INFLUENCE OF ELECTRODE TYPE ON THE MECHANICAL PROPERTIES OF THE RESULT AISI 1018 STEEL SMAW WELDING

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ABSTRAK

Karakteristik mekanis dan fisik dari sebuah sambungan las sangat dipengaruhi oleh pemilihan jenis elektroda beserta besaran arus yang diaplikasikan. Oleh karena itu, riset ini dilaksanakan guna mengevaluasi dampak kedua variabel tersebut terhadap performa spesimen, yang mencakup tinjauan makro-mikro, pemetaan tingkat kekerasan, serta daya tariknya. Eksperimen dilakukan menggunakan metode *Shielded Metal Arc Welding* (SMAW) pada material baja AISI 1018 dengan laju pengelasan yang dijaga konstan. Pengujian melibatkan tiga varian elektroda (E6013, E7016, dan E7018) yang dikombinasikan dengan tiga tingkatan kuat arus (70A, 110A, dan 130A). Berdasarkan hasil analisis, terbukti bahwa besaran arus memegang peranan vital dalam mengubah sifat material. Ditemukan adanya korelasi berbanding terbalik: peningkatan arus pengelasan secara konsisten memicu penurunan pada angka kekerasan maupun ketahanan tarik. Terkait perbandingan antar elektroda, tingkat kekerasan paling optimal menyentuh angka 105 HRB yang didapatkan dari kombinasi elektroda E7018 dengan setelan arus 70A. Di sisi lain, daya tarik maksimal tercatat sebesar 34,697 MPa, yang dihasilkan melalui penggunaan elektroda E6013 pada kuat arus 110A.

Kata kunci: Pengelasan; elektroda; kuat arus; SMAW.

ABSTRACT

The mechanical and physical characteristics of a welded joint are greatly influenced by the choice of electrode type and the applied current. Therefore, this research was conducted to evaluate the impact of these two variables on specimen performance, which includes macro-micro review, hardness mapping, and tensile strength. Experiments were conducted using the Shielded Metal Arc Welding (SMAW) method on AISI 1018 steel material with a constant welding rate. The test involved three electrode variants (E6013, E7016, and E7018) combined with three current levels (70A, 110A, and 130A). Based on the analysis results, it was proven that the current plays a vital role in changing material properties. An inverse correlation was found: increasing the welding current consistently triggered a decrease in both hardness and tensile strength. Regarding the comparison between electrodes, the most optimal hardness level reached 105 HRB obtained from the combination of the E7018 electrode with a current setting of 70A. On the other hand, the maximum tensile strength was recorded at 34.697 MPa, which was produced through the use of E6013 electrodes at a current strength of 110A.

Keywords: Welding; electrode; current; SMAW

INTRODUCTION

The welding technique is a method of uniting metal materials, especially steel, through liquid phase melting which is widely applied in machine construction assembly [1]. Because steel has a very wide range of specifications, not all variants are ideal for welding. One type of metal that has been proven to have a superior level of weldability is AISI 1018 steel. In contrast to mechanical splicing such as nuts or rivets, the welding process triggers a much more extreme voltage spike. This phenomenon begins from changes in the properties of materials in the connection area, especially in the heat-affected area or Heat Affected Zone (HAZ), which is the zone around the weld line that is exposed to extreme temperatures during the unification process [2].

Another major factor that often triggers welding defects is the selection of electrode type. These components have a direct impact on the mechanical characteristics of welds, including tensile strength, toughness, and hardness [2]. Studies indicate that the results of the connection using the E7016 electrode generally have more massive dimensions than E6013 [3]. However, the E6013 electrode actually recorded superior elongation, tensile strength, and cross-sectional reduction values compared to E7016—which is known to produce a greater heat input. In contrast, the lack of heat input in the E6013 electrode results in a higher level of material hardness than E7016 [4].

Fundamentally, steel is an alloy between iron as the base element and carbon (with a weight percentage between 0.2% to 2.1%) as the main alloying agent. In its crystal lattice structure, carbon acts as a hardener that locks in the movement of dislocation. In addition to carbon, additional elements such as manganese, tungsten, chromium, and vanadium are often included [5]. It should be noted that the tensile strength values of materials can fluctuate depending on the type of electrode and the test standards applied [5]. In fact, the modification of the amount of current in the use of identical electrodes has been proven to change the performance of the tensile strength of the welded result [6]. The mechanical properties of carbon steel are ultimately largely controlled by their carbon composition and microstructure, while the presence of other comorbidities is purely the result of manufacturing procedures.

Referring to the literature [7], the classification of carbon steel rests on its percentage of content. Low carbon steel (less than 0.3% C), which is often called mild steel, has less harsh properties. Medium carbon steel (0.3%–0.6% C) allows for a partial hardening process through heat treatment. Meanwhile, high-carbon steel (0.6%–1.5% C) is generally produced through heat rolling. At the global level, this material testing quality standard usually refers to ASTM (American Society for Testing and Materials), an institution from the United States whose validity of the analysis is widely recognized.

AISI 1018 steel is classified as a low carbon steel with a C content below 0.3%. Its main characteristics include an excellent level of ductility and toughness, although it must be compensated for by low wear resistance and hardness. This material is also very reactive so that it is easily oxidized into iron oxide (rusty) if exposed to water, oxygen, or free ions. The weldable quality of AISI 1018 steel is highly dependent on its sensitivity to weld cracks and the strength of its notch. Departing from this background, this paper aims to investigate in depth how the impact of the modification of the welding current and the variation of electrode types on the hardness distribution, micro and macro structure, and tensile strength of the test material.

RESEARCH METHODS

The main material explored in this research is AISI 1018 type steel. To support the course of the experiment, various instruments were prepared including plate cutting tools, milling machines (milling machines), AC-powered SMAW welding devices, metallographic microscopes, to hardness and tensile strength testing equipment. The scheme of the implementation of the procedure can be observed in Figure 1. In the initial preparation stage, the material is formed into plates with dimensions of 250 x 130 x 5 millimeters whose edges are modified into V-shaped weld fields. Once the welding is complete, the connection area is documented using a macro camera lens. Next, the workpiece is cut into specific parts for the purposes of macroscopic inspection, hardness evaluation, and tensile stress tests. Specifically for tensile test needs, specimens are formed using a frais machine so that their dimensions precisely meet the guidelines of the ASTM E8 standard.

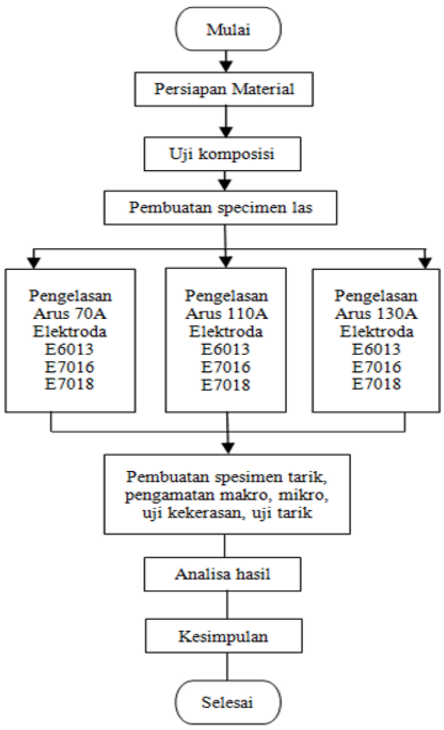


Figure 1 Research flow chart

RESULTS AND DISCUSSION

Macro Observations

The illustration in Figure 2 shows a macroscopic analysis of the weld joint, which highlights the influence of different current parameters as well as electrode types. Quite severe welding defects, such as cavities and cracks, were found in specimens welded using a current of 130 A and the E7016 electrode (Figure 2.f) due to high thermal effects. On the other hand, a drop in current to 70 A with the E7018 electrode (Figure 2.g) causes the failure of optimal metal melting due to lack of temperature. This happens because the small current is directly proportional to the low heat input, so the specific heat received by the plate is not adequate for a perfect melting process.

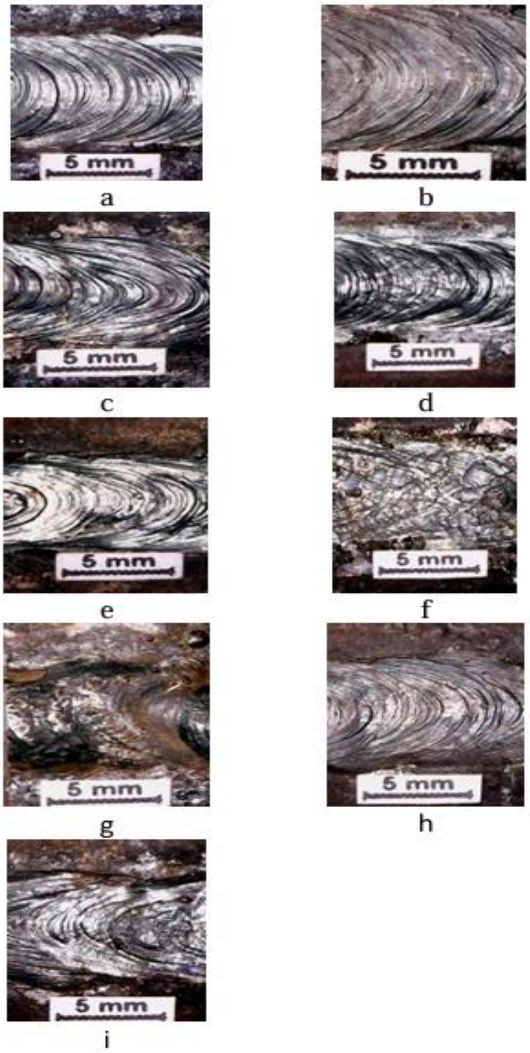
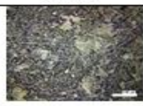
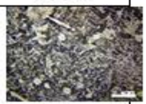
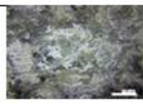
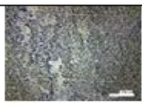
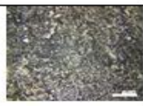
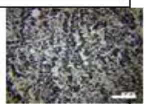
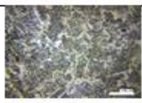
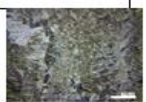
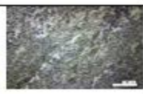


Figure 2. Macro structure of welding results(a). 70 A, E6013; (b). 110 A, E6013; (c). 130 A, E6013; (d). 70A. E7016; (e). 110A, E7016; (f). 130A, E7016; (g). 70A, E7018; (h). 110A, E7018; (i). 130A, E7018.

Micro-Observation

Table 1 presents the results of the evaluation of microstructures in the weld zone and the Heat Affected Zone (HAZ). In general, the main constituent phases in both areas are perlite and ferrite. The thermal exposure received by the HAZ zone during the splicing process leads to the formation of perlite and ferrite configurations with high densities. In contrast to the area of welded metals, where the most formed morphologies include asicular ferrites, grain boundary ferrites, and Widmanstatten ferrites. The most significant contrast of microstructural characteristics is seen in the application of the E6013 electrode with a current strength of 130A. At this parameter, the weld area is characterized by the presence of Widmanstatten ferrite, asicular and grain boundaries, while the HAZ area contains only a combination of ferrite and perlite structures.

Table 1. Comparison of Microstructures to HAZ areas and welding areas

	Daerah HAZ		
	70A	110A	130A
E6013			
E7016			
E7018			
	Daerah Las		
	70A	110A	130A
E6013			
E7016			
E7018			

Hardness Testing

Rockwell hardness on the parent metal, heat-affected area (HAZ) and weld metal as shown in Figure 3 of the hardness graph.

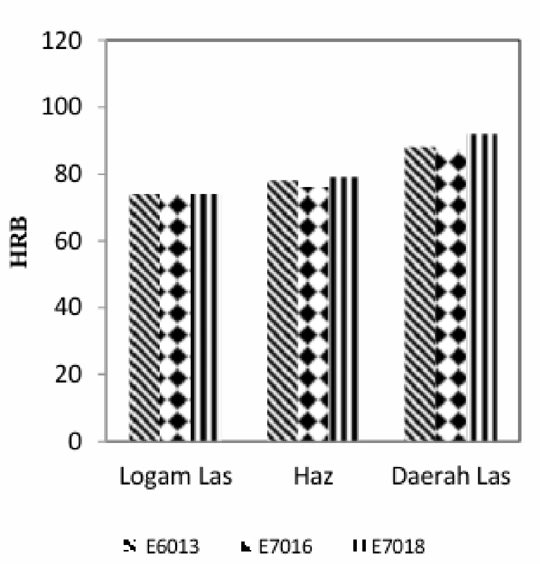


Figure 3. Hardness graph

Based on Rockwell's hardness evaluation, the use of E7018 electrodes with a current strength of 110A resulted in a hardness level of 92 HRB in the welded metal area. This figure is influenced by the lack of heat input in the region. This pattern is different from the application of 130A current, where the hardest point actually moves to the Heat Affected Zone (HAZ). On the other hand, the record highest hardness in the HAZ area of 84.67 HRB was found in the welding of the E6013 electrode with a current of 70A. Overall, the peak hardness value for the welded metal area is dominated by the E7018 electrode at a current variation of 70A, which is capable of reaching the figure of 105 HRB.

Tensile Testing

Visualization of the effect of current on the tensile strength of the specimen can be seen in Figure 4. Mechanical strength data from the welding process with electrode variations (E6013, E7016, E7018) at currents 70A, 110A, and 130A have been evaluated. Details of the results include: testing with a current of 70A yielded a yield voltage of 295.03 MPa, a maximum voltage of 346.97 MPa, and a peak load of 133.24 N. Current settings at 110A yielded values of 251.98 MPa for the yield voltage, 251.27 MPa for the maximum voltage, and 16,409.58 N for peak load. The current of 130A recorded a yield voltage of 287.22 MPa, a maximum voltage of 342.91 MPa, and a peak load of 15,973.85 N.

When viewed from its highest record, the combination of the E6013 electrode with a current of 110A is the most superior with an achievement of 399.2 N. This success is motivated by the compatibility between the electrode, current, and heat distributed to the working metal. Inversely proportional to this, the combination of E6013 electrodes at 70A current occupies the lowest position (267.9 N) due to the lack of temperature intensity that penetrates the material.

CONCLUSION

Referring to the data analysis and previous exposure macroscopically, the most even weld profile with the deepest penetration power is generated through the application of E7016 type electrodes at a current strength of 110A. Metallographic analysis showed that the welded metal zone with a current of 110A was dominated by the asicular ferrite structure with the largest area compared to a combination of other test parameters. On the other hand, the Heat Affected Zone (HAZ) area gives rise to phase variations that include asicular ferrite, widmanstatten, grain boundary, to coarse and fine-grained ferrite. Meanwhile, the parts of the base material (the parent metal) that do not undergo thermal cycling during welding retain their original structure, namely perlite and ferrite. Hardness testing proved that the HAZ area reached a maximum of 88.33 HRB when using the E7018 electrode at 130A current. The record for the highest hardness specifically for welded metal points is at 105 HRB, which is also produced by the use of the E7018 electrode. The mechanical characteristics of the base metal based on tensile tests show an average yield stress of 298.25 MPa with a max stress of 379.13 MPa. Post-welded, the most superior tensile strength was recorded in specimens with a 110A current E7018 electrode, which is capable of withstanding loads of up to 390.99 MPa.

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