LOGIC
Journal of Engineering Design and Technology
Vol. 24 No.3 November 2024 ; p. 141 - 149

p-ISSN : 1412-114X
e-ISSN : 2580-5649
http://ojs2.pnb.ac.id/index.php/LOGIC

INFLUENCE OF MIG WELDING PROCESS PARAMETERS ON THE STRENGTH OF BIMETAL JOINTS: STUDY OF GAS FLOW RATE AND MACROFRACTURES

1,2,3,4) Mechanical Engineering, Malang State Polytechnic, Malang City, Indonesia

Corresponding email 1) :
talifatim.machfuroh@polinema.ac.id

Talifatim Machfuroh 1*), Kris Witono 2), Septyana Riskitasari 3), Etik Puspitasari 4)

Abstract. Bimetal joints are often used in various industries, such as automotive, power generation, electronics, and manufacturing. This is because bimetal joints allow the joining of two types of metal with different properties. Welding two different types of metal can pose its own challenges, such as the difficulty of controlling welding parameters so that the results are optimal for both types of metal, as well as differences in the thermal and mechanical properties of the two metals. This has led to extensive research on bimetal plate connections. Based on this background, this research aims to determine the effect of variations in flow rate and current strength on the tensile strength of robotic welding bimetal welded joints, as well as determine the results of macro photos of fractures resulting from tensile tests for each variation. The research was carried out experimentally where each variation was repeated with data 3 times. Based on the results and discussion, it is known that the optimal gas flow rate in general is 20 l/min, where the tensile strength reaches 353.1442 MPa–455.5458 MPa. At this flow rate, the dominant fracture occurs in the base metal and is ductile, which indicates good plastic deformation. On the other hand, gas flow that is too low or too high causes joint defects and reduces the tensile strength. Meanwhile, other welding parameters, namely variations in welding current, affect tensile strength. At a gas flow of 10 l/min, increasing the current to 180 A produces the highest tensile strength of 449.4357 MPa with ductile fracture characteristics. However, at a current of 120 A there is a significant decrease due to overheating, especially at higher gas flows such as 20 l/min and 30 l/min, which results in brittle fracture in the heat-affected zone (HAZ). The results of this research contribute to the understanding of the influence of welding parameters on the tensile strength and fracture characteristics of bimetallic joints. In addition, this research can be a reference for the development of more efficient and reliable welding processes in various industries, such as automotive, power generation and manufacturing, which require bimetallic joints with optimal quality.

Keywords : Bimetal, Mig, Joint, Welding

1. INTRODUCTION

The modern manufacturing industry continues to develop rapidly along with increasing demand for high quality products and efficient production processes. Welding is one of the most commonly used methods of joining materials in the manufacturing industry [1]. One important application of this technology is bimetal welding, which involves wcombining two types of metal with different physical properties into one unit [2].

Bimetal welding between steel plates and stainless steel has important uses in various industries because it combines high mechanical strength and corrosion resistance [3][4]. In the construction, energy and military industries, bimetallic welding is applied to bridges, power plants, armored vehicles and warships, where it can provide the combination of heat resistance, strength and corrosion resistance required in harsh and extreme environments [5][6]. Apart from that, bimetal is also used to make pipes and other components that require corrosion resistance on one side and high mechanical strength on the other side, such as in oil and gas piping systems, heat exchangers, pressure vessels, and so on [7].

The bimetal welding process has its own challenges, especially in terms of the strength of the resulting joint. Differences in the thermal and physical properties of the two metals being welded can cause discrepancies in the connection, such as cracking or freezing. To overcome this problem, various welding parameters need to be carefully controlled, including the gas flow rate and the electric current used during the welding process.

Shielding gas in MIG welding functions as a protector against dangerous contamination that can cause defects. In addition to these main functions, shielding gases significantly influence the weld shape, weld geometry, layer appearance, metallurgical and mechanical properties, welding speed, metal displacement, arc stability or light and smoke emissions [8]. Setting the gas flow rate affects the environment around the welding arc and the weld results [8]. Bintarto, et al [9] have analyzed the effect of Tungsten Inert Gas (TIG) protective gas flow rate on tensile strength and toughness (shock) in welded joints between galvanized steel and aluminum 5052, using Al-Si 4043 filler. This welding process involves two metals that have different characteristics. Control of the inert gas flow rate is essential to prevent oxidation and produce strong joints. Cai, et al, [10] analyzed the effect of a mixture of argon (Ar) and helium (He) shielding gases on the welding characteristics of the fiber laser-MIG (Metal Inert Gas) hybrid welding method for aluminum alloys. This research focuses on how variations in the proportions of Ar and He in the shielding gas mixture affect welding results, including joint strength, surface quality, as well as the stability and efficiency of the welding process on aluminum alloys. X. Yang, H., et al, [11] and Campana [12] studied the effect of shielding gas flow rate on the welding process in hybrid laser-arc welding and MIG welding methods.

Several studies have been carried out to determine the factors that influence the quality of MIG welded joints, including research conducted by Sarjiyana [13] and Kurniawan [14] in their research on tensile strength in welding. In this research, it was found that there was an influence of voltage and current strength on the tensile strength of welded joints. In their research, Wenny [15] and Roymons [16] also examined the effect of variations in welding electric current on the strength of MIG welding joints. In this research, it was also found that there was a significant influence. Other research related to the influence of gas flow rate has also been studied by Swami [17]. In his research, it was found that the optimum value of tensile strength of 356 N/mm^2 was observed at a welding current of 190 A, a gas flow rate of 15 l/minute, & a gas combination of 50% CO2+50 % Argon. Of the several studies that have been carried out, not many have conducted research on bimetal plate connections. Most joints are made in the same material. Apart from that, the welding carried out still uses manual welding, so the quality of the welding is also determined by operator factors. Bahar et al., 2018 in their research Sukhbir, 2022 [18] observed the impact of MIG welding input variables on hardness and UTS of dissimilar metals mild steel and stainless-steel welded joints. The contribution of gas flow rate was greater than other parameters. Improved UTS of the weldment was achieved at lower welding voltage and higher weld speed. The maximum UTS value was approximately 235 MPa. Zhu et al., 2018 analyzed the influence of preheating on the microstructural behavior of MIG welded 5083 aluminum alloy joints. A large number of equiaxed grains were noticed in the HAZ [19].

On the other hand, research on the strength of bimetallic steel welded joints was carried out by Kris Witono in his research [20] on variations in travel speed and stickout length on the tensile strength of bimetallic steel. In this research, the connection used was a low carbon steel bimetallic connection with stainless steel. It's just that other factors such as current strength and gas flow rate have not been studied further in this research. In bimetallic joining, setting this parameter becomes more critical due to the differences in the thermal characteristics of the two metals being joined. Errors in parameter setting can cause cracks, distortion, or other defects in the joint that can reduce the strength of the joint. Therefore, this study aims to understand how variations in gas flow rate in the MIG welding process affect the strength of bimetal joints and the form of fracture that occurs, as well as to find optimal parameters that can produce joints with the best strength.

2. METHODS

Research methods and stages include: 1) material preparation. The materials used are low carbon steel plates and 304 series stainless steel plates with a thickness of 3 mm. 2) Welding process. After the material is cut, the joining process is carried out using MIG welding which is operated with varying gas flow rates of 10 l/minute, 20 l/minute, and 30 l/minute. The travel speed was controlled, and currents of 100 A, 120 A, 140 A, 160 A, and 180 A were used. The filler wire used in the welding process is type ER308L with a diameter of 0.8 mm. 3) Tensile testing. Tensile testing is carried out using the ASTM E8M tensile test standard. Each sample was pulled using a tensile testing machine to measure ultimate tensile strength (UTS) and elongation. This test is carried out for each variation of welding speed to obtain data on the effect of travel speed on tensile strength. Each variation was tested three times. 4) Observation of macro photos involves identifying ductile fracture patterns (presence of necking, cup and cone pattern) or brittle fracture. 5) Analysis and discussion. The results of data analysis are prepared in a clear and structured research report.

Figure 1. ASTM E8M standard test specimen

The tensile test results in the form of a stress-strain curve were observed and the test results were compared between sample groups. From this curve, various important parameters such as yield strength, ultimate tensile strength, and fracture strain can be identified. Apart from that, macro and micro photos of the joint results were also observed to understand the fracture characteristics and crack morphology in the joint or material being tested. Data obtained from these observations include the type and pattern of cracks, the location of the initial crack, and the type of failure that occurred (e.g., ductile failure or brittle failure).

3. RESULTS AND DISCUSSION

3.1. Results

a. Effect of varying gas flow rate on welding current 100A

The relationship between variations in gas flow rate and tensile strength at a welding current of 100 A is shown in Figure 2. Based on this graph, the effect of variations in gas flow rate on the tensile strength of bimetal joints can be seen from the trend shown which is linear and tends to increase. The higher the flow rate of the shielding gas, the greater the maximum tensile stress produced in the bimetallic joint.

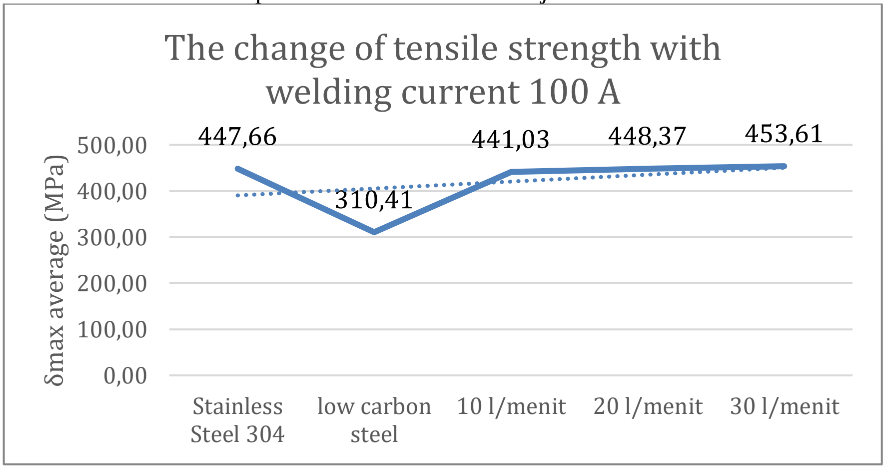

Figure 2. Graph of changes in tensile strength at a current of 100 A

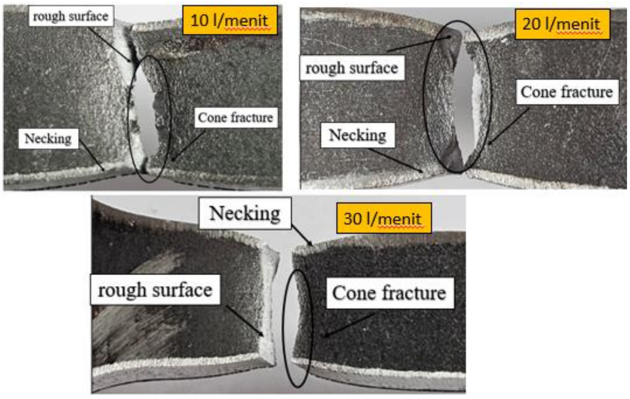

Figure 3. Macrofracture of tensile strength at a current of 100 A

At a gas flow rate of 10 l/minute, the tensile strength is quite high, namely 441.0269 MPa. Then it increased to a variation of 20 l/minute, namely 448.3745 MPa. When the gas flow rate was increased again to 30 l/min, there was still an increase in the tensile strength to 453.6147 MPa. The increase that occurred was not very significant from each variation. At a gas flow rate variation of 10 l/min, the welded joint was well protected, but increasing the gas flow rate to 20 and 30 l/min showed that a larger shielding gas had a better effect on the joint quality. This is because the higher the gas flow rate, the greater the gas's ability to remove oxygen, nitrogen and other elements that can reduce the quality of the welded joint. Better protection results in stronger connections and higher maximum tensile stress. Based on the macro photo of the tensile test results in Figure 3, for all variations in gas flow rate from 10 l/min to 30 l/min, the fracture occurred in the basemetal area and the fracture was ductile. This happens because it is characterized by necking, which is an indication of plastic deformation before fracture.

b. Effect of varying gas flow rate on welding current 120A

Based on the graph in Figure 4, the tensile strength of the bimetallic connection of low carbon steel plate and stainless steel 304 at a current of 120 A has a different trend. At a gas flow rate of 10 l/min, the tensile strength is relatively low, namely 297.9797 MPa. Then there was a significant increase in the variation of 20 l/minute, namely 431.8566 MPa. This value is the highest tensile strength of the other variations. However, when the gas flow rate was increased again to 30 l/min, the tensile strength decreased to 318.4333 MPa. Based on the macro photo of the tensile test fracture results in Figure 5, it shows that at gas flow rates of 10 and 30 L/minute, the fracture is brittle and occurs in the HAZ area. When compared with the decrease in tensile strength that occurs in this variation, this is possible because there is an inappropriate gas flow at the 120A current, resulting in rapid cooling and creating a more brittle structure. A gas flow rate of 20 L/min is the optimal condition for this flow. The highest tensile strength occurs at a gas flow rate of 20 l/minute, where the fracture results from the tensile test occur in the basemetal area and the fracture nature is ductile.

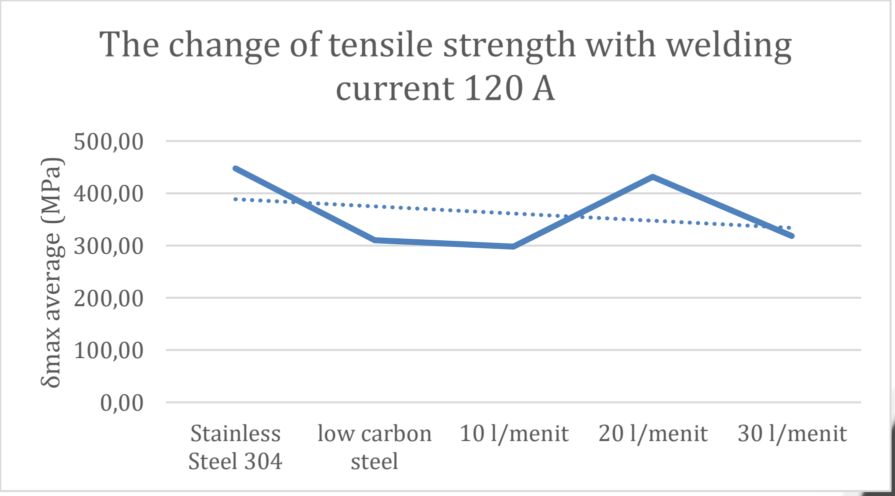

Figure 4. Graph of changes in tensile strength at a current of 120 A

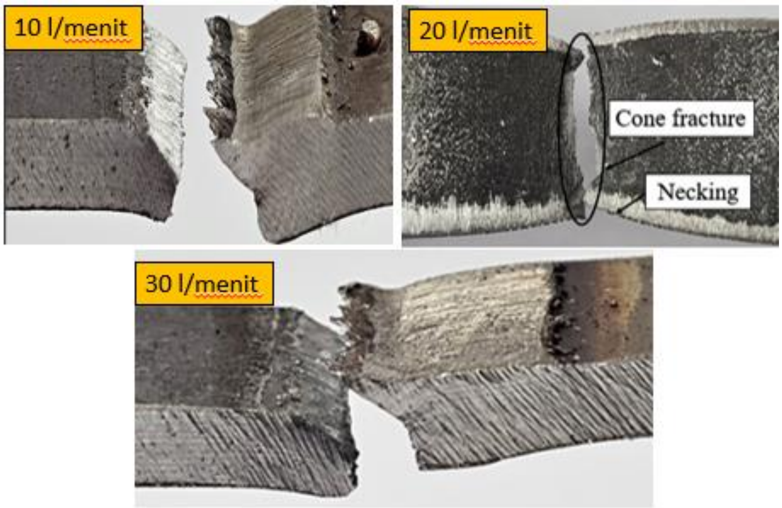

Figure 5. Macrofracture of tensile strength at a current of 120 A

c. Effect of varying gas flow rate on welding current 140A

Based on the graph in Figure 6, which is a graph of changes in tensile strength at a welding current of 140 A. In the picture, it can be seen that there is a trend of increasing maximum tensile stress along with increasing gas flow rate. This graph pattern is similar to the 100A current graph pattern, where increasing the gas flow rate increases the maximum tensile stress. At a gas flow rate of 10 l/minute, the tensile strength is quite high, namely 441.0058 MPa. Then it increased to a variation of 20 l/minute, namely 455.3382 MPa. When the gas flow rate was increased again to 30 l/min, there was still an increase in the tensile strength to 466.3382 MPa. Increasing the gas flow rate from 10 L/min to 30 L/min resulted in an increase in the maximum tensile stress of approximately 25.33 MPa.

In this current, the fracture form from the tensile test results is shown in Figure 7. Fractures at varying gas flow rates of 10 l/minute and 30 l/minute occurred in the basemetal with ductile fracture character. At a gas flow rate of 20 l/min, fracture occurred in the basemetal which was close to the HAZ, but the fracture character was still ductile, because there was a reduction in the dimensions of the fracture. Even though the gas flow rate was increased by welding at a current of 140 A, the welding results are more stable and produce a strong joint.

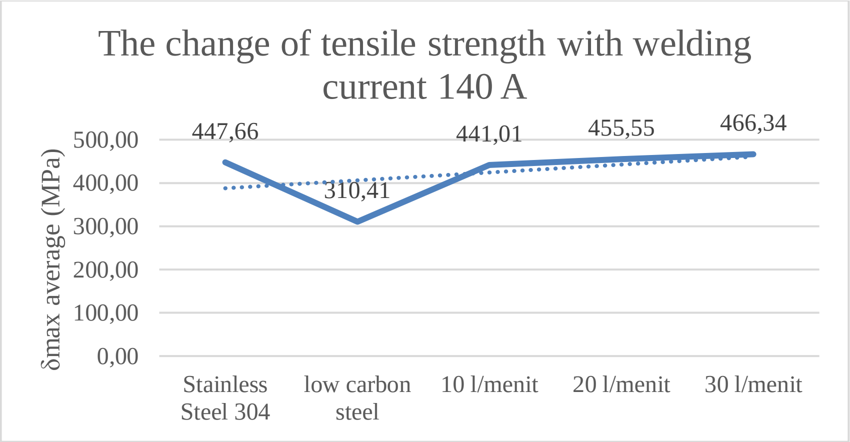

Figure 6. Graph of changes in tensile strength at a current of 140 A

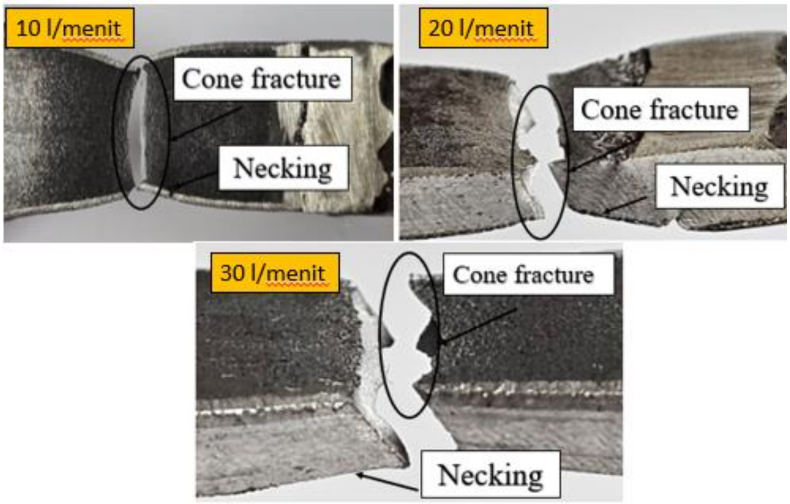

Figure 7. Macrofracture of tensile strength at a current of 140 A

d. Effect of varying gas flow rate on welding current 160A

Based on data on variations in gas flow rate towards the maximum tensile stress of the bimetal joint in Figure 8, the graphic trend shown tends to form a non-linear trend where at a gas flow rate of 10 L/minute, the maximum tensile stress is at a high point, namely 448.4457 MPa. When the gas flow rate was increased to 20 L/minute, the tensile stress actually decreased to 420.5255 MPa. Then, when the gas flow rate was increased to 30 l/min, the tensile stress increased again with a result of 448.4173 MPa, this tensile stress was almost the same as the variation of 10 l/min. Under these conditions, the optimal gas flow rate is around 10 L/min and 30 L/min, while 20 L/min may not provide ideal conditions for the formation of a strong joint. Based on the fracture shape of the tensile test results shown in Figure 9, at a flow of 160 L/min it was found that there was a significant difference between gas flow rates of 10 l/minute and 30 l/minute, both of which produced fractures in the HAZ with a brittle character. However, at a gas flow rate of 20 l/min, fracture occurred in the base metal with ductile character. This indicates that at higher flows, control of the gas flow rate becomes more critical, as too high or too low a rate can result in brittle fracture and lower tensile strength.

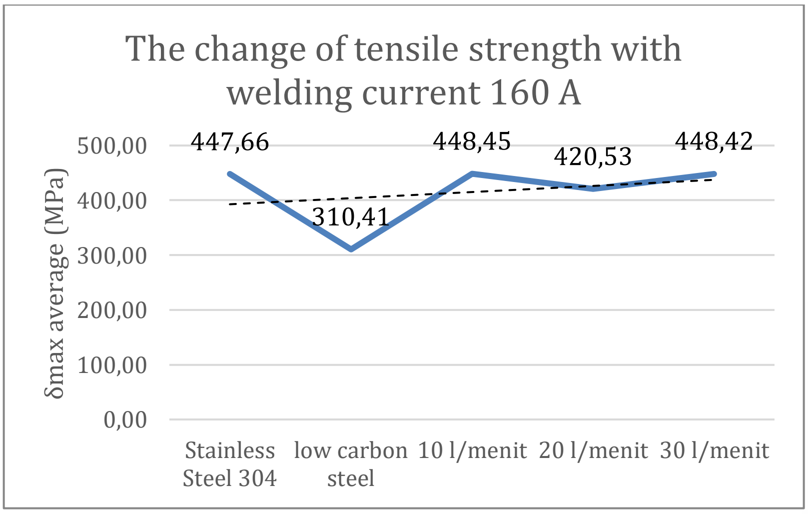

Figure 8. Graph of changes in tensile strength at a current of 160 A

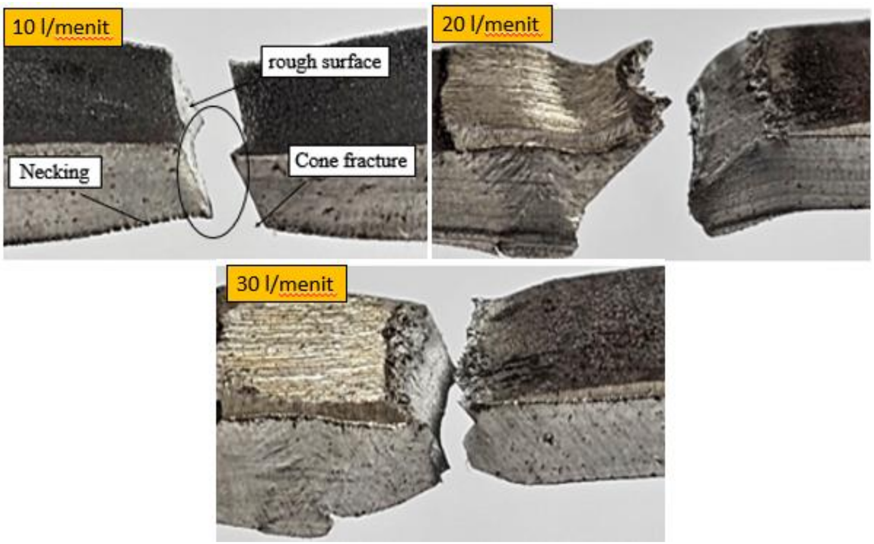

Figure 9. Macrofracture of tensile strength at a current of 160 A

e. Effect of varying gas flow rate on welding current 180A

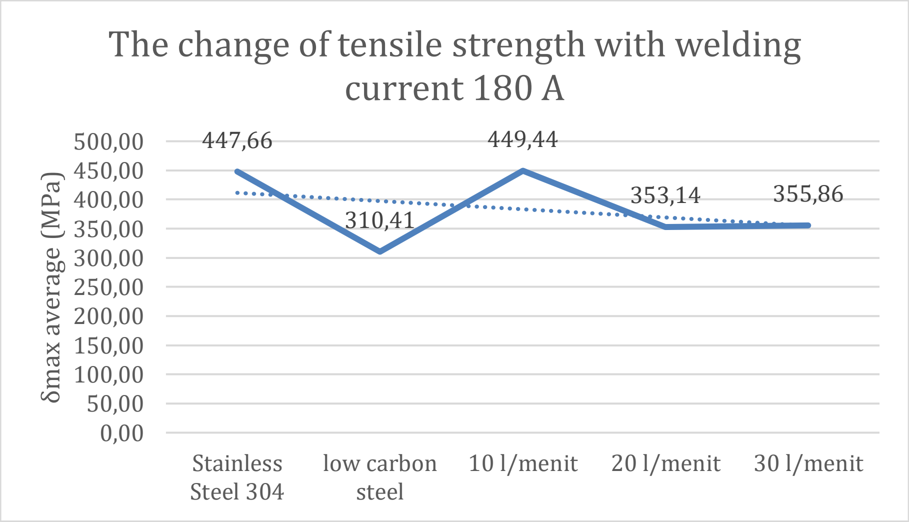

Figure 10. Graph of changes in tensile strength at a current of 180 A

Based on data on variations in gas flow rate towards the maximum tensile stress of the bimetal joint in Figure 10, the graphic trend shown tends to decrease. At a rate of 10 l/min, the maximum tensile stress is 449.4356 MPa with fracture occurring in the basemetal and its ductile nature, and there is necking. At a rate of 20 l/min, the tensile stress dropped drastically to 353.1441 MPa, with ductile fracture occurring in the base metal. The fracture form is shown in Figure 11. At a rate of 30 l/min, the tensile stress slightly increases to 355.8598 MPa with ductile fracture and remains in the base metal. This shows that at very high currents, despite ductile deformation, the maximum tensile strength decreases. This decrease in tensile strength is likely due to overheating which can cause degradation of the mechanical properties of the material.

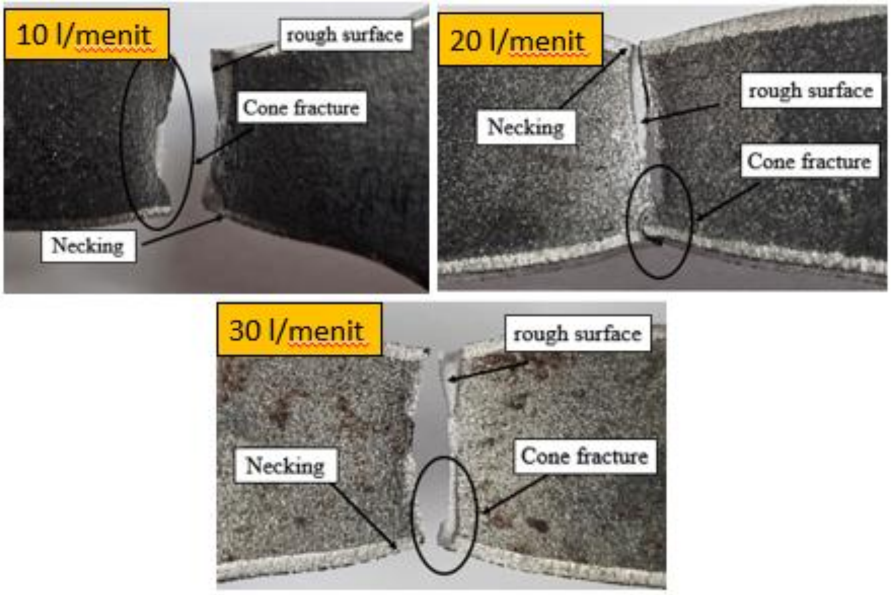

Figure 11. Macrofracture of tensile strength at a current of 180 A

3.2. Discussion

Based on the all graphs of the effect of gas flow rate on the tensile strength of the weld, and and the fracture shape, it can be concluded that variations in gas flow rate parameters in the welding process have a significant influence on the tensile strength and shape of the fracture in the weld. The gas flow rate functions to protect the molten metal from oxidation and contamination from external air (such as oxygen and nitrogen). In this research, varying gas flow rates influence the results of the tensile strength of the welded joint and its fracture characteristics, both in terms of the location of the fracture and the type of fracture that occurs.

If the gas flow rate is too low, the shielding gas may not be sufficient to protect the weld area from air contamination. This can cause oxidation or other contamination that results in weld defects, such as porosity and slag inclusion [9] [19]. As a result, the tensile strength of the weld will decrease due to the presence of weak points in the weld joint structure. For example, at a gas flow rate of 10 l/min with a current of 120A and 160A, a fracture occurred in the HAZ with brittle fracture characteristics, indicating that the low gas flow rate was not sufficient to protect the weld from atmospheric influences.

If the gas flow rate is at an optimal level, namely at a current of 100A and a gas flow rate of 20 l/minute, the protective gas will be effective in protecting the welding area from contamination. This allows the formation of a cleaner weld joint, free from weld defects, thereby increasing the tensile strength of the weld. Apart from that, the gas flow rate is too high, namely at a current of 180A with a gas flow rate of 30 l/minute, the tensile strength decreases to 355.8598 MPa. High gas flow rates can cause turbulence effects in the welding area, which actually causes atmospheric air to be drawn into the welding area. In addition, too heavy a gas flow can disrupt the stability of the welding arc, resulting in poor weld quality.

Effect of gas flow in the welding process According to Swami (2018), the flow of protective gas such as argon or CO_2 functions to protect the welding area from air contamination, which can reduce the quality of the joint [17]. In this study, the effect of gas flow rate is clearly visible, especially at currents of 100A to 140A, where increasing the gas flow rate causes a significant increase in the maximum tensile strength. For example, at a current of 140A, the tensile strength increases from 441.0058 MPa (10 L/min) to 466.3382 MPa (30 L/min). This indicates that sufficient shielding gas helps prevent porosity and other defects

4. CONCLUSION

Overall, variations in the optimal gas flow rate produce different maximum tensile strengths, depending on the welding current. Optimal conditions are generally found at a moderate gas flow rate of 20 l/minute. At this gas flow rate the tensile strength is 353.1442 MPa– 455.5458 MPa. The fractures that occur are almost all in the base metal and are ductile in nature, even though at a current of 160 A the fractures occur in the HAZ area, but the tensile strength is still high. A gas flow rate that is too low or too high can cause defects in the joint and reduce the tensile strength of the weld.

5. REFERENCES

[1] M. Choirul U. Nuha and Samsudi, “Pengaruh variasi kuat arus dan tekanan gas pelindung terhadap kekuatan tarik hasil pengelasan MIG (metal inert gas) pembuatan front chasis mobil listrik dengan bahan ST 60,” *J. Mech. Eng. Learn.*, vol. 11, no. 2, pp. 1–11, 2022.

[2] T. Abe and H. Sasahara, “Dissimilar metal deposition with a stainless steel and nickel-based alloy using wire and arc-based additive manufacturing,” *Precis. Eng.*, vol. 45, pp. 387–395, 2016, doi: https://doi.org/10.1016/j.precisioneng.2016.03.016.

[3] R. Mittal and B. S. Sidhu, “Metallurgical aspects of dissimilar metal weldments : A Review,” *Int. Conf. Adv. Futur. Trends Mech. Mater. Eng.*, no. June, pp. 1–8, 2015.

[4] J. P. Oliveira *et al.*, “Dissimilar laser welding of a CoCrFeMnNi high entropy alloy to 316 stainless steel,” *Scr. Mater.*, vol. 206, p. 114219, 2022, doi: https://doi.org/10.1016/j.scriptamat.2021.114219.

[5] A. B T, J. Devasia, T. Krishna, and M. T. Kuruvila, “Manufacturing of a bimetallic structure of stainless steel and mild steel through wire arc additive manufacturing – A Critical Review,” *Int. J. Innov. Sci. Res. Technol.*, vol. 5, no. 6, pp. 679–685, 2020, doi: 10.38124/ijisrt20jun583.

[6] T. Lei, Y. Rong, H. Wang, Y. Huang, and M. Li, “A review of vision-aided robotic welding,” *Comput. Ind.*, vol. 123, p. 103326, 2020, doi: https://doi.org/10.1016/j.compind.2020.103326.

[7] B. B. Sherpa and R. Rani, “Explosive welding process to clad materials with dissimilar metallurgical properties,” S. Kumar, Ed. Rijeka: IntechOpen, 2021, p. Ch. 2. doi: 10.5772/intechopen.94448.

[8] B. Mvola and P. Kah, “Effects of shielding gas control: welded joint properties in GMAW process optimization,” *Int. J. Adv. Manuf. Technol.*, vol. 88, no. 9, pp. 2369–2387, 2017, doi: 10.1007/s00170-016-8936-2.

[9] R. Bintarto, M. S. Ma’arif, D. Widhiyanuriyawan, T. D. Widodo, R. Raharjo, and N. A. Purnomo, “Pengaruh laju alir tungsten in-ert gas terhadap kekuatan tarik dan kejut pada sambungan las tig baja galvanis dan aluminium 5052 dengan filler Al-Si 4043,” *J. Rekayasa Mesin*, vol. 14, no. 1, pp. 1–12, 2023, doi: 10.21776/jrm.v14i1.656.

[10] C. Cai, S. He, H. Chen, and W. Zhang, “The influences of Ar-He shielding gas mixture on welding characteristics of fiber laser-MIG hybrid welding of aluminum alloy,” *Opt. Laser Technol.*, vol. 113, pp. 37–45, 2019, doi: https://doi.org/10.1016/j.optlastec.2018.12.011.

[11] X. Yang, H. Chen, Z. Zhu, C. Cai, and C. Zhang, “Effect of shielding gas flow on welding process of laser-arc hybrid welding and MIG welding,” *J. Manuf. Process.*, vol. 38, pp. 530–542, 2019, doi: https://doi.org/10.1016/j.jmapro.2019.01.045.

[12] G. Campana, A. Ascari, A. Fortunato, and G. Tani, “Hybrid laser-MIG welding of aluminum alloys: The influence of shielding gases,” *Appl. Surf. Sci.*, vol. 255, no. 10, pp. 5588–5590, 2009, doi: https://doi.org/10.1016/j.apsusc.2008.07.169.

[13] Sarjiyana, Subagiyo, and L. Agustriyana, “Kekuatan tarik pada pengelasan bimetal plat baja karbon rendah dan stainless steel 304 dengan las GMAW,” *Jurnal Energi dan Teknologi Manufaktur (JETM)*, vol. 4, no. 2, pp. 7–12, 2021.

[14] A. L. Kurniawan and E. Pranatal, “Analisis kekuatan sambungan las pada plat untuk dek kapal berbahan plat baja A36 terhadap sifat fisis dan mekanis dengan metode pengelasan MIG,” *J. Sumberd. Bumi Berkelanjutan*, vol. 1, no. 1, pp. 327–331, 2022, doi: 10.31284/j.semitan.2022.3284.

[15] W. Marthiana, Y. Mahyoedin, D. Duskiardi, and A. Rahim, “Analisa pengaruh variasi arus listrik pengelasan terhadap kekuatan sambungan pengelasan MIG pada material ST 37,” *J. Kaji. Tek. Mesin*, vol. 5, no. 2, pp. 140–144, 2020, doi: 10.52447/jktm.v5i2.4217.

[16] R. J. Dimu and O. D. Rerung, “Kekerasan material baja karbon rendah pada daerah lasan TIG dan MIG,” *J. Tek. mesin*, vol. 2, no. 1, pp. 12–19, 2019.

[17] S. A. Swami, S. Jadhav, and A. Deshpande, “Influence of MIG Welding process parameters on tensile properties of mild steel.,” *Eur. J. Eng. Technol. Res.*, vol. 1, no. 2, pp. 1–5, 2018, doi: 10.24018/ejeng.2016.1.2.133.

[18] S. Singh, V. Kumar, S. Kumar, and A. Kumar, “Variant of MIG welding of similar and dissimilar metals: A review,” *Mater. Today Proc.*, vol. 56, pp. 3550–3555, 2022, doi: https://doi.org/10.1016/j.matpr.2021.11.287.

[19] C. Zhu, X. Tang, Y. He, F. Lu, and H. Cui, “Effect of preheating on the defects and microstructure in NG-GMA welding of 5083 Al-alloy,” *J. Mater. Process. Technol.*, vol. 251, pp. 214–224, 2018, doi: https://doi.org/10.1016/j.jmatprotec.2017.08.037.

[20] K. Witono, T. Machfuroh, S. Sarjiyana, and E. Faizal, “Pengaruh variasi travel speed terhadap kekuatan tarik pada pengelasan disimilar metal dengan MIG robotic welding,” *Otopro*, vol. 19, no. 1, pp. 34–39, 2023, doi: 10.26740/otopro.v19n1.p34-39.