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Mechanical Properties of ST 37 Manufactured by Gas Tungsten Arc Welding using Cannibal Consumable Manufacturing Filler

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Abstract: In this paper, the macrostructure and mechanical properties of medium carbon steel with cannibal consumable filler by using the GTAW process have been investigated. The medium carbon steel (ST 37) plates with dimensions of 300 × 250 ×3 mm were used for welding and 2.5 mm of thickness for the filler. For welding parameters, current of 80 A was chosen and observed over the welded specimen. Welding was performed with single Vgroove butt Joint design, 30° bevel angle. Preparation of samples was done according to standard. To explore the optimum welding specimen, both tensile and bending tests were carried out. The result of the welding process with the current of 80A shows that the face part tends to be more embossed and the root part looks less embossed, there are parts that lack penetration. This causes a lack of weld strength due to incomplete penetration of the root part. The face section produces maximum and strong results, while at the root there are cracks that are almost broken. This is due to lack of fusion because the current is too small resulting in differences in weld strength between the face and root, which affects the bending test results. In the tensile test results, a fracture occurred in the weld metal in the form of a brittle fracture. This is caused by a lack of fusion and very minimal penetration of the filler metal into the weld groove. Based on the macro test analysis carried out, minimal root penetration or no penetration occurs, while the weld seam accumulates on the face. Based upon the present study it is not recommended that 80 A of welding current when GTAW process using canibal consumable filler. The current of 80A may need to improve to produce good welding.

Keywords: Cannibal, Consumable, Filler, GTAW.

Abstrak: *Dalam penelitian ini, struktur makro dan sifat mekanik baja karbon sedang dengan penggunaan cannibal filler habis pakai melalui proses GTAW telah diteliti. Pelat baja karbon sedang (ST 37) dengan dimensi 300 × 250 × 3 mm digunakan untuk pengelasan dan filler dengan ketebalan 2,5 mm. Parameter pengelasan menggunakan arus sebesar 80 A yang diamati pada spesimen las. Proses pengelasan dilakukan dengan desain sambungan butt V tunggal dengan sudut bevel 30°. Persiapan spesimen dilakukan sesuai standar. Untuk mengeksplorasi spesimen las yang optimal, dilakukan uji tarik dan uji tekuk. Hasil dari proses pengelasan dengan arus 80 A menunjukkan bahwa bagian permukaan las cenderung lebih menonjol, sedangkan bagian akar terlihat kurang menonjol dan terdapat bagian yang mengalami kurang penetrasi. Hal ini menyebabkan kekuatan las menjadi rendah akibat tidak sempurnanya penetrasi pada bagian akar. Bagian permukaan menghasilkan hasil maksimal dan kuat, sementara pada akar terdapat retakan yang hampir patah. Hal ini disebabkan oleh kurangnya fusi karena arus yang terlalu kecil, sehingga terjadi perbedaan kekuatan las antara bagian permukaan dan akar, yang memengaruhi hasil uji tekuk. Pada hasil uji tarik, terjadi patahan pada logam las dalam bentuk patah getas. Hal ini disebabkan oleh kurangnya fusi dan sangat minimnya penetrasi logam pengisi ke dalam alur las. Berdasarkan analisis uji makro yang dilakukan, ditemukan penetrasi akar yang minimal bahkan tidak ada, sementara logam las menumpuk pada permukaan. Berdasarkan penelitian ini, tidak disarankan menggunakan arus 80 A dalam proses GTAW dengan cannibal filler habis pakai. Arus 80 A perlu ditingkatkan untuk menghasilkan kualitas pengelasan yang baik.*

Kata kunci: *Kanibal, Habis Pakai, Filler, GTAW.*

INTRODUCTION

Welding is the fabrication process of joining materials by heating to melt and allow them to cool causing fusion. Fusion welding is a joining process that uses fusion of the base metal to make the weld. The three major types of fusion welding processes are gas welding, arc welding and high-energy beam welding [1]. The Gas tungsten arc welding (GTAW) is a type of arc welding that uses a tungsten electrode that does not melt and what does melt is a filler. The GTAW method uses a shielding gas which functions to protect the liquid metal during the welding process so that it is not oxidized by oxygen in the surrounding environment. The shielding gas used is argon, helium or a mixture of the two gases [2]. The GTAW is a widely used joining technique due to its process more flexible, low welding cost, high welding quality and provides a sustainable environment by low energy consumption [3], [4].

The GTAW possible to join metals with or without filler metal. The welding arc from the tungsten electrode will melt the two base metals and unite them. However, to make the weld stronger and avoid cracking, use filler metal. Several cases in the field involve using fillers that are similar to the workpiece to be welded, or are referred to as cannibal consumables. The filler was made from the same or similar material as the material being welded and separated from the welding torch [5], [6]. Tarmizi et.al [7] investigated welding combination between GTAW and SMAW. The filler metal used in the GTAW process is ER80S-Ni_2. S. Senthilkumar et.al [8] observed the non-consumable tungsten electrode fused by high heat energy supplied via an electrical source and arc produced between the metal surfaces is melted and joined together through a filler rod. To the authors' best of knowledge, rarely discussion regarding testing this method to ensure that the cannibal consumable method can be used properly. Therefore, this study is designated to fabricate and analyze the cannibal consumable on tensile and bending properties of ST37 using GTAW.

METHODS

In this study, the low carbon steel of ST 37 with dimensions of 300×125× 3mm were used for welding specimen and 2.5 mm thickness for filler. Cutting of samples was performed by a hydraulic cutting machine and edge preparation was done by a grinding machine. The welding parameters were selected based on the first trials and the parameters were identified based on previous study as listed in Table 1 [8], [9]. Welding was performed with single Vgroove butt Joint design, 30° bevel angle. Preparation of samples was done according to ISO 2553:2019 [10] standard and also, according to the thickness of carbon steel, as show in Fig. 1 (left).

Table 1. Welding parameters of GTAW with welding consumable of ST 37

Parameters	Current (A)	Voltage	Welding speed	Position	Shielding gas	Polarity	Filler
Sample	80	12.3	6.11 mm/s	1G	Argon	DCEP	ST 37

Figure 1. Butt-weld joint preparation with 30° of bevel angle (left), The ARL optical emission spectrometer machine (right)

The ARL optical emission spectrometer (Fig. 1(right)) was used to determine the element composition of the metals. Tensile testing is carried out in the transverse direction. The ASTM E8M was used for the reference standard for making tensile testing specimens [11]. The ductility and strength of welded connection were analyze by using bend test. The ASTM E290-14 was used for the reference standard for making bending testing specimens [12]. The macrostructure of the sample in different welding zone was examined by optical microscope (Nikon Eclipse E600 Fluorescence Microscope)). Macro testing includes several steps, namely mounting, grinding, polishing, etching, and analysis using an optical microscope according to the ASTM E407 standard [13].

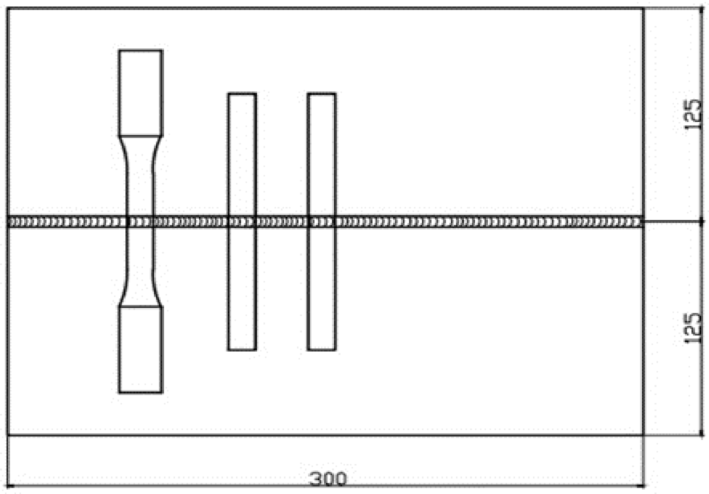

Figure 2. Specimen test lay-out of tensile and bend test

RESULT AND DISCUSSION

Based on the test results on the ARL optical emission spectrometer, the elemental composition contained in the ST37 steel material is shown in table 2. ST 37 is classified as medium carbon steel because it has a carbon content of 0.165. Carbon equivalent (CE) formulae are used to predict susceptibility to Hydrogen Induced Cracking (HIC). In general, the higher the value of CE, the more susceptible the steel is to HIC. Unfortunately, there is not a single CE formula that can be used for all steels. The International Institute of Welding (IIW) CE formula, CE_{IIW}, is the one that is most widely used because it can be generally applied to most plain-carbon and C–Mn steels [14].

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + (Ni + Cu)/15 \qquad Eq. 1$$

Based on equation 1, the result is 0.42. So from the calculation results it is concluded that ST 37 is a metal that has good weldability properties. If the calculation results exceed 0.45 then the metal does not have weldable properties which results in poor weld results.

Table 2. The elemental composition of ST 37

Elements	Percentage (%)
Carbon (C)	0,165
Silicon (Si)	0,253
Sulfur (S)	0,011
Phosphorus (P)	0,020
Manganese (Mn)	0,564
Nickel (Ni)	0,04
Chromium (Cr)	0,62
Molybdenum (Mo)	0,016
Vanadium (V)	0,004
Copper (Cu)	0,053
Wolfram/ Tungsen (W)	0,004
Titanium (Ti)	0,002
Tin (Sn)	0,005
Aluminium (Al)	0,001
Plumbun/Lead (Pb)	0,0015
Antimony (Sb)	0,002
Niobium (Nb)	0,001
Zirconium (Zr)	0,000
Zinc (Zn)	0,048
Ferro / Iron (Fe)	98,193

After cleaning the welding specimen, the weld results can be seen visually to observe the quality of the weld results. The result of the welding process (Fig. 3) with the current of 80A shows that the face part tends to be more embossed and the root part looks less embossed, there are parts that lack penetration. This causes a lack of weld strength due to incomplete penetration of the root part [15].

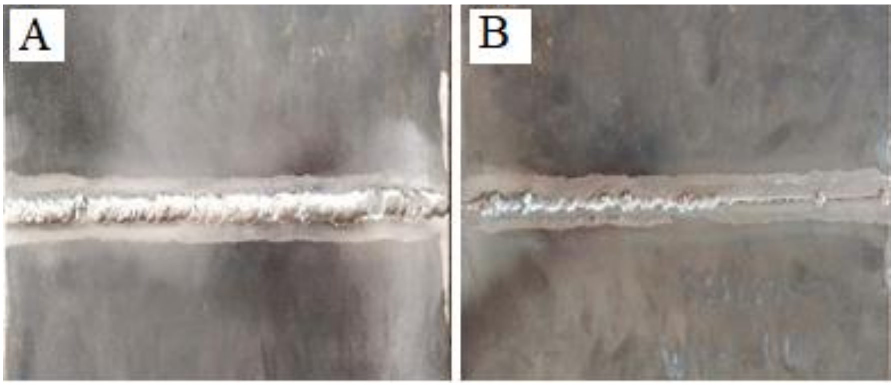

Figure 3. Weld bead of GTAW on ST 37 (a) Face (b) Root

Fig. 4 shows the bending test result on face and root. Bending test results shows differences in welding results between the face and root sections. The face section produces maximum and strong results, while at the root there are cracks that are almost broken. This is due to lack of fusion because the current is too small resulting in differences in weld strength between the face and root, which affects the bending test results [16]. The bending test results on the weld root show that the results are consistent with those on the weld bead that lack of fusion that effect for this case.

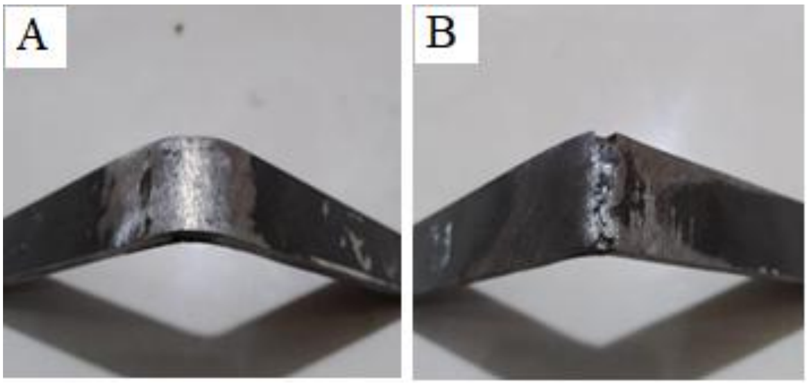

Figure 4. Test result for bending of (a) face (b) root

Table 3. Test results for tensile strength of specimen

Current	Thickness	Width	Surface Area	Length	UTS	YS	Elongation
80 A	3.04 mm	12 mm	36 mm^2	50 mm	316 N	285	2%

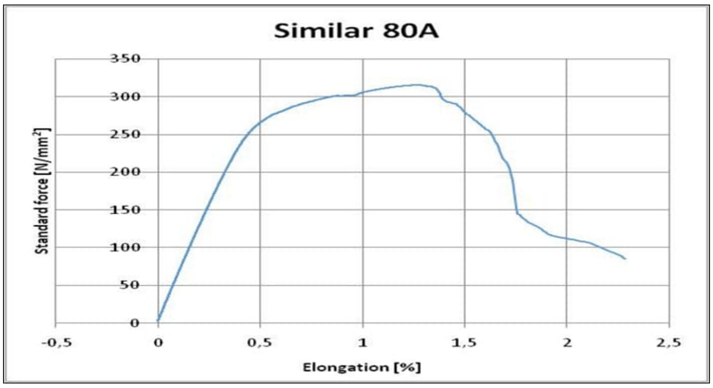

Figure 5. Stress-strain curve of GTAW with welding consumable of ST 37

Figure 6. Fractured photographs of tensile specimen of GTAW with welding consumable of ST 37

The detailed summary of the tensile test data (ultimate tensile strength, yield strength, and elongation is shown in Table 3. The characteristic stress-strain diagram is showed in Fig.5. Figure 6 shows the position of the fracture that occurred in the tensile test results, a fracture occurred in the weld metal in the form of a brittle fracture. This is caused by a lack of fusion and very minimal penetration of the filler metal into the weld groove.

The macrostructure of the welded specimen is shown in Fig. 7 with the marking of each area (BM (Base Metal, HAZ (Heat Affected Zone) and WM (Weld Metal)). Based on the macro test analysis carried out, minimal root penetration or no penetration occurs, while the weld seam accumulates on the face as same as shown in Fig 3b and 4b. The failure that occurred in all specimens was britlle, indicating that the material was still capable of withstanding continuous loads before experiencing significant due to rapid cooling after welding [17].

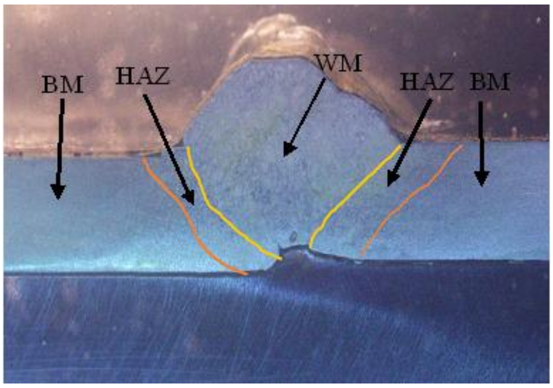

Figure 7. Macrostructure of a weld showing the marked regions: BM (Base Metal), HAZ (Heat-Affected Zone), and WM (Weld Metal)

CONCLUSIONS

The following are the main conclusions deduced from the present study:

1. Based on the calculation of Carbon Equivalent the specimen ST 37 was 0.42 which is good weldability properties. If the calculation results exceed 0.45 then the metal does not have weldable properties which results in poor weld results.
2. The result of the welding process with the current of 80A shows that the face part tends to be more embossed and the root part looks less embossed, there are parts that lack penetration. This causes a lack of weld strength due to incomplete penetration of the root part.
3. The face section produces maximum and strong results, while at the root there are cracks that are almost broken. This is due to lack of fusion because the current is too small resulting in differences in weld strength between the face and root, which affects the bending test results.
4. In the tensile test results, a fracture occurred in the weld metal in the form of a brittle fracture. This is caused by a lack of fusion and very minimal penetration of the filler metal into the weld groove.
5. Based on the macro test analysis carried out, minimal root penetration or no penetration occurs, while the weld seam accumulates on the face.

Based upon the present study it is not recommended that 80 A of welding current when GTAW process using canibal consumable filler. The current of 80A may need to improve to produce good welding.

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