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The Effect of Welding Speed on The Welding Quality AISI 1020 and AISI 1050 Steel Using Shielded Metal Arc Welding Technology

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Abstract
Material joining techniques are divided into two categories: similar joints and dissimilar joints. The difference in thermal cycles experienced by each material is the reason why dissimilar welding is more challenging than similar welding. The welding process that joins two materials with different properties is commonly used to improve effectiveness and efficiency in production, as well as to improve product quality. This trend has become popular in the manufacturing industry, including in the manufacture of tailor welded blanks, transportation vehicle frames such as aircraft, trains, and cars, as well as in the manufacture of public and private vehicle accessories such as aircraft panels and exhausts. The materials currently widely used in exploration are stainless steel combined with carbon steel, as well as a mixture of stainless steel and low carbon steel, which is quite challenging to weld but offers the advantages of higher strength, corrosion resistance, and lighter weight. This challenge can be overcome through liquid welding methods, one of which is the "SMAW (Shielded Metal Arc Welding)" technique. This study used variations in welding time at 5, 10, and 10 m/minute. Quality testing was carried out using visual tests, tensile tests, and impact tests, using AISI 1020 steel and AISI 1050 steel. Based on the test results, there was a significant difference in that the welds appeared to be shinier. The tensile strength results were in the form of average strain values for each specimen, which were 0.0705 mm, 0.0487 mm, and 0.1074 mm. The impact test results, which compared toughness values using a predetermined welding time variation of 16.5 joules, showed an average toughness value of 0.1948 J/mm².

Keywords: SMAW Welding; AISI 1020 steel; AISI 1050 steel; Red dye penetrant test; Tensile and impact test.

1. Introduction

There are several materials that can be welded, namely metal products such as low carbon steel and medium carbon steel. Currently, the metal welding technique that has been developed is the technique of joining two dissimilar metals. Dissimilar metal joints are joints between two metals with different properties that are welded together [1].

Welded joints are currently widely used in construction (factories) due to their advantages in terms of load-bearing strength and ease of implementation, which affect economic value,

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making welding the primary choice for construction [2].

In a study [3], welding results can be influenced by the current settings used during welding. If the current used during welding is too low, it will cause difficulty in striking the electric arc (electrode), resulting in an unstable electric arc. The heat used is insufficient to melt the electrode with the base material, resulting in small and uneven weld beads and shallow weld penetration. Conversely, if the current used is too high, the electrode will melt too quickly and produce a wider weld surface and deeper penetration, resulting in low tensile strength and increased brittleness of the weld.

In the study [4], dissimilar metal welding is currently the most widely conducted research by international researchers in finding the appropriate welding parameter data for both types of materials that are welded with very different mechanical properties, making this a major challenge in the welding process in industry. Based on the research results, it can be concluded that repairs to the welding results greatly affect the tensile strength of the welded joint. Tensile testing results show that the tensile strength of repaired weld metal decreases compared to welding results without repairs.

In research [5], joining two or more different types of materials aims to reduce the weight of a vehicle so that fuel consumption can be optimized. In addition, joining different types of metals is also useful for reducing production costs because the prices of metals vary. Lack of experience with new materials or combinations thereof often results in the use of suboptimal welding parameters. The use of suboptimal parameters for the material to be welded results in inefficient use of time and energy. In welding, time is very important for optimizing work productivity. Short welding times that produce maximum productivity are important due to high output demands.

In a study [6], dissimilar welding on low carbon steel is the right choice due to its good material quality and ease of forming on certain joints. One application is on ships that still require welding to connect their parts.

In the study [7], welded joints that utilize heat energy will usually affect changes such as strength results in plates that will be smaller due to several factors such as residual stress or crack defects during the welding process, which means reducing the strength efficiency of the initial base metal, for example at a current of 100 A with SMAW welding without heat treatment as in the study.

The problems encountered in joining two different materials are differences in melting point, expansion coefficient, and the physical and mechanical properties of the metals. Dilution of the filler metal and the formation of intermetallic compounds at the interface cause fractures. Due to these differences, welding two different metals requires a proper welding procedure in order to achieve maximum weld quality. The strength of the weld is influenced by the welding arc voltage, welding current, welding speed, penetration depth, and the polarity of the electricity used. Determining the amount of current in material joining using an arc affects the efficiency of the work and the welding material. The determination of the current in this welding takes 3 variations of welding speed, namely: 5 meters/minute, 10 meters/minute, and 15 meters/minute. The above time intervals are intended for collecting test result data. The variation in welding speed is intended to determine the results of tensile testing, impact testing, and liquid penetrant testing.

2. Materials and Methods

The materials used in this study were AISI 1020 steel and AISI 1050 steel in the form of plates obtained from a steel factory retailer. The main equipment used was an SMAW welding machine for joining two different types of metal. A Charpy impact testing machine was used for impact testing, and an MTS Landmark machine was used for tensile testing. The testing process was carried out by first cutting the plate-shaped metal steel to the standard size specified for impact testing with the E-23 standard, namely a specimen diameter of 55 mm with a thickness of 10 mm. then cutting the specimen material for tensile testing using the specified standard, namely the E-8 specimen size with a specimen size of 190 mm and a thickness of 6 mm. Welding was carried out by selecting the welding speed time, namely 5 (m/minute), 10 (m/minute), and 15 (m/minute). The welding current was set at 90 amperes for a welding speed of 5 m/min, 80 amperes for a welding speed of 10 m/min, and 70 amperes for a welding speed of 15 m/min. The SMAW welding machine used is shown in Figure 1.

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Figure 1. SMAW Welding Machine

The specifications of the SMAW welding machine are shown in Table 1.

Table 1. SMAW Welding Machine Specifications

SMAW Welding Machine Specifications	
Model	ARC 4001
Serial Number	EN60974-1
Year	2012
Voltage	380 V
Capacity	30-400A
Voltage	62 V

The tensile testing machine used in this study is shown in Figure 2.

Figure 2. MTS Landmark Tensile Testing Machine

The specifications of the MTS Landmark tensile testing machine are shown in Table 2.

Table 2. Specifications of the MTS Landmark U PD 10 (2015) Tensile Testing Machine

Specifications	**Details**
Brand	MTS Landmark
Capacity	100 KN
Type	U PD 10
Year	2015
Load Scale A	0 to 20 kN
Load Scale A + B	0 to 50 kN
Load Scale A + B + C	0 to 100 kN

Testing using liquid red dye penetrant testing which is suitable for testing cracks and porosity. Added with liquids such as zincate and coolant, discontinuities must be thoroughly cleaned and the surface must be open. The results of the observation are weld defects obtained from observation using red dye penetrant liquid first, by spraying it so that weld defects that arise after standing for 10-20 minutes on the welded material can be seen. Penetrant testing usually has 4 stages, i.e.: initial cleaning, application of the penetrant, penetrant removal, and application of developer

The following figure 3 is the example results of welding test using liquid red dye penetrant.

Figure 3. Results of red dye penetrant testing

3. Results and Discussion

3.1 Impact Testing

The following are visual observation results in the form of weld defects obtained from direct observation without using red dye penetrant first. The following are the observation results using red dye penetrant, as shown in Figure 4.

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Figure 4. Data from observations using red dye penetrant on tensile test specimens

Meanwhile, the observation results using red dye penetrant on the impact test specimen are shown in Figure 5.

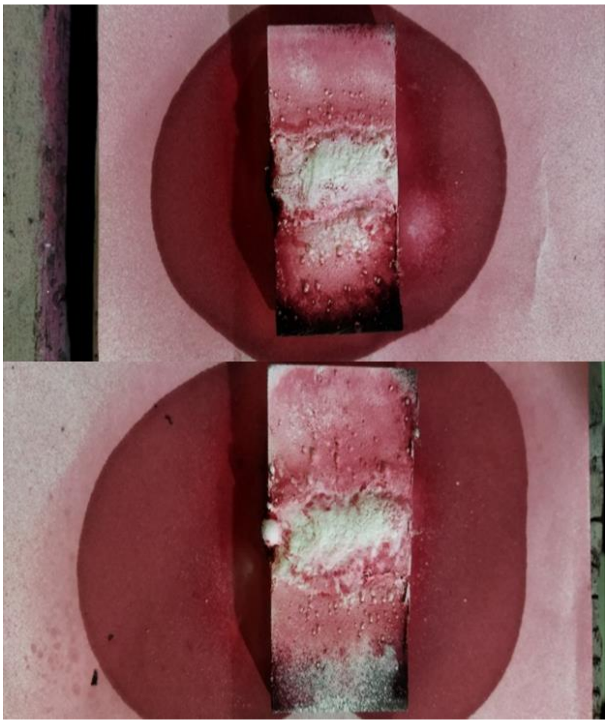

Figure 5. Data from observations using red dye penetrant on impact test specimens.

Figure 4 shows spatter and undercut weld defects. Spatter weld defects are weld spatters that occur during the welding process. The next figure shows undercut weld defects. Undercut defects are caused by very fast welding travel speeds, which prevent the filler metal from completely filling the weld groove. The impact test results based on each welding speed variation used are shown in Figure 6.

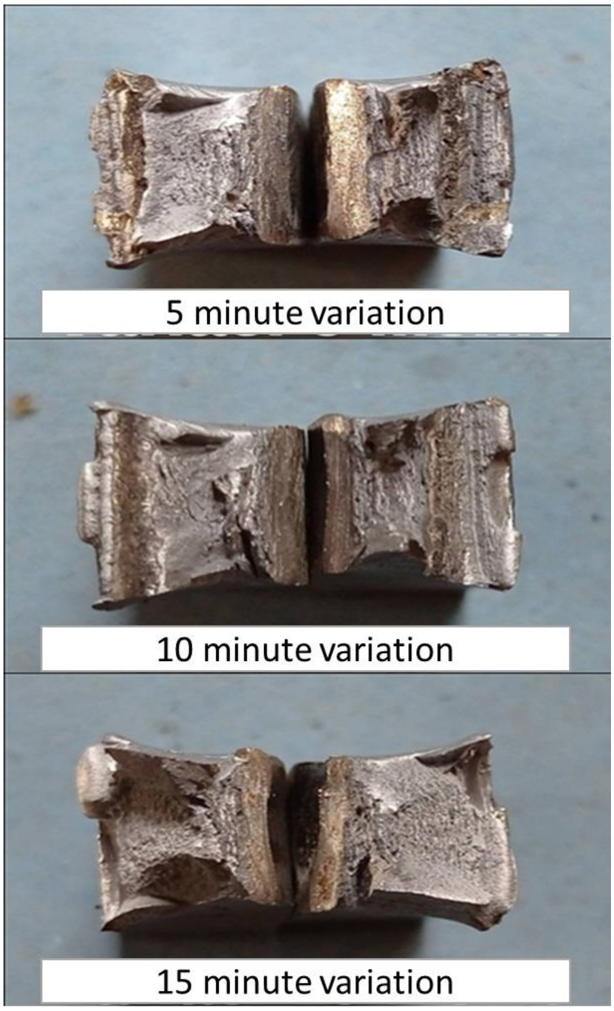

Figure 6. Impact test results for each welding speed variation

The impact test results data is in Table 3 below.

Table 3. Impact Test Data

Welding Duration Variation	Specimen	Area A (mm²)	Energy E (Joule)	Average Energy (Joule)	Impact Value (Joules/mm²)
5 m/min	1	85	17		
10 m/min	1	85	16	16.5	0.1948
15 /min	1	85	16.7		

The data above in Table 3 is the impact energy value data using varying welding speeds. It can be seen that the impact energy value for a welding speed variation of 5 m/minute is 17 joules higher than that for welding speed variations of 10

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m/minute and 15 m/minute, which are 16 joules and 16.7 joules, respectively. The average impact energy and impact price diagrams are shown in Figures 7 and 8.

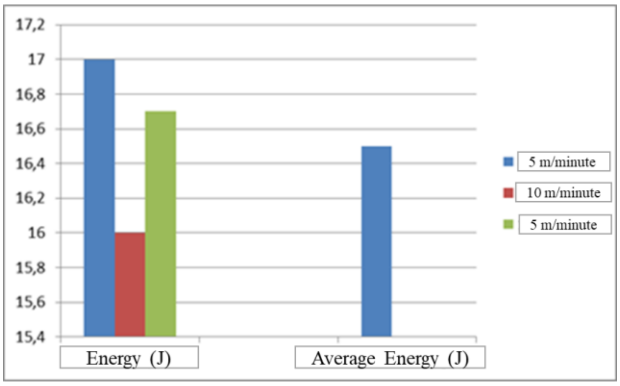

Figure 7. Average impact energy diagram

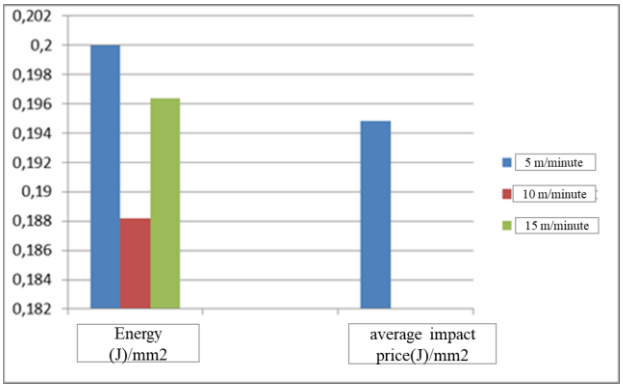

Figure 8. Average impact price diagram

The diagram above shows that the impact value of welding is not uniform in AISI 1020 steel and AISI 1050 steel. It can be seen that the highest impact value is in the 5 m/minute welding speed variation with an impact value of 0.2 Joules/mm2. Meanwhile, the lowest impact value is found in the 10 m/minute welding speed variation, which is 0.1882 Joules/mm2.

The diagram above shows the average energy diagram of 16.5 joules (J) and the average impact value (J) mm2 of 0.1948. After obtaining the average impact value in the impact test, a slight difference in values can be seen. Testing using a variation of 5 m/minute with an impact value of 0.2 Joules/mm2 yielded higher results compared to using a variation of 15 m/minute, which yielded an impact value of 0.1964 Joules/mm2. This was due to the influence during the welding process, where the welded specimen was not completely filled [8]. This is what causes the impact test value at a variation of 5 meters/minute to appear larger. From the impact test results and the slight difference in values obtained between the welding times of 5 m/minute and 15 m/minute, it can be concluded that the best impact test is at a variation of 10 m/minute, as the current strength tends to be stable [9].

From the impact test results, a slight difference in values can be seen. This is due to the dimensions of the specimens used in the welding process and the welding metal not being completely filled in the welded specimens. This results in higher impact test values for specimens with a welding speed variation of 5 m/minute [10]. The impact test results on the specimens showed unsatisfactory fractures, as they were classified as brittle fractures. This type of fracture is characterized by cracks that occur very quickly, unlike ductile fractures. Based on previous research by Ikhsan [11], brittle fractures are considered more dangerous than ductile fractures. This is due to the brittle fracture nature that occurs without prior plastic deformation and takes place in a very short time. Brittle fracture is defined as a type of fracture in materials that begins with rapid cracking, without prior plastic deformation, and occurs in a short time. This contrasts with ductile fracture, which, according to [12], is characterized by energy absorption and plastic deformation. As a result, the surface of a ductile fracture has distinctive characteristics, namely a rough, fibrous texture and a grayish color. The fractures that occurred in the impact test specimens were located in the welded area.

3.2 Tensile Testing

In this study, tensile testing was carried out using an MTS Landmark Universal Testing Machine, in accordance with the ASTM E-8 standard [13]. The testing steps with initial measurements were carried out using digital calipers to ensure the accuracy of the results.

The test specimens were then mounted on a tensile testing machine that had been calibrated to zero. The testing process began at zero load and was gradually increased until the specimens reached their maximum breaking point. After the specimens broke, the cross-sectional area and elongation length resulting from the tensile test were remeasured. The materials used in this test were AISI 1020 and AISI 1050 steel, which have specific mechanical characteristics [14]. The tensile test results are shown in Table 4.

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Table 4. Impact Test Data

Ultimate strength	Strain
490.6 MPa	1. 0.0663 mm
496.8 MPa	2. 0.0747 mm
500.7 MPa	2. 0.0649 mm
488.6 MPa	1. 0.1084 mm
462.1 MPa	2. 0.1064 mm

As can be seen from the table above, the tensile test results show that the maximum result welded at a speed of 15 m/minute is the highest. The tensile results between specimens show significant differences, due to the heat or welding amperage not being stable. The analysis indicates that optimizing welding parameters, such as speed and amperage, is crucial for achieving consistent tensile strength in welded joints [15]. Therefore, the results of metal welding do not meet the specifications. After all the data was collected, the results of the specimens with the selected welding speed variations after the tensile test are as follows. The first test on specimens welded at a speed of 5 m/min broke at the base metal, and broke at the fracture point in the low-carbon steel section.

Then, for this tensile test, it was used and broke at the breaking point on the low-carbon steel type, with the material undergoing plastic deformation until it broke with an elongation value of 7.5% on specimen 1 and an elongation value of 8.3% on specimen 2 at a test speed of 0.250 kN/s. The tensile strength test results, namely the strain value, produced 0.0663 mm in specimen 1 and 0.0747 mm in specimen 2 using a welding variation of 5 m/minute. The findings emphasize the need for precise control of welding parameters to enhance joint integrity and mechanical performance in low-carbon steel app [16].

The second test on specimens welded at a speed of 10 m/min broke at the heat affected zone (HAZ) and broke at the fracture point in the low carbon steel section. The material underwent plastic deformation until it broke, with an elongation value of 7.8% in specimen 1. Then, for this tensile test, a test speed of 0.250 kN/s was used. The tensile strength test results, namely the strain value, showed that the material elongated after testing, producing a value of 0.0649 mm using a welding variation of 10 m/minute.

The third test on specimens welded at a speed of 15 m/minute broke at the heat affected zone (HAZ) and broke at the maximum strain point in the low carbon steel section. The material underwent plastic deformation until it broke, with an elongation value of 9.7% in specimen 5 and an elongation value of 8.7% in specimen 6. This tensile test used a test speed of 0.250 kN/s. The tensile strength test results showed that the strain (elongation) experienced by the material after testing was 0.1084 mm in specimen 5 and 0.1064 mm in specimen 6 using a welding variation of 15 m/minute. The welding variation results and tensile test graphs are shown in Figures 9 and 10.

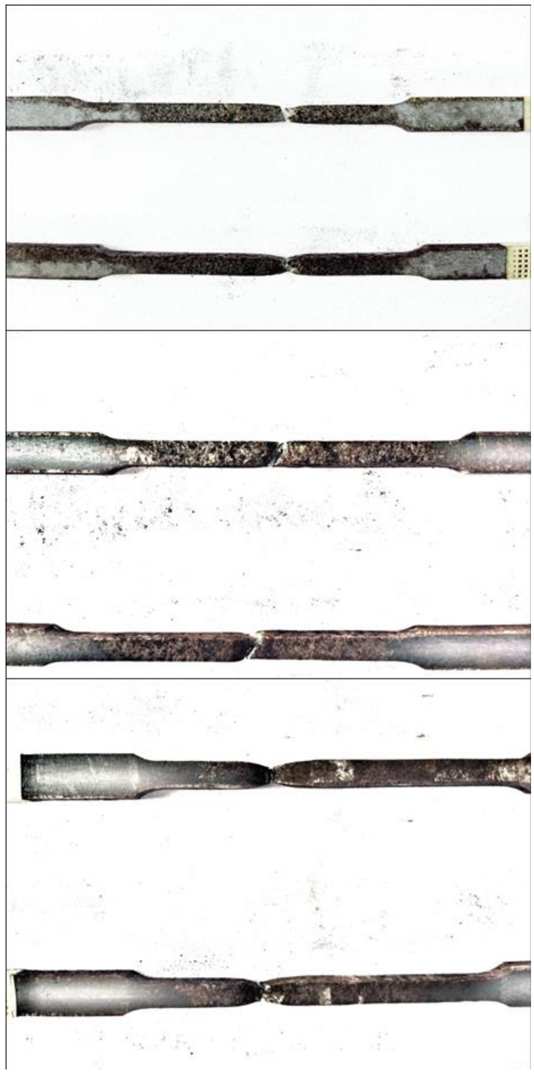

Figure 9. Variations in welding speeds of 5, 10, and 15 m/min on AISI 1020 and AISI 1050 steel after tensile testing

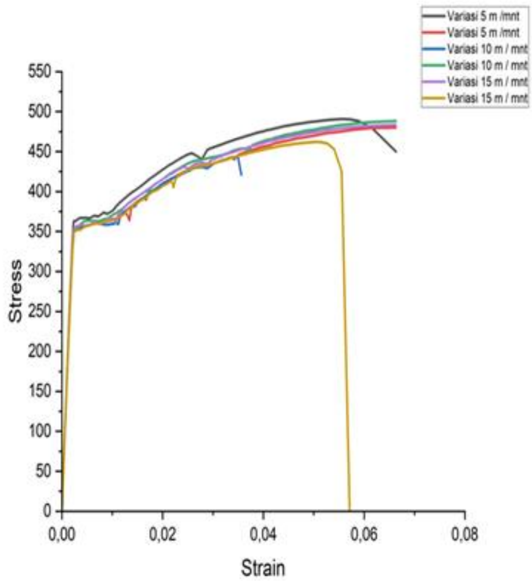

Figure 10. Combined Tensile Test Graph

Based on the above explanation, the average strain values obtained from the tensile strength testing of specimens using a welding speed of 5 m/min had an average of 0.07 mm, while those using a welding speed of 10 m/min had an average of 0.05 mm. Meanwhile, the welding variation at 15 m/min had an average value of 0.11 mm.

The tensile test results in the form of the average strain value obtained on the tested specimens came from two data collections for each welding speed variation, which were then divided by two to obtain the average result (strain).

Why is the strain value low at a variation of 5 m/minute, this is because the welding speed is very fast and high amperage is used, so that after the material is tested, the material elongation tends to be low due to several factors.

Meanwhile, for the 10 m/min variation, the strain values show that the filler metal is stable in the welds that have been made. The welding process for this variation is very thin compared to the 5 m/min variation, indicating that the material diffuses well during the welding process. The selected amperage is also stable at 80 amperes.

Why is the strain value high at a variation of 15 m/minute? This is because the welding speed is quite slow and uses a low amperage of 70 amperes. This can be explained by the fact that a slower welding speed has a significant effect on the quality of the weld, because the longer the welding time, the better the quality of the weld. The toughness and strength of the material and how strong the weld is on the material welded using two different types of metal. Here we can see that the strain data tends to be very high, experiencing material elongation, because several factors can influence this. The main focus is the toughness and strength of the welded material to analyze the quality of the weld with the selected variations.

Based on previous research by [17], the instability of the tensile values produced by each specimen tested was assumed to exist in the initial dimensions of the AISI 1020 and AISI 1050 steel specimens. Whereas in the welding process for this study, each AISI 1020 and AISI 1050 steel specimen measured P = 120 mm, L = 20 mm, T = 6 mm and used the normalizing or room temperature cooling method and the specimens were in the form of plates. The tensile test results obtained from specimens 1 and 2 with a welding speed variation of 5 m/minute are shown in the comparison graph above, which shows the strain values for each specimen with a slight difference in the strain results, namely 0.0663 mm and 0.0747 mm. And they were at the breaking point. This indicates that the selection of a welding time of 5 m/minute affects each welding result and tends to break quickly after tensile testing and breaks in the low-carbon steel section, namely in the AISI 1020 steel specimen. Furthermore, in the tensile test results obtained from specimens 3 and 4 with a welding speed variation of 10 m/min, the comparison graph above shows the strain value for each specimen, with varying strain data, namely 0.0325 mm and 0.0649 mm. And it is at the breaking point. This indicates that the selection of a welding time of 10 m/min affects each welding result and tends to vary. This is because the metal electrode in the weld area is well filled and breaks after the tensile test. The 10 m/min specimen also breaks at the low-carbon steel section, specifically the AISI 1020 steel specimen.

Then, tensile testing was conducted on specimens 5 and 6 with a welding speed variation of 15 m/minute. The comparison graph above shows the strain values for each specimen, with a slight difference in the strain results, namely 0.1084 mm and 0.1064 mm. These values are at the maximum strain point. This indicates that selecting a welding time of 15 m/minute affects each welding result and tends to cause a slight delay in breaking after the tensile test. This shows that selecting a welding time of 15 m/minute is a fairly good variation because the welded specimens experienced maximum strain after the tensile test, meaning the quality of the weld results tends to be good, allowing it to undergo strain up to the maximum value. The fracture process of each specimen after tensile testing tends to be slightly prolonged (toughness) and occurs at the low-carbon steel section, specifically on the AISI 1020 steel specimen.

If the width of the specimen is made larger, the value during the welding process can be longer and make the heat input more stable due to the length of the welding time and the length of the weld, and during the change of the welding layer, the output of the weld metal is better due to sufficient heat input. Lack of heat input causes the weld metal to not fuse properly, which affects the tensile strength. It can be concluded that the best welding results and the best tensile test results are obtained with a welding time variation of 10 m/minute, because the results of the stress-strain ratio comparison are more varied, and the welding results are quite good due to the more stable heat input because the welding time is stable and the welding length is appropriate, and when changing the welding layer, the weld metal comes out better because of sufficient heat input. Insufficient heat input causes the weld metal to not fuse properly. For example, for welding with a long welding time variation of 5 m/minute, this affects the tensile strength. Similarly, with a long welding time variation of 15 m/minute, the welding process that is too long also produces different strain values and experiences a break point at maximum strain. This indicates that welding for too long is also not ideal for mechanical test results in terms of strain values.

4. Conclusion

Based on the results of research conducted on the effect of *dissimilar* welding speed variations on the joining of AISI 1020 and AISI 1050 steel materials using the *shielded metal arc welding* method, the following conclusions can be drawn:

1. *Shielded Metal Arc Welding* (SMAW) on AISI 1020 and AISI 1050 steel with the combination of two different steel materials using the *dissimilar welding* method. Visual observation and the use of *red dye penetrant* showed weld defects in the welding results, namely *undercut* and *spatter defects.*
2. The tensile strength tested on AISI 1020 and AISI 1050 steel specimens with welding speeds of 5 m/min, 10 m/min, and 15 m/min showed stable results with average strain values of 0.07 mm, 0.05 mm, and 0.11 mm, respectively.
3. The tensile test results showed that using a welding speed variation of 10 m/min yielded better results than variations of 5 m/min and 15 m/min. This shows that welding results with a welding speed of 10 m/min, the heat input of the weld metal is fully filled in the welded area and tends to be stable for a long welding time and diffuses well, so that the weld results are the best compared to other variations.

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