Araid Journal of Science and Technology (AJST)
Higher Institute of Science and Technology-Al Shmokh
مجلة الرائد للعلوم والتقنية
المعهد العالي للعلوم والتقنية - الشموخ

Received: 20 May 2026 | Accepted: 13 June 2026 | Published online: 30 June 2026

Study the comprising between TIG and MIG process and their effect on the mechanical properties and microstructure of the welding joints for low carbon steel

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ABSTRACT
TIG welding produces superior quality, cleaner and stronger joints in thin low-carbon steel due to precise heat control, while MIG welding offers higher productivity and deeper penetration, making it ideal for thicker sections. TIG typically results in finer microstructures (acicular ferrite) compared to the coarser grains often found in MIG. A review of the literature indicates that both welding techniques—whether used individually or in combination—achieve full weld penetration, and that the heat-affected zone in TIG-MIG welding is wider than in standalone TIG or MIG welding. TIG-MIG joints typically exhibit ductile fracture behavior compared to joints produced by standalone MIG or TIG welding. Nevertheless, they demonstrate favorable properties, such as tensile strength, when compared to the individual TIG and MIG processes. Furthermore, a comparison between TIG-MIG techniques and conventional MIG welding reveals a more refined joint appearance, as evidenced by the various microstructures of the joints.

KEYWORDS: Microstructure, Mechanical properties, MIG welding, TIG welding.

1. INTRODUCTION

Quality of the welded joint with appropriate geometry, mechanical properties and physical properties. Carbon steel characteristics are appropriate for its carbon level which is considerably used in mechanical engineering components. It is categorized into low-carbon steel considerably used for heavy components, and medium carbon steel used for pressure components, gears, railways, and shafts. High-carbon steel is used for cutting tools, brackets, and the fabrication processes [1,2]. The technology progresses through to the industrial aspect quickly. Many industrial areas utilize Metal Inert Gas (MIG) welding for several occupations in steel construction, especially mild carbon steel. Metal Inert Gas welding procedure generates efficiency, mainly in welding results and quick time of process [3]. In general, steel material is used not in sheet form or pieces, but it is used by making it in a shape so necessary for joining (welding) process is carried out to produce a product ready-to use product. There are various types of welding available. So must be able to choose the right welding technique to obtain a product with good results. Welding-related issues vary depending on the specific type of stainless steel being welded. This research aims to determine the effect of welding methods—specifically TIG and MIG—on the tensile strength, impact and toughness, Vickers micro-hardness, and microstructure of SS304 and SS316 stainless steels. Welding was performed on samples ranging from 2 to 3 mm in thickness, followed by a series of tests, including tensile, impact and hardness testing, as well as microstructural analysis. Both TIG and MIG welding techniques influence the properties of each material, affecting the results of microstructural, hardness, tensile, and impact tests [4]. Welded joint configurations significantly influence the selection of welding current and joint type (weld geometry) when using filler materials compatible with the base metal. This research aims to determine the effect of joint configuration and electric welding current on the strength of MIG-welded low-carbon steel. Test results, conducted using varying current levels, indicate that each joint configuration requires a specific current to achieve high-quality welds. Tensile test data—performed in accordance with the ASTM E-8 standard—revealed that the highest tensile strength for MIG welding was recorded using a Type-I joint at a current of 150 A, reaching 45.582 kg/mm^2. It was also observed that increasing the current intensity resulted in more distinct grain structures and a smoother texture in the weld metal zone [5].

An evaluation of the mechanical properties of TIG-welded low-carbon steel showed that the specimen's ultimate tensile strength increased with a higher gas flow rate; conversely, a decrease in tensile strength was observed when the gas flow was reduced. The specimen processed with a current of 60 A, a 2 mm diameter filler rod (electrode), and a gas flow rate of 6 L/min exhibited a maximum tensile strength of 424.31 MPa, whereas the specimen processed with a current of 40 A, a 1.5 mm electrode diameter, and a gas flow rate of 5 L/min recorded a tensile strength of 356.10 MPa [6].

This study investigated the welding of low-carbon steel used in the manufacture of automotive liquefied petroleum gas (LPG) tanks, employing key characterization techniques such as scanning electron microscopy (SEM), hardness testing, X-ray diffraction, and optical microscopy. The study revealed variations in microstructure and mechanical properties among the welded joints; consequently, findings were established regarding the base metal, the heat-affected zone, and the fusion zone of joints produced using the two methods.

The area of the fusion zone in the laser-welded joint sample differs from that of the TIG-welded joint. X-ray diffraction analysis showed that no new phases formed in the welded joint samples, whereas hardness test results revealed microstructural differences among the three zones [7].

2. METHODOLOGY

The type- low carbon steel plate material of dimension of (175 mm × 100 mm × 4 mm) was used for the welding operation. 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 120 A, 140 A and 160 A were used on the three different joint procedures one passes using the Super TIG 250 arc welding machines, ventilated, controlled by thyristors for TIG and MMA welding a direct current (DC) and alternating current (AC) supplied with HF generator (high frequency) for starting in TIG without contact. Universal use for low carbon steel. THERMAMAX welding machine. Similarly, The MIG welding process was carried out in two passes using a Miller CP-300 MIG welding machine, with the polarity set to electrode negative (DCEN) and current values identical to those used in the TIG welding process. Pure argon gas was used to shield the weld zone during the operations.

Table (1) presents the chemical composition of the low-carbon steel used as the base metal.

Table 1: shows the chemical composition of low-carbon steel.

Element	C	Si	Mn	S	P	Ni	Cu	Cr	Fe
wt %	0.114	0.149	0.547	0.0271	0.0113	0.163	0.271	0.157	Bal.

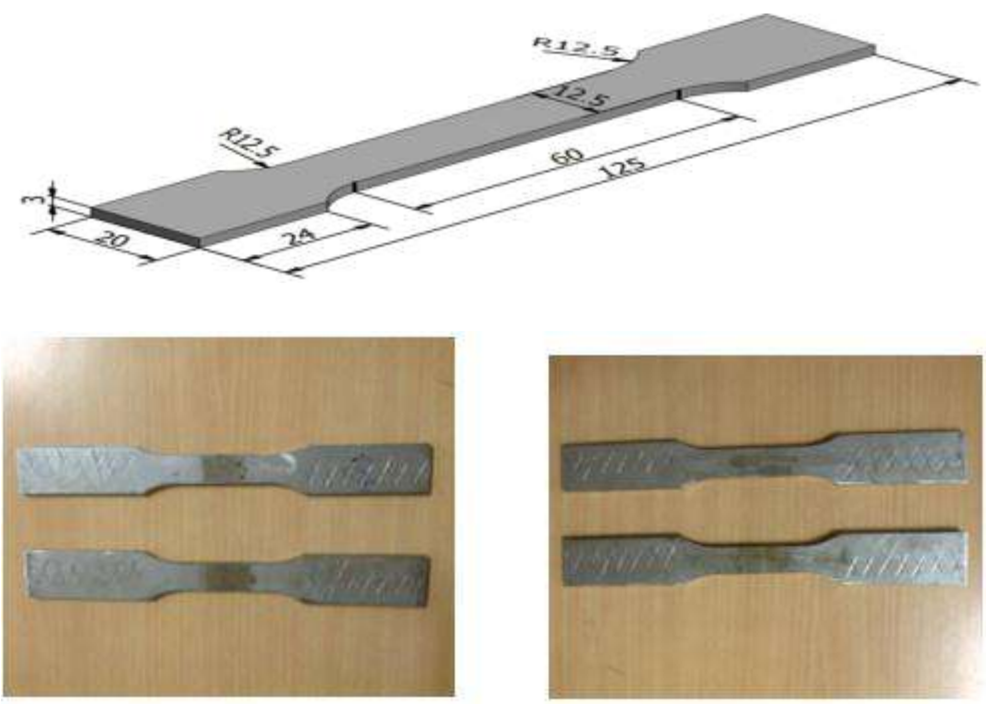

Figure 1: Illustrate standard tensile test for TIG and MIG specimens

3. RESULTS AND DISCUSSION

3.1. Mechanical properties of TIG welding process

3.1.1. Tensile strength

The tensile properties of joints produced via Tungsten Inert Gas (TIG) welding were evaluated; tests were conducted on three replicate samples for each welding type, and average values were calculated. Fracture occurred in the base metal region for all welded joints—indicating the strength of the weld joints—which is industrially acceptable. Figure (2) shows the fractured samples for both welding types.

Figure 2: Illustrate the TIG and MIG Testing specimen after tensile test

Table.2: Tensile strength test values for TIG and MIG welding processes

Welding type	Specimen No	Rpy (Nmm^2)	Rm(Nmm^2)	Fm(kN)	Fb(kN)	Elongation
TIG	A	155	236	26.71	22.31	10%
MIG	B	164	243	26.82	23.64	11%

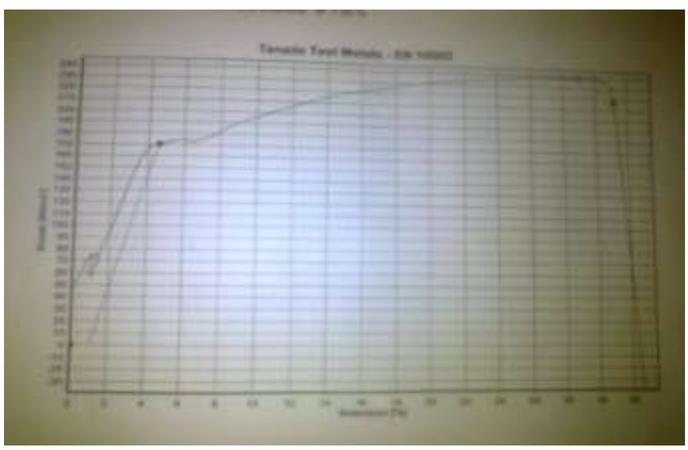

Figure 3: Illustrate the stress-strain plot for the low carbon steel of TIG welding processes

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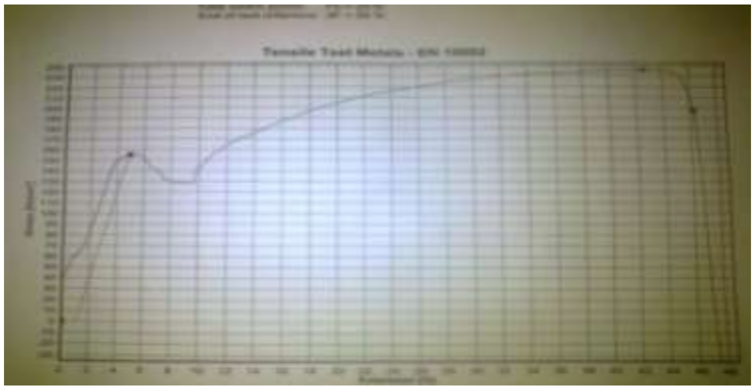


Figure 4: Illustrate the stress-strain plot for the low carbon steel of MIG welding processes

A comparative stress-strain plot for one out of the three replicates specimens for each welding type is presented in figures 3 and 4.
Tensile test results indicate that the hybrid (TIG-MIG) joint exhibited superior tensile strength, yield strength, and elongation compared to joints welded using the MIG or TIG methods individually. Additionally, the MIG-welded joint demonstrated higher tensile and yield strengths than the TIG-welded joint. However, the elongation of the TIG-welded joint was higher than that of the MIG-welded joint. Tensile strength determines the load-bearing capacity of the welded parts, whereas yield strength defines the limit below which no failure occurs. Notably, although the heat input during the hybrid (TIG-MIG) welding process was higher than in the separate TIG and MIG processes, the tensile properties were not adversely affected.

3.1.2. Hardness Testing

Hardness testing of the welded joints was conducted in accordance with the ASTM A370-14 standard using a Rockwell hardness tester. The specimen was positioned with its surface resting on the machine's base (anvil), and the handwheel was slowly turned to raise the specimen until it made contact with the indenter; the values were then read directly from the dial indicator and converted to the Vickers scale.
Hardness tests were conducted sequentially to ensure coverage of the base metal, the heat-affected zone, and the weld metal, at a distance of less than or equal to 2 mm from the surface and 2 mm from the fusion line. The figure presents a schematic diagram of the butt joint and groove weld, indicating the hardness test locations.
Figure 6 also illustrates the Vickers hardness distribution for the three welding processes (TIG, MIG, and combined TIG-MIG welding for low-carbon steel).

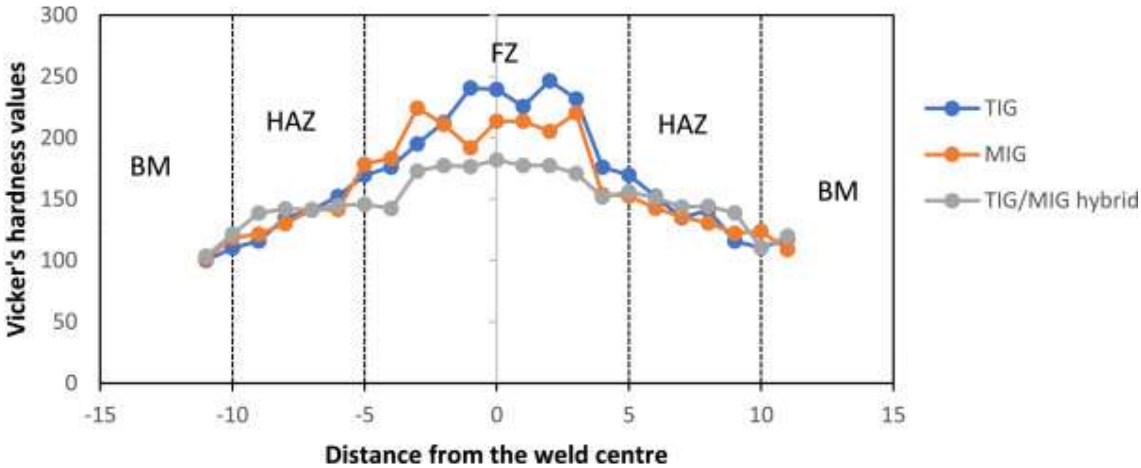
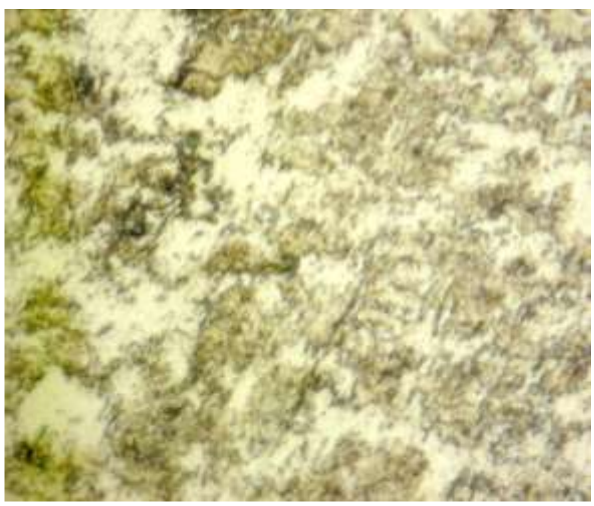


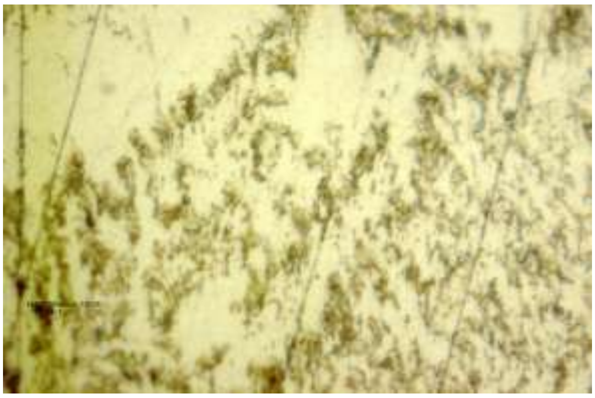
Figure 5: Illustrate the hardness test of TIG and MIG for low carbon steel

3.1.3. Microstructure analysis

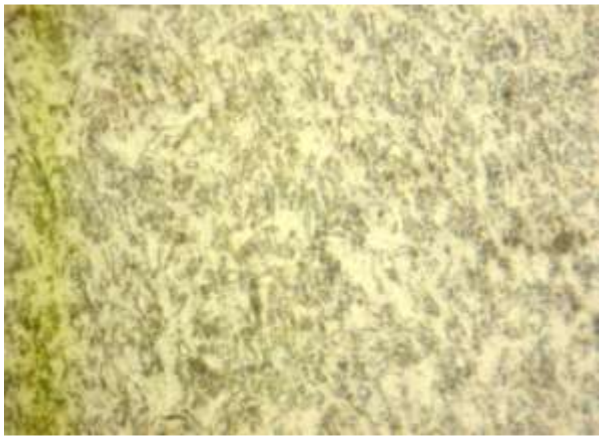
The microstructure of the low-carbon steel is shown in Figure 4.4a. This structure consists of ferrite (the light-colored matrix) and pearlite (the dark phase); signs of segregation are evident, and impurities are present at the grain boundaries. The microstructure of the low-carbon steel used in this study comprised ferrite and pearlite, with the base metal containing approximately 80–85% ferrite and 15–20% pearlite. Following the welding process, the weld metal zone exhibited significant changes compared to the other regions, resulting from recrystallization and microstructural inhomogeneity caused by rapid cooling. The microstructure of the weld can vary significantly depending on the number, size and distribution of inclusions present



(a) Base metal



(b) HAZ

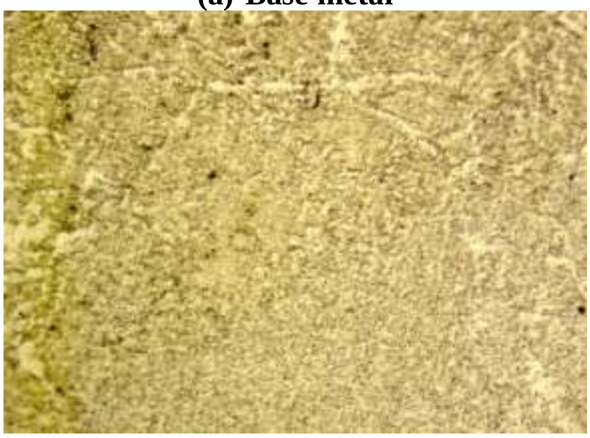


(c) Fusion zone

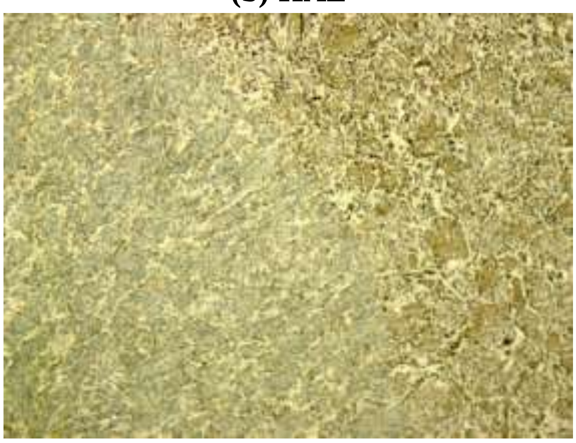
Figure 6: Illustrate the base metal, HAZ and fusion zone microstructure of low carbon steel for TIG welding process

Different microstructures form in the weld metal zone of low-carbon steel, depending on heat input and cooling rates. Figure 4.5 shows that the microstructure of the TIG weld joint consists predominantly of polygonal ferrite grains and ferrite laths. While the MIG weld microstructure also contained polygonal ferrite and ferrite, the TIG joint structure was composed primarily of acicular ferrite (a needle-like form of ferrite) with a small amount of ferrite at the grain boundaries; additionally, it was observed in the low-carbon steel weld that the lengths of the ferrite laths were governed by the carbon diffusion process. Studies on the microstructural evolution of weld metal demonstrate that heat input and filler metal composition play a critical role in determining the resulting weld microstructure. Observations indicate that high heat input leads to slower cooling rates, resulting in a coarse-grained microstructure, whereas low heat input leads to faster cooling and a finer-grained microstructure. Furthermore, the combination of high heat input and rapid cooling rates in weld metals can lead to the formation of fine-grained polygonal ferrite at room temperature. On the other hand, the delta ferrite content decreased as the heat input increased. Specifically, the ferrite content in samples welded with heat inputs of 0.72, 0.84 and 1.0 kJ/mm was approximately 13%, 9% and 5%, respectively—a result of the relationship between heat input and cooling rate. In this study, the heat inputs were calculated to be 0.91, 1.33, and 3.37 kJ/mm for the TIG and MIG welding processes, respectively. Examination of the microstructure of the heat-affected zone (HAZ) revealed some grain coarsening resulting from heat transfer within this region.

(a) Base metal



(b) HAZ



(c) Fusion zone

Figure 7: Illustrate the base metal, HAZ and fusion zone microstructure of low carbon steel for MIG welding process

4. CONCLUSION

MIG and TIG welding processes were performed on 4 mm thick low-carbon steel plates using a two-pass welding procedure, successfully producing defect-free welded joints. The welded samples underwent further testing to determine their microstructure and mechanical properties. It was found that the melting capacity in MIG welding is significantly higher than in TIG welding. The following conclusions can be drawn from this study:

a-The surface finish quality of TIG welds is superior to that of MIG welds.

b-The penetration depth in MIG welds is greater than in TIG welds.

c-The tensile strength of the welded joint varied with changes in welding parameters, such as welding current and speed; however, TIG-welded joints exhibited higher tensile strength values than MIG-welded joints when using the same welding current.

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