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Swing and Electrode Diameter Effects on Toughness and Hardness of Stainless Steel 304 MIG Welding Results

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ABSTRACT

Welding is one of the commonly used methods for joining metals. One of the welding techniques frequently employed is MIG welding (Metal Inert Gas welding). This type of welding is typically used for joining stainless steel. Consequently, many factors need to be analyzed to achieve optimal welding results. The objective of this research is to investigate the influence of swing variation and electrode diameter on hardness, toughness, and macrostructure from the welded stainless steel 304 using MIG welding. The research results showed the highest toughness test results with a 2.0 mm electrode diameter and a zig-zag swing of 0.459 J/mm^2, while the lowest toughness test results were obtained with a 2.6 mm electrode diameter and a spiral swing of 0.201 J/mm^2. The highest hardness test results were observed with a 2.6 mm electrode diameter and a zig-zag swing in the Heat Affected Zone (HAZ) at 292.0 kg/mm^2, whereas the lowest hardness test results were obtained with a 2.0 mm electrode diameter and a zig-zag swing in the welded metal at 203.6 kg/mm^2. The widest HAZ occurred with the spiral swing variation and a 1.5 mm electrode diameter, resulting in a HAZ width of 1.92 mm, while the narrowest HAZ of 1.25 mm occurred with the spiral swing variation and a 2.0 mm electrode. Thus, it can be concluded that the electrode diameter variation affects the results of toughness, hardness, and macrostructure tests.

Keywords: *electrode diameter, hardness, MIG welding, stainless steel, swing variation, toughness*

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ABSTRACT

Pengelasan merupakan salah satu metode yang banyak dijumpai untuk teknik penyambungan logam. Salah satu jenis pengelasan yang sering digunakan adalah pengelasan MIG (*Metal Inert Gas*). Jenis pengelasan ini umumnya digunakan untuk menyambung logam stainless steel. Sehingga banyak faktor yang perlu dianalisis untuk mendapatkan hasil pengelasan yang optimal. Tujuan dari penelitian ini adalah untuk mengetahui pengaruh variasi ayunan dan diameter elektroda pada kekerasan, ketangguhan dan struktur makro pada baja *stainless steel* 304 hasil las MIG. Dari hasil penelitian didapatkan hasil pengujian ketangguhan tertinggi pada diameter elektroda 2,0 mm dengan ayunan zig-zag sebesar 0,459 J/mm^2, sedangkan pada pengujian ketangguhan terendah pada diameter elektroda 2,6 mm dengan ayunan spiral sebesar 0,201 J/mm^2. Pengujian kekerasan tertinggi pada diameter elektroda 2,6 mm dengan ayunan zig-zag pada logam HAZ sebesar 292,0 kg/mm^2, sedangkan pada pengujian kekerasan terendah pada diameter elektroda 2,0 mm dengan ayunan zig-zag pada logam las sebesar 203,6 kg/mm^2. Lebar HAZ terbesar terjadi pada variasi ayunan spiral dengan diameter elektroda 1,5 mm dengan lebar HAZ 1,92 mm, sedangkan lebar HAZ terendah 1,25 mm terjadi pada variasi ayunan spiral dengan elektroda 2,0 mm. Sehingga dapat diketahui perbedaan diameter elektroda mempengaruhi hasil pengujian ketangguhan, kekerasan, dan struktur makro.

Kata Kunci: *diameter elektroda, kekerasan, las MIG, stainless steel, variasi ayunan, ketangguhan*

INTRODUCTION

Welding is a metal joining process in which metals are combined into a continuous shape using heat from the welding process, carried out with or without filler metal [1]. The welding process is widely used in various sectors, such as construction, automotive, and so on. In its application, the welding process requires many factors to be considered to produce optimal results and correspond to the needs. These factors are like welding groove, position, speed, electrode type, and diameter [2]–[4]. The MIG (Metal Inert Gas) is a welding process utilizing flame gas from an electric arc as a heat source to melt the metal to be joined, as well as additional metal in the form of solid wire which is often referred to as *solid wire* [5]. This welding type is mostly used to perform in joining aluminums [6], [7] and stainless steels [8], [9].

Type 304 stainless steel or commonly called SS 304 is an austenitic type of stainless steel made from an alloy of iron, 18% chrome, 8.8% nickel and small amounts of other metals. It is widely used for construction materials, especially in several chemical fields because of its good corrosion resistance [10]. In its application, the use of SS 304 often requires joints so that it can function according to its needs. This joining process uses welding, one of which is MIG welding. Many factors need to be determined to produce weld results that have the most optimum mechanical properties, such as swing and electrode diameter. Therefore, this study aims to analyze the effect of variations in swing (spiral and zig-zag swings) and electrode diameter (1.5; 2.0; and 2.6 mm) on the results of welding SS 304 with MIG welding techniques on impact strength and hardness.

METHOD

Metal Inert Gas (MIG) Welding

The MIG (Metal Inert Gas) welding process is a welding process that creates heat through the burning of an electric arc formed between an electrode in the form of a wire (*wire electrode*) and the working object. During the MIG welding process, the wire electrode will melt and add weld metal to the joint, forming weld beads. Protective gas is used to prevent oxidation and protect the welding results during the solidification process [11].

Stainless Steel 304

Stainless steel 304 (SS 304) is a type of metal that is highly sought after in industry. This is due to its characteristic which is resistant to oxidation, so it does not corrode easily like other steel metals [12]. SS 304 is an austenitic type of stainless steel with the main content of chrome and nickel. The stainless steel used in this research has a carbon content of C 0.023%, Cr 18.2%, and Ni 8%. This type is widely applied as construction materials in many chemical industries because of its corrosion resistant properties [10].

The Influence of Welding Swing and Electrode Diameter

The quality results of welding strongly depend on the factors applied during the welding process. Such as swing and electrode diameter. Research on the welding process with variations in electrode movement or swing shows that the use of spiral and zigzag swings affects the tensile strength results in the weld with the highest tensile strength of 616.6 MPa when spiral swing is applied. Besides, the highest hardness value was obtained by using a zigzag swing with a value reaching 147.44 kg/mm^2 [13].

Moreover, the use of electrode diameter has also been proven to cause differences in mechanical strength. The larger the electrode diameter, the higher the tensile strength resulting from the welded metal. For example, using electrode diameters of 2 mm, 2.6 mm, and 3.2 mm in welding dissimilar metals AISI 304 – ST42, produces the highest tensile strength reaching 391.92 N/mm^2 when using a diameter of 3.2 mm [3]. Other similar research using electrode diameters of 1.6 mm, 2.4 mm, and 3.2 mm in welding of AISI 1050, shows the highest tensile strength when using electrodes with a diameter of 3.2 mm [4]. The welded metal is SS 304 stainless steel with dimensions of 300 x 100 x 10 mm. The electrodes used were Enka NK-58 with a diameter of 1.5 mm; 2.0mm;

and 2.6mm. The welding process is carried out using a current of 85 A with a spiral swing welding speed of ±0.38 mm/second and a zigzag swing of ±0.41 mm/second according to the specified variations. This research was carried out according to the flow diagram in Figure 1.

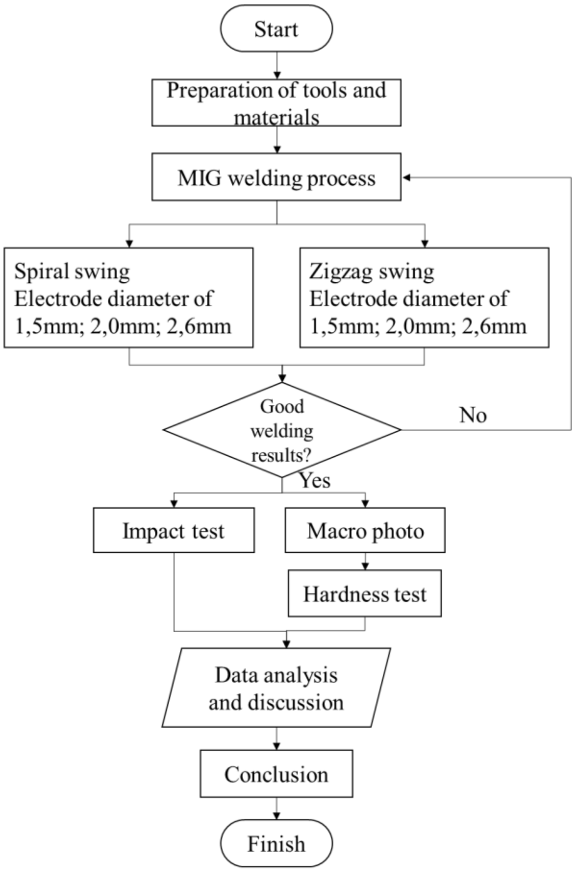
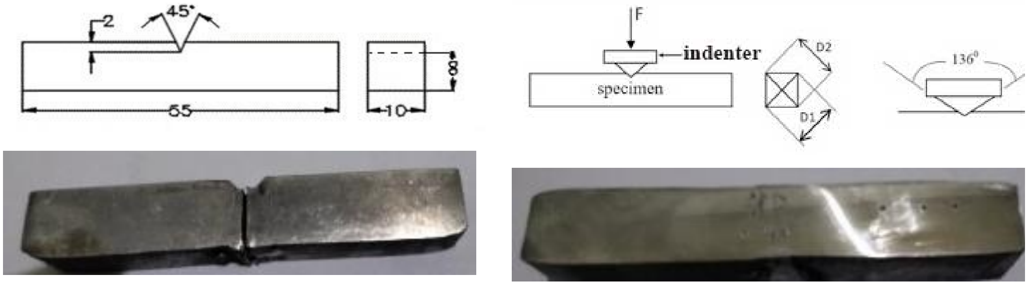


Figure 1. Research flow diagram.

Impact toughness testing was carried out using the Charpy method at room temperature. A V notch was given to the sample with a depth of 2 mm based on ASTM E23 standard. The dimensional specifications of the impact test specimen are shown in Figure 2(a). Meanwhile, macro photos are taken to determine the width and position of the HAZ, and then a hardness test is carried out on each weld area. Macro photos were taken by rubbing the sides of the specimen with sandpaper from coarse to fine grit, then applying 15% nitric acid for a few seconds until the HAZ area was visible. Then the HAZ width is measured using a loop. After observing macro photos, a hardness test was carried out in the HAZ area. The hardness test carried out was the Vickers hardness method. The size of the specimen tested was 55 x 10 x 10 mm, as in Figure 2(b).



(a) (b)

Figure 2. a) Impact test specimen, b) hardness test specimen.

RESULTS AND DISCUSSION

Impact Toughness Results

The results of the Charpy method impact test on SS 304 steel MIG welding results are shown in Figure 3. The impact strength value shows that the highest value of 0.459 J/mm^2 was obtained in a zigzag swing with an electrode diameter of 2 mm. This indicates that the specimen absorbs the most energy, which means the sample has high ductility. Meanwhile, the lowest impact strength value was found in the weld with an electrode diameter of 2.6 mm and a spiral swing. This shows that the larger electrode diameter and the use of a spiral swing cause the weld to become more brittle.

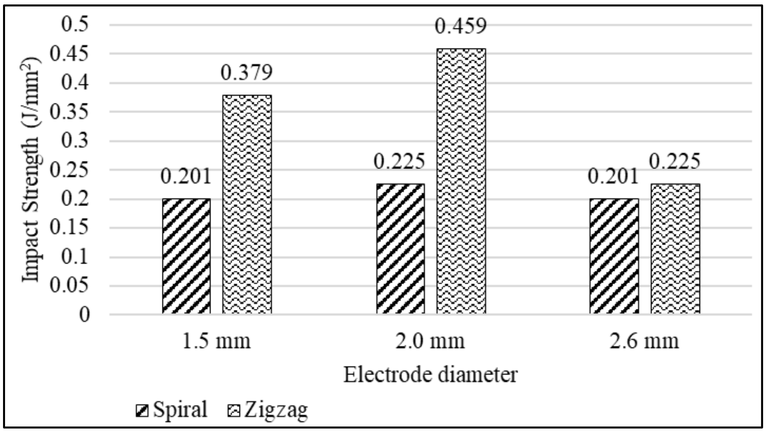


Figure 3. Impact toughness values resulting from MIG welding of SS 304 steel with variations in swing and electrode diameter

Vickers Hardness Results

Hardness testing was carried out at three points in the HAZ area, then the average value was calculated. The average value for each variable is presented in Figure 4. The highest hardness value obtained was 292 kg/mm^2 from welding results with a zigzag swing and an electrode diameter of 2.6mm. A larger electrode diameter generally causes the hardness value to increase. These results are in accordance with previous research which states that the mechanical properties of the weld results increase with increasing electrode diameter [11].

In addition, the zigzag swing provides the highest hardness value at the largest electrode diameter. However, in general, the spiral swing is able to provide the highest hardness values when using electromagnetic diameters of 1.5 and 2.0 mm. The spiral swing is able to provide higher hardness values due to longer welding times or lower welding speeds, so it is able to provide better electrode melting times. This causes more perfect melt penetration.

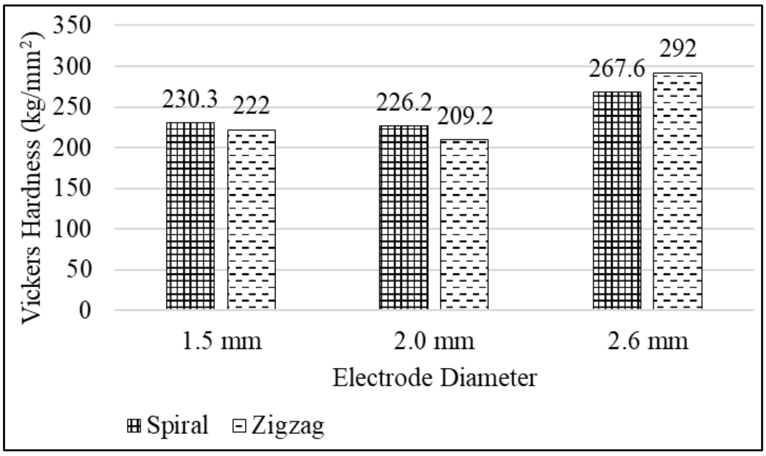


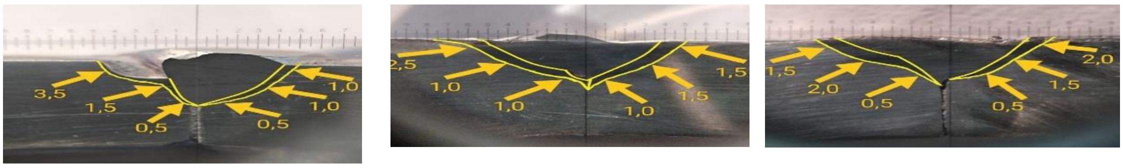
Figure 4. Hardness value of HAZ area resulting from MIG welding of SS 304 steel with variations in swing and electrode diameter

Macro Photo of Welding Results

Macro photo observations were carried out with the sample having gone through a grinding and polishing process, then given a 15% nitric acid solution to reveal the HAZ area. After the HAZ area is visible, measurements are taken using a loop, then a picture is taken and the weld area is mapped which looks like in Figure 5.

(i) Diameter of 1.5 mm (ii) Diameter of 2.0 mm (iii) Diameter of 2.6 mm

(a) Spiral swing



(iv) Diameter of 1.5 mm (v) Diameter of 2.0 mm (vi) Diameter of 2.6 mm

(b) Zigzag swing

Figure 5. Macro photo of MIG welding results for SS 304 steel with variations in swing and electrode diameter

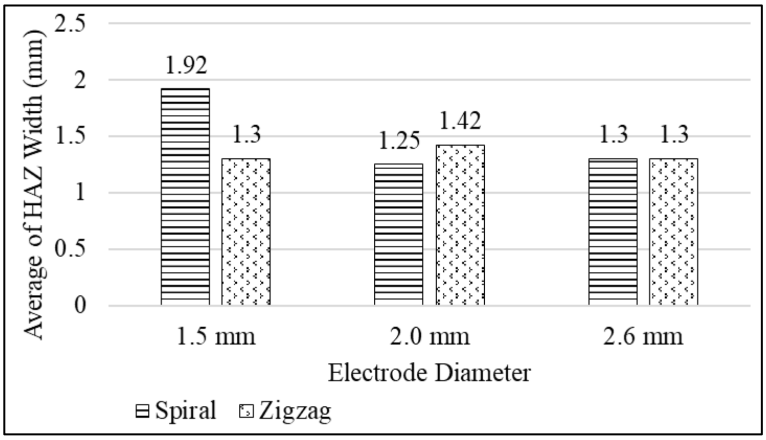


Figure 6. HAZ width resulting from MIG welding of SS 304 steel with variations in swing and electrode diameter

The HAZ width calculation is carried out at several points, three points each on the left and right sides, and then the average is calculated. The results of HAZ observations through macro photos show that the spiral swing provides the highest average HAZ width (Figure 6). The widest HAZ value of 1.92 mm was obtained for samples with a spiral swing and an electrode diameter of 1.5 mm. Overall, spiral swing provides the largest HAZ width due to the lower welding speed during the welding process, thus providing better penetration.

CONCLUSION

Based on the results and discussion that have been described, variations in the swing and diameter of the electrode used in the welding process affect the mechanical properties of the welded steel. The highest impact strength value was 0.459 J/mm^2 with zigzag swing and an electrode diameter of 2 mm. Then, the best hardness value was produced in zigzag welding and an electrode diameter of 2.6 mm, amounting to 292 kg/mm^2. Meanwhile, the widest HAZ was obtained at 1.92 mm in the welding results with spiral swing and a diameter of 1.5 mm.

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