Comparative Study between TIG and MIG Welding Processes

E. O. Ogundimu 1*, E. T. Akinlabi 1, 2 and M. F. Erinosho 3

1Department of Mechanical Engineering Science, University of Johannesburg, Auckland Park Kingsway Campus, Johannesburg, South Africa, 2006.
2Department of Mechanical Engineering, College of Engineering, Covenant University. Ota, Nigeria.
3Department of Mechanical and Industrial Engineering, University of Namibia, P.O. Box 3624, Ongwediva, Namibia.
Corresponding Author; segunbolly@gmail.com

Abstract-
In this research, studies were done on the material characterization of type 304 austenitic stainless steel weld produced by TIG and MIG welding processes. This research is aimed to establish optimized process parameters that will result in a defect-free weld joint, homogenous distribution of the iron (Fe), Chromium (Cr) and Nickel (Ni) was observed at the welded joint of all the six samples. The welded sample produced at the current of 170 A by TIG welding process had the highest UTS value of 621 MPa at the welds zone, and the welded sample produced by MIG process at the welding current of 150 A had the lowest UTS value of 568 MPa. However, it was established that TIG welding process is more appropriate for the welding of type 304 austenitic stainless steel compared to the MIG welding process.

Key words: EDS analysis, microstructure, MIG welding, TIG welding, average yield strength, UTS.

1. Introduction
Metal inert gas (MIG) joined two pieces of materials with a consumable wire attached to an electrode current. A wire is passed across the welding gun at the same contact as the inert gas and a range of materials with different thicknesses can be welded using the MIG arc process. This process is remarkable because of high penetration and quickness in producing welds [1]. However, MIG welding has some disadvantages including less stable arc, some irregular wire feedback, burn-back, more spark, and production of smoke and fumes in the process of welding. On the other hand, Tungsten inert gas (TIG) welding process is used widely in industries for welding stainless steel due to its arc stability, less contamination in its welds, higher quality weld and smooth head appearances. It is often used for thin and thinner gauge metals. One of the biggest advantages of this process is that the power can be controlled really low so that the material is not damaged [2]. However, the arc is sometimes influenced by electromagnetic forces, and the arc direction changes unexpectedly. Therefore it will be difficult to obtain sound welded joints in such situations. And also, the penetration in TIG arc welding is relatively small and the process is time consuming. The TIG welding process is most suitable for metal plate of thickness of about 5 - 7mm [3]. Thicker plates materials may also be welded using multi passes of TIG process which may resolved in high heat inputs on the base metal and resulting in distortion and decrease in tensile strength and low hardness values of the base metal. This welding operation is widely used in the so-called high-tech industry applications such as...
automobile industry, nuclear industry, food processing industry etc [4, 5]. Many recent surveys have proposed several ways by which the output work of a TIG welding process can be improved. Welding using oxygen content played a crucial part in the weld shape of work piece in TIG welding [6]. A very high-class of weld can be accomplished by applying TIG welding technology. In contrast, the penetration depth of a solo-pass TIG process is not more than 3 mm due to the limited penetration ability of TIG process [6 - 7]. A large thick work piece requires an appropriate weld joint planning, preparation and multiple passes welding are required to deposit a surplus filling metal into the layered groove [8]. The production cost at this moment is hereby high and the efficiency of weld joint is low compare to that of thin metal [9]. Although, the most two commonly used types of welding processes are tungsten inert gas (TIG) and metal inert gas (MIG) welding process. But the two processes differ in operation and some application. MIG technology utilized a consumable electrode for welding while TIG system used a non-consumable electrode for joining [10]. In MIG and TIG welding processes, the common parameters that influences a good quality and productivity are the arc voltage, welding speed and arc current [11, 12]. Though when hydrogen or helium is mixed with the shielding gas, then the welding speed can be considerably increased up to 160 % [13-15]. When MIG arc welding process is used as a substitute to the TIG arc welding process, it was permitted in a single pass the welding of a 6 mm thick welding joint. However, a number of appearance defects characteristically including humping, undercut and excess penetration welds were easily formed, which resist the further development of production [16]. An analysis was done on the welding region of Type-304 austenitic stainless steel after plasma nitriding process. It was conveyed that plasma nitriding is attainable on welded joints provided stress minimization during welding is applied [17].

A TIG welding process of Type- 304L austenitic stainless steel was revealed through the microstructure and mechanical test examination. The pulsed current setting and the weld bead profiles were compared. Residual stress with lower degree was detected in the pulsed welding current compared to the constant welding current. The formation of finer grains in the microstructure was reported [18]. A higher ultimate tensile strength (UTS) and yield strength were revealed in a non-pulsed current used for welding 304 stainless steel compared to the specimen welded with pulsed welding current [19]. The influence of welding current on the mechanical properties of TIG welding of Type-304 austenitic stainless steel was surveyed. It was reported that the joints welded with low current depicted a better UTS value than the weld that took place at high power supply [20]. However, this work gives a comparison between the MIG and TIG welding operation at different currents.

2. Methodology

The type-304 austenite stainless steel plate material of dimension of 175 mm × 100 mm × 6 mm was used for the welding operation and using 316 austenitic stainless steel rod as the filler material. The solid electrode is of diameter 2.4 mm for TIG operation and 1.2 mm for MIG welding respectively. In this present study, a single-groove at an angle of 45° was performed on the base materials so that welding process could be done in one number of pass for the both welding processes and to ensure full weld penetration.
TIG welding operations with three different currents of 150 A, 170 A and 190 A were used on the three different joint procedures in two passes using the direct current electrode negative (DCEN) TIG 200P THERMAMAX welding machine. Similarly, the MIG welding operation was done in two passes using the direct current electrode negative (DCEN) Miller CP-300 model MIG welding machine also using the same currents applied for TIG operation. Pure argon gas was used for shielding the processes.

The chemical compositions of Type-304 stainless that was used as the base metal are listed in Table 1.

| Elements | Maximum Requirement (%) |
|----------|-------------------------|
| Cr       | 19.50                   |
| Ni       | 12.0                    |
| Si       | 0.75                    |
| P        | 0.045                   |
| Mn       | 2.00                    |
| S        | 0.030                   |
| N        | 0.10                    |
| C        | 0.030                   |

After the welding operations, the samples were prepared for metallography. The samples are designated as T1, T2 and T3 for TIG samples and M1, M2 and M3 for MIG samples respectively. Prior to etching, the samples were grinded and polished. The samples were etched in a solution containing 4.25 g of ferric chloride, 1.2 g of cupric chloride, 62 ml of alcohol, 62 ml of hydrochloric acid and 3 ml of Nitric acid, for about 15 seconds [21]. The microstructures were characterized using the Scanning Electron Microscope (SEM). The tensile test was also carried out using the INSTRON. The specimen was cut according to ASTM E8/E8M-13a standard [22].

3. Results and discussion

Figures 1 (a) to (c) show the visual inspection of the welded front surface for TIG operation using current of 150 A, 170 A, and 190 A respectively. Likewise Figures 1 (d) to (f) show the visual assessment of the welded front surface for TIG operation using the same currents started above.
Figure 1: MIG and TIG welds at three different parameters: (a and d) welding current of 150 A, (b and e) welding current of 170 A, and (c and f) welding current of 190 A

The weldment quality was observed at the front and bottom views. There was no spatter and porosity observed from the welds. The weld shape is thin and smooth and the width of welds is about 4 mm approximately. The heat affected zones (HAZ)s are measured to about 30 mm in all the welds. A sound weld and smooth welding surfaces were noticed in samples T1, T2 and T3 with complete penetrations but little excess penetration was observed in welds of samples M2 and M3.

Figure 2 shows the microstructure of the base metal before the joining process.

![Microstructure of base metal](image)

Figure 2: Microstructure of base metal

The base material is characterized with the austenitic-grain microstructure of the Type-304 stainless steel and also shows equiaxed grains.

Figures 3 (a) to (c) depict SEM analyses of MIG welded samples M1, M2 and M3 welded at current of 150 A, 170 A and 190 A and Figures 3 (d) to (f) show the SEM analyses of TIG weld samples T1, T2 and T3 welded at the stated above currents.
In the HAZ, the microstructure on the austenitic side consisted of the untransformed δ-ferrite at the austenite grain boundaries. The HAZ was mostly better than the base metal microstructure and this could lead to a higher mechanical properties. The deviation in the dendrite magnitude can be credited to the fact that the cooling rate of a low welding is comparatively faster due to the creation of the steep thermal gradients in the welded joint, and which reduces the duration of the generation of dendrites. Some columnar grains were observed in the MIG welding as well as segregation which was as a result of microscopic banding and the cooling rate. The microstructures of the MIG welding were more refined compared to the TIG welding due to the weld efficiency and high penetration which however gives room for high cooling rate.

Figure 3: SEM images of the welding zones of the welded samples: (a) M1, (b) M2, (c) M3, (d) T1, (e) T2, (f) T3
Moreover, a higher welding current in samples M3 and T3 have led to the slow cooling rate and then provides bounteous time for the dendrites to propagate farther into the fusion zone. Figures 4 (a) and (b) show the EDS analyses of sample M2 and T2 welded at a current of 170 A at high spectrum.

Figure 4: EDS spectra of the welded samples: (a) M2, (b) T2

In the MIG weld of the samples, it was observed that iron (Fe) is the most prominent element in the composites with weight percent (wt %) between 63.8 wt % and 69.7 wt %; and depending on the region analyzed. Chromium (Cr) is the second noticeable element in the composition and ranges between 17.6 wt % and 18.0 wt % approximately. While in the TIG welded samples, the wt % of Fe is between 66.7 wt % and 71.6 wt % and the range between 18.4 wt % and 19.0 wt was observed for chromium. Carbon (C) and Nickel (Ni) were also obvious in the weld with other traceable elements. The presence of Fe has improved the mechanical properties of the welded joints.

The average ultimate tensile strengths (UTS) of the welded test samples were also conducted and the results were varied from 517 to 621 MPa for the participating. The yield strengths (YS)s are also varied from 367 to 400 MPa; these variations are depended upon the welding parameters used. Figure 5 shows the plot of the average UTS and YS of MIG and TIG welded samples.
Among the six welded samples assessed in this study, the lowest average UTS and YS values of 517 MPa and 367 MPa respectively were observed in sample T1 welded which was the welds produced by TIG at the current of 150A while the highest UTS and YS of 621 MPa and 400 MPa were observed in the welded plates of sample T2 which was welded by the TIG welds at current of 170A. From the data analyses of the tensile results, it was also observed that in each of the two welding methods used, the highest UTS and YS were found at the welding current of 170A.

4. Conclusion

MIG and TIG welding of 6 mm thick of type-304 stainless steel plates were carried out by two passes procedures. Successfully, without any weld defects, welded joints were produced. The welded samples were further characterized for the microstructures and mechanical properties. The melting power of MIG welding is thus very much higher than with the TIG process. From this study, the following conclusions can be deduced:

- Welds surfaces finishing of TIG welds are better than that of MIG welds.
- Penetrations of MIG welds are deeper than that of TIG welds.
- The UTS of the weld joint was varied with the welding parameters such as welding current and speed. However, the UTS values of the TIG welded joint are higher than that of MIG at the same welding current.
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