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The effect of the MIG welding technique on the tensile strength results for cross-member making in an electric car with ST60 material

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ABSTRACT

This study aims to determine the chemical composition and tensile strength of ST60 material in MIG (Metal Inert Gas) welding for the manufacture of electric car cross members and to reveal the effect of the welding technique on the welding results. The material was medium carbon alloy steel with a thickness of 5 mm for each. MIG welding was done using a single 90-degree V joint with a current of 150 A. The welding techniques were straight, circular, and zigzag. The results showed a significant effect occurred in circular welding with an average tensile strength of 391.528 kg/mm^2, while straight welding showed the lowest average tensile strength of 373.793 kg/mm^2. The zigzag welding had the highest average tensile strength of 526.107 kg/mm^2.

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1. Introduction

Welding is crucial in today's industrial world because it has become integral to engineering and metal products [1]–[3]. There are various welding techniques in the welding process, one of which is MIG (Metal Inert Gas) [4]. This welding technique refers to gas arc welding in which the welding wire is also used as an electrode, a coil of wire with movement regulated by an electric motor. The MIG welding uses argon and helium gases to protect the arc and molten metal from atmospheric influences [5]. The recommended electrodes for carbon steel welding are AWS A5.18 E70S-5 and E70S-6 [6]. These elements are often used in the vehicle industry, especially in cars.

Nowadays, the use of electric cars is considered more effective and environmentally friendly [7], [8]. The electric car engine has a simpler form, requiring a chassis to bear all the loads on the vehicle [9]. One of the components in the chassis of an electric car is a cross member in the form of a transverse beam. It is made of pieces of iron which are then assembled with bolts on the car frame. The cross member is the main component receiving tensile loads, shear loads, and compressive forces when the car is operating. Therefore, cross-member welding must consider the forces that will affect it.

Based on the description above, the author researched the effect of MIG welding techniques on the tensile strength of welding results in the manufacture of electric car cross members with ST 60 material. This study was based on identifying several factors that affected metal strength due to the welding process, i.e., the variation of the welding motion.

2. Method

This study was experimental research using three group post-test design. The specimens were given different treatments, namely zigzag, circular and straight welding motion using type E 70 S-6 electrodes. Those were analyzed to determine the tensile strength of the welding results.

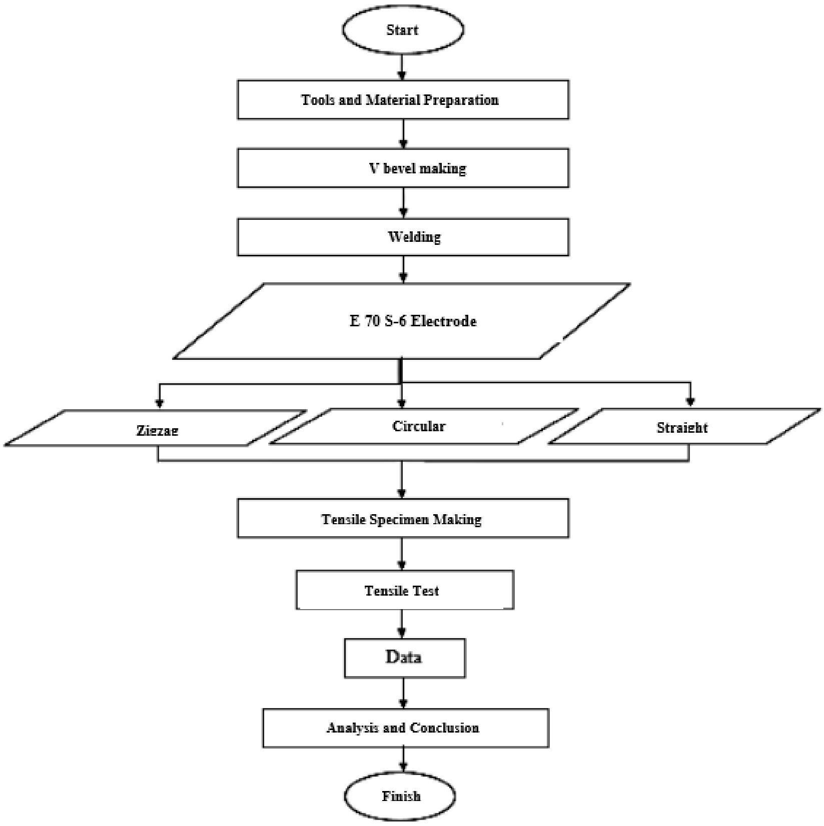

Fig. 1. Research procedure

The equipment for the research included ESAB Warrior MIG (Metal Inert Gas) welding machine, tensile test equipment as shown in Fig. 2, sawing machine, grinding machine, milling machines and equipment, caliper, bevel protractor to measure the bevel angle.

Fig. 2. Tensile test tool

The research materials consisted of ST 60 steel, electrode of E 70 S-6 with a diameter of 0.9 mm, protection of CO_2 gas.

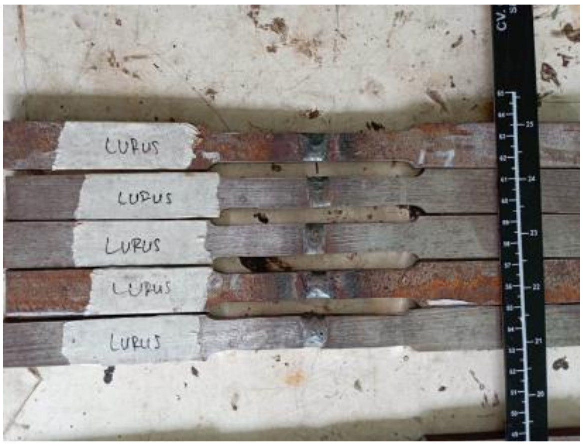

Fig. 3. Tensile test specimen

Tensile test

Tensile strength testing was carried out at the Material Testing Laboratory of the Department of Mechanical Engineering, Wahid Hasyim University, Semarang. It was done with a Gotech Hydraulic Universal Testing Machine with a capacity of 100 kN. The testing process was done by clamping the workpiece on the two vises on the tensile test equipment. If the specimen had been installed, it would be followed by inputting the dimensions of the specimen being tested into the monitor screen, i.e., the length of the gauge (83.80 mm) and the width of the gauge (12.5 mm). The magnitude of the force listed on the monitor screen should be zero score. Then, the machine was run for applying the tensile force until the workpiece broke and produced a stress-strain curve on the test monitor. It was done for each specimen.

From the tensile test results, the maximum tensile force data was obtained. It was then calculated by the equation of force $\sigma_m = F_m/A$, where σm = maximum tensile stress (N/mm^2), F_m = maximum tensile force (N), and A = cross-sectional area of the workpiece (mm^2). The tensile testing was carried out with the ASTM E8M tensile test specimen standard.

3. Results and Discussion

The results of the tensile test on the manufacture of electric car cross members using ST 60 material are as follows.

Table 1. Tensile Test Results

Tensile Test Results						
Welding	Welding results using electrodes E 70 S-6					Mean
Technique	I	II	III	IV	V	(kg/mm^2)
Straight	210.903	505.743	378.720	322.991	450.609	373.793
Circular	451.687	402.023	422.122	361.261	320.545	391.528
Zigzag	473.780	467.196	601.123	513.741	574.697	526.107

Table 1. shows the tensile strength values of the specimens treated with straight, circular, and zig-zag welding techniques. The straight motion obtained the lowest average tensile strength value of 373.793 kg/mm^2, followed by the circular motion of 391.528 kg/mm^2 and the zig-zag motion attained the highest average tensile strength value of 526.107 kg/mm^2. This results is in line with previous research that the motion affects the mechanical properties of the welded joints [10].

The data obtained from tensile testing on the manufacture of electric car cross members were analyzed using the IBM SPSS Statistic 24 application. Statistical tests used to analyse data require assumptions for the results to be valid [11]. The results are as follows:

Normality test

Based on the normality test among straight, circular, and zig-zag welding techniques, the following results are obtained.

Table 2. Normality Test Results

Test of Normality						
Treatment	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Straight	0.149	5	0.200*	0.980	5	0.937
Circular	0.181	5	0.200*	0.977	5	0.917
Zigzag	0.209	5	0.200*	0.896	5	0.386

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

From Table 2, it can be seen that the welding treatment with straight, circular, and zig-zag welding has a significance value of 0.937, 0.917, and 0.386, respectively. It means that the data obtained from the normality test is normally distributed because of the value of Sig. > 0.05.

Homogeneity test

One of the standard problems in statistics is determining if two samples come from the same population [12]. the homogeneity testing shows the following results.

Table 3. Homogeneity Test Results

Test of Homogeneity of Variances			
Tensile test results			
Levene Statistics	df1	df2	Sig.
1.662	2	12	0.231

From the homogeneity test results shown in Table 3, it is known that the Levene Statistic value equals 1.662, where the significance value equals 0.231 > 0.05. It is found that data have the same variance. In another word the data is homogeneous data.

Hypothesis Test

Many problems in engineering has been solved by hypothesis testing, such as in generalizing the traditional leakage estimation methods which further quantitatively determine the existence of leaks in pipe line and also optimization in building waterwheels and windmills [13], [14].

The hypothesis testing shows the following results.

Table 4. Hypothesis Testing Results

ANOVA					
Tensile test results					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	69376.412	2	34688.206	5.377	0.022
Within Groups	77419.619	12	6451.635		
Total	146796.031	14			

Table 4 shows the value of F = 5.377, where the significance value = 0.022 ≤ 0.05. It can be known that there is a significant effect of the straight, circular, and zigzag welding motion.

Advanced Post Hoc Test

Table 5 shows the most significant effect is in the zig-zag welding combined with the straight welding (152.314200).

Table 5. Advanced Post Hoc Test

Multiple Comparisons						
Dependent Variable: Straight technique						
LSD						
Welding Technique		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Straight	Circular	-17.734400	50.800137	0.733	-128.41839	92.94959
	zigzag	-152.314200*	50.800137	0.011	-262.99819	-41.63021
Circular	Straight	17.734400	50.800137	0.733	-92.94959	128.41839
	zigzag	-134.579800*	50.800137	0.021	-245.26379	-23.89581
Zigzag	Straight	152.314200*	50.800137	0.011	41.63021	262.99819
	Circular	134.579800*	50.800137	0.021	23.89581	245.26379

*. The mean difference is significant at the 0.05 level.

Tensile testing which reveals tensile strength of a specimen is one of the most popular methods used in mechanical research [15]. It is in line with the test results in Table 1 that the straight welding motion has the lowest average tensile strength of 373.793 kg/mm^2 and the zig-zag welding has the highest tensile strength value (526,107 kg/mm^2). In the post hoc test results using the IBM SPSS Statistics 24 application, it is found that each welding technique variation influences the tensile strength value. The variation of straight and circular welding shows zero significant effect. It is indicated by the mean difference value of -17.734400. The variation of straight welding and zigzag technique shows a significant effect with the mean difference value of -152.314200.

Moreover, the circular and straight welding technique variation shows little effect, with a mean value of 17.734400. The variation of circular and zigzag welding obtains a significant effect by having the mean difference value of -134.579800. The variation of zigzag and straight welding motion shows a significant effect with the mean difference value of 152.314200. The variation of zigzag and circular welding motion reveals a significant effect, including the mean difference value of 134.579800. It can be deduced that the most meaningful average difference occurs between the zigzag and the straight welding motion. It is in line with the value obtained in the tensile test where the variation of the straight welding motion has the lowest tensile strength value (373.793 kg/mm^2). Meanwhile, the variation of the zig-zag welding motion has the highest tensile strength value (526.107 kg/mm^2).

4. Conclusion

Based on the research and results analysis, it can be concluded that there is an effect of the welding techniques, namely: straight, circular, and zigzag to the tensile strength of the manufacture of electric car cross members with ST 60 material, in which the circular technique shows the highest tensile strength. There is a significant effect on the advanced Post Hoc test on variations of straight, circular, and zig-zag welding techniques. A significant effect occurred in the zigzag welding motion with a straight welding motion with the largest average of 152.314 kg/mm^2. It is in line with the tensile test results that straight welding has the lowest average tensile strength of 373.793 kg/mm^2. Thus, the straight welding technique has the lowest tensile strength value, and the zig-zag welding motion has the highest tensile strength.

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