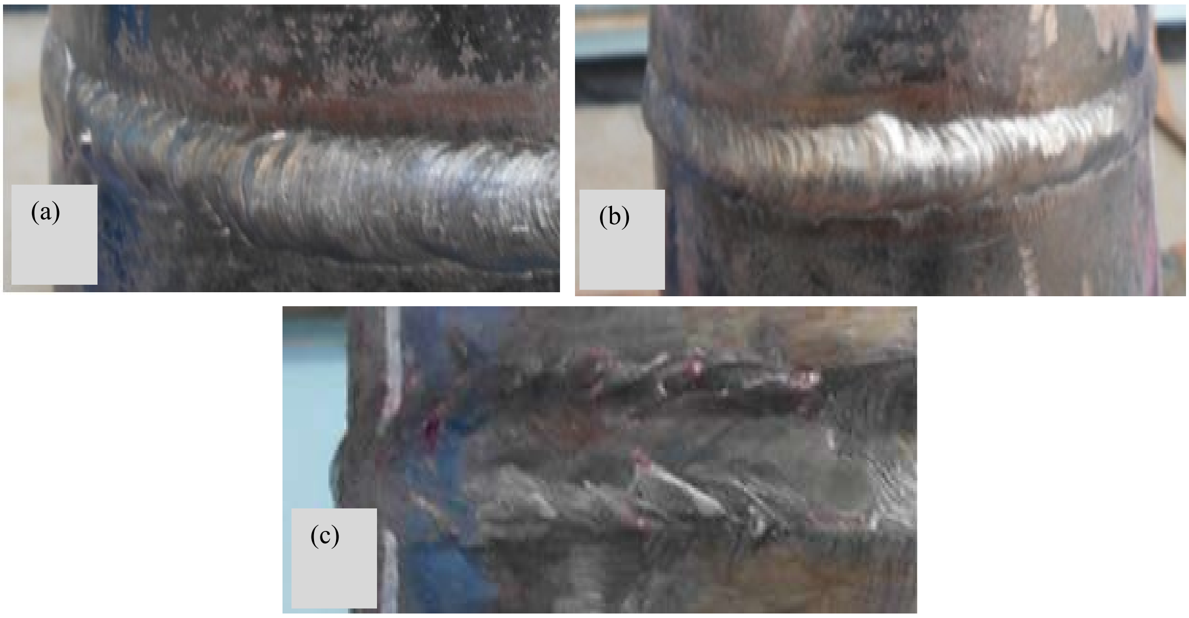

Figure 2: Welding results, a) 50A, b) 80A, and c) 140A

This work considers SMAW (shielded metal arc welding). The visual test of welding results for 50A, 80A, and 140A can be seen in Figure 2. From Figure 2(b) the visual test results can be seen that the specimen with a current of 80A has no defects in the weld. The welding results are acceptable. From Figure 2(c) the visual test results can be seen that the specimen with a current of 140A has welding defects, namely porosity defects and undercut defects with a length of 60 mm and a depth of 2 mm. The welding defects were unacceptable.

3.1 Non Destructive Test

The quality of the welding results was assessed using Non-Destructive Testing (NDT) methods, specifically the Dye Penetrant Test (DPT) and Radiography Testing (RT). The primary purpose of employing these techniques is to determine the presence of flaws or damage in the welded joint without compromising the integrity of the material. This approach is crucial for quality assurance in fabrication, as it allows for the inspection of every component without rendering it unusable. Both DPT and RT provide critical data on internal and surface discontinuities, ensuring the weld meets the required specifications for structural integrity and performance.

The Dye Penetrant Test (DPT) utilizes a specialized liquid penetrant material to identify surface-breaking discontinuities. Its fundamental principle is visual inspection, enhanced by the ability of the penetrant to seep into very small, otherwise overlooked surface flaws such as cracks, porosity, or laps through capillary action. After the excess penetrant is removed and a developer is applied, the penetrant bleeds back out of the defect, creating a highly visible indication against the contrasting developer background. This makes the DPT an excellent, cost-effective method for quickly and reliably identifying shallow, surface-breaking flaws that could act as stress concentrators and potentially lead to failure under operational loads. The observed dye penetrant test can be shown in Table 1.

Tabel 1: Obsevation dye penetrant

Welding current	Dye Penetrant Testing Observation Position		
	Initial welding	Center welding	Final welding
50A	Good	Fine crack at weld edge	Fine crack at weld edge
	Fine crack at weld edge	Fine crack at weld edge	Fine crack at weld edge
	Good	Good	Fine crack at weld edge
80A	Good	Good	Good
	Good	Good	Good
	Good	Good	Good
140A	Good	Fine crack at weld edge	Fine crack at weld edge
	Good	Fine crack at weld edge	Fine crack at weld edge
	Good	Fine crack at weld edge	Good

The results of the dye penetrant test on the test samples for the welded specimens 50A, 80A and 140A in three areas, initial, center and final, it turned out that the good results were at 80 A, in the center welding area for specimens 50A and 140A, the results were fine cracks on the edge of the weld (reject) as seen in Figure 3. Figure 3(a): The results of the penetrant test show that the specimen with a current range of 50A has an undercut defect with a length of 10 mm and a depth of 1 mm. The welding defect is unacceptable. Figure 3(b): The results of the penetrant test show that the specimen with a current of 80A has no defects in the weld. The welding results are acceptable. Figure 3(c): The results of the penetrant test show that the specimen with a current of 140A has welding defects, namely porosity defects and undercut defects with a length of 60 mm and a depth of 2 mm. The welding defects are unacceptable.

The results of radiographic testing of test samples for specimens welded 50A, 80A and 140A in three areas, initial, center and final. There are good results in the use of 50 A current, there are 2 mm porosity defects and 3.55 mm IC (reject). Welding current 80 A, there are no defect. Welding current 140 A there is a 2 mm porosity defect (reject). Figure 4(a): The results of the radiography test can be seen that the welding results for specimens with a current of 50A recorded by negative film show that there are porosity and IC defects. In the API 1104 standard, the welding defects are unacceptable. Figure 4(b): The results of the radiography test can be seen that the welding results for specimens with a current of 80A recorded by negative film show that there are no welding defects. The welding results are acceptable In the API 1104 standard. Figure 4(c): radiography test results can be seen that the welding results for specimens with a current of 140A recorded by negative film show that there are porosity and burn trough defects. Welding defects are unacceptable in the API 1104 standard.

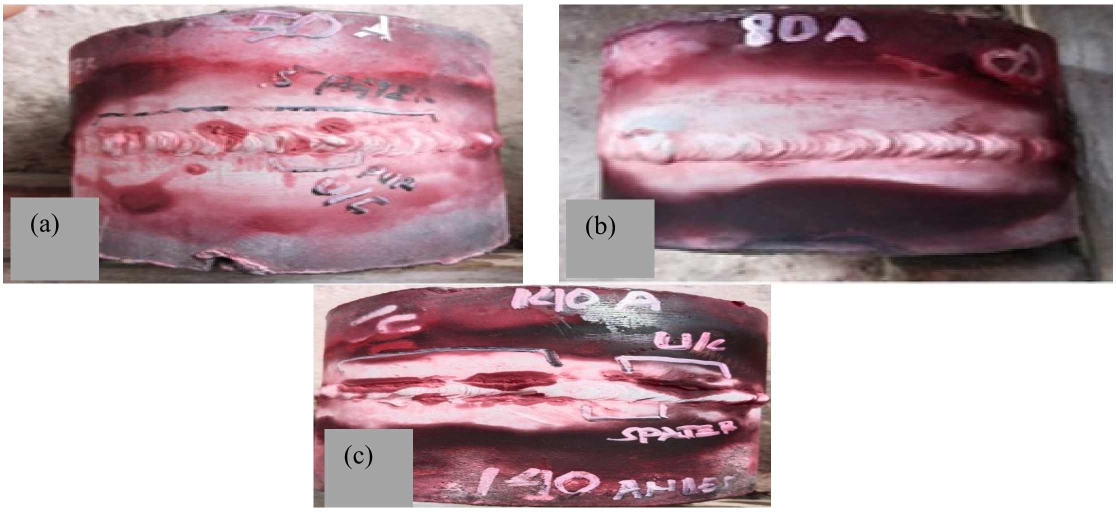

Figure 3: Dye penetrant test, a) 50A, b) 80A, c) 140A

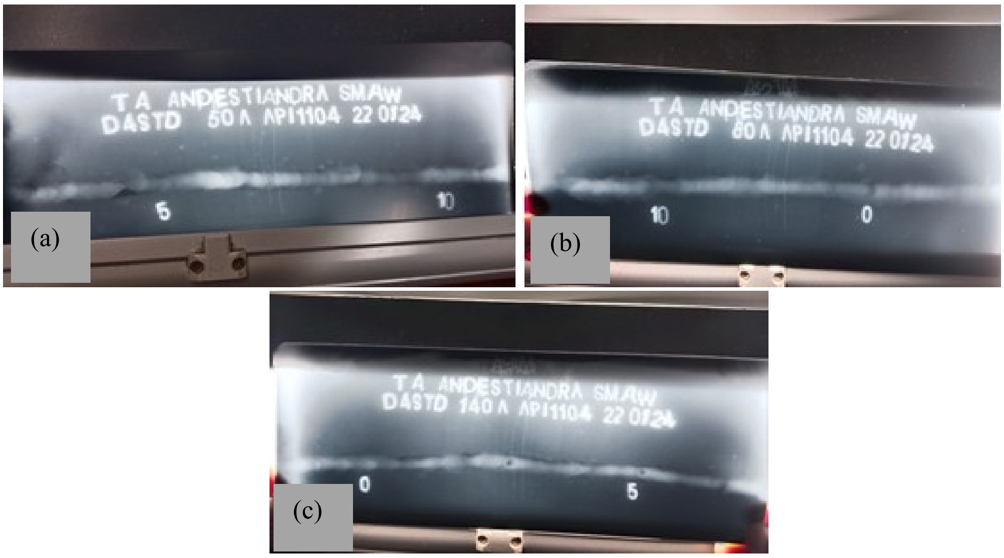

Figure 4: Radiography test (a) 50A, (b) 80A, (c) 140A

3.2 Destructive test

The destructive tests that will be carried out are tensile tests to determine the tensile strength properties of the welding current influence of the joints and hardness tests of the HAZ area.

3.2.1 Tensile test

In Figure 5, the tensile strength test results are shown with variations in welding current where the ultimate stress with 50 A welding is 295.31 MPa and yield stress was 216.41 MPa. The tensile strength with a welding current of 140 A produces an ultimate strength of 261.98 MPa and a yield stress is 191.41 MPa so that the SMAW welding process by increasing the current can reduce the tensile strength of the welding results. The increase in heat provided by the welding arc can increase hardness and reduce the tensile strength in the welding area so that increasing the welding current can reduce the tensile strength.

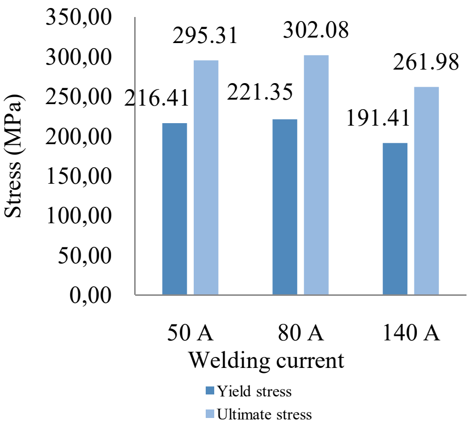

Figure 5: Graph tensile test with welding current variation

3.2.2 Hardness Test

The Rockwell hardness test was conducted to evaluate the mechanical response of the welded material, specifically focusing on the Heat-Affected Zone (HAZ). A total of two test specimens were analyzed for each of the three distinct welding currents: 50 A, 80 A, and 140 A. Within each specimen, hardness measurements were taken at three separate test points across the HAZ area, and the average hardness values were subsequently presented in Figure 6.

The experimental data indicates a subtle but observable trend between the welding current and the resulting HAZ hardness. The specimen welded with a 50 A current yielded an average HAZ hardness of 48.1 HRA, while the specimen welded at the highest current of 140 A resulted in a slightly greater average hardness of 48.4 HRA. This finding suggests that hardness increases marginally with increasing welding current. This increase is generally attributed to the greater heat input associated with higher currents, which can influence the cooling rate and the subsequent microstructural evolution in the HAZ. Specifically, a higher heat input often leads to the formation of a coarser, or a higher volume of, ferrite in the HAZ, which affects the overall mechanical properties of the region.

The Rockwell hardness scale was on a scale with welding hardness of 50A, 80A and 140A for every 2 test specimens for each welding current. Each specimen was tested at 3 test points in each HAZ area, the average hardness is shown in Figure 6. The welding current of 50A produces an average hardness of 48.1 HRA in the HAZ area while the welding current of 140 A was 48.4 HRA. Hardness increases with increasing welding current which can increase heat input so that the ferrite around the HAZ area increases.

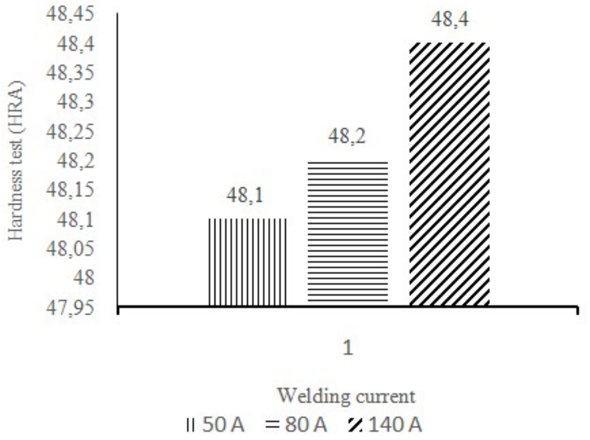

Figure 6: Graph hardness test with welding current variation

This susceptibility to failure is particularly relevant in high-strength materials like the API 5L Gr.B steel used in oil and gas pipelines, where the HAZ can develop brittle micro structures (e.g., martensite or certain bainitic structures) if the heat input is too low or the cooling rate is too rapid. Conversely, excessive heat input can lead to grain coarsening, reducing the material's toughness. Therefore, the hardness measurement across the HAZ is a direct proxy for the achieved microstructure; a very high hardness value often signals a brittle region prone to cracking (cold cracking), while an extremely low hardness can indicate an over-tempered or soft zone that may fail by plastic collapse. Understanding and controlling the HAZ properties is paramount to ensuring the long-term structural integrity and preventing catastrophic failure of pipelines and welded components.

4. CONCLUSION

This paper firstly presents experimental non-destructive and destructive test results of variation welding current SMAW of API 5L Gr.B steel pipe oil and gas. Non-destructive testing process using dye penetrant and radiography can minimize welding success. The SMAW welding process by increasing the current can reduce the tensile strength of the welding results. The hardness of the welding process with increasing welding current can increase the hardness in the HAZ area.

REFERENCES

[1] Youn, G.G., Kim, Y.J., & Miura, Y. (2021). Thermal aging effect on fracture toughness of GTAW/SMAW of 316L. *Nuclear Engineering and Technology*, 53(4), 1357–1368.

[2] Xu, Z., & Huang, F. (2012). Plastic behavior and constitutive modeling of armor steel over wide temperature and strain rate ranges. *Acta Mechanica Solida Sinica*, *25*(4), 418–430.

[3] Grajcar, A., Morawiec, M., Różański, M., & Stano, S. (2017). Twin-spot laser welding of advanced high-strength multiphase microstructure steel. *Optics & Laser Technology*, *92*, 52–61.

[4] Banerjee, S., Dhar, S., Acharya, D., & DattaNayak, N. (2015). Determination of Johnson Cook material and failure model constants and numerical modelling of Charpy impact test of armor steel. *Materials Science and Engineering: A*, *640*, 200–209.

[5] Reddy, G.M., Mohandas, T., & Papukutty, K.K. (1998). Effect of welding process on the ballistic performance of high-strength low-alloy steel weldments. *Journal of Materials Processing Technology*, *74*(1–3), 27–35.

[6] Lakshminarayanan, A.K., Shanmugam, K., &Balasubramanian, V. (2009). Effect of welding processes on tensile and impact properties, hardness and microstructure of AISI 409M ferritic stainless joints fabricated by duplex stainless steel filler metal. *Journal of Iron and Steel Research, International*, *16*(6), 66–72.

[7] Verma, J., & Taiwade, R.V. (2016). Dissimilar welding behavior of 22% Cr series stainless steel with 316L and its corrosion resistance in modified aggressive environment. *Journal of Manufacturing Processes*, *24*, 1–10.

[8] Pamnani, R., Jayakumar, T., Vasudevan, M., & Sakthivel, T. (2016). Investigations on the impact toughness of HSLA steel arc welded joints. *Journal of Manufacturing Processes*, *21*, 75–86.

[9] Shirmohammadi, D., Movahedi, M., & Pouranvari, M. (2017). Resistance spot welding of martensitic stainless steel: Effect of initial base metal microstructure on weld microstructure and mechanical performance. *Materials Science and Engineering: A*, *703*, 154–161.

[10] Barényi, I., Híreš, O., & Lipták, P. (2011). Degradation of mechanical properties of armoured steels after its welding. Dalam*Proceedings of the International Conference of Scientific Paper AFASES 2011* (hlm. 845–848). Henri Coanda Air Force Academy.

[11] Jeon, J.Y., Kim, Y.J., Kim, J.W., & Lee, S.Y. (2015). Effect of thermal ageing of CF8M on multiaxial ductility and application to fracture toughness prediction. *Fatigue & Fracture of Engineering Materials & Structures*, *38*(12), 1466–1477.

[12] Youn, G.G., Nam, H.S., Kim, Y.J., & Kim, J.W. (2019). Numerical prediction of thermal aging and cyclic loading effects on fracture toughness of cast stainless steels CF8A: Experimental and numerical study. *International Journal of Mechanical Sciences*, *163*, 105120.

[13] Sarsilmaz, F., Kirik, I., & Batı, S. (2017). Microstructure and mechanical properties of armor 500/AISI2205 steel joint by friction welding. *Journal of Manufacturing Processes*, *28*, 131–136.

[14] Ahmed, S.R., Agarwal, L.A., & Daniel, B.S.S. (2015). Effect of different post weld heat treatments on the mechanical properties of Cr-Mo boiler steel welded with SMAW process. *Materials Today: Proceedings*, *2*(4), 1059–1066.

[15] Pandey, C., Mahapatra, M.M., Kumar, P., Saini, N., & Srivastava, A. (2017). Microstructure and mechanical property relationship for different heat treatment and hydrogen level in multi-pass welded P91 steel joint. *Journal of Manufacturing Processes*, *28*, 220–234.