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Laser and TIG Welding of Low Carbon Steel for LPG Car Tank Industry

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Abstract

The objective of this study was the investigation of the effect of the welding process on low carbon steel. This steel was welded by TIG and laser welding. This steel is used for manufacturing of car GPL storage tanks. Four main characterization techniques were used: optical microscopy, scanning electron microscopy, hardness measurement, and X-ray diffraction. We have found a microstructural and mechanical difference between the welded joints.

Keywords: Microscopy; Carbon steel; X-Ray Diffraction; GPL Storage tanks; Welding process; Heat-Affected Zone; Weld metal; Fusion zone; Liquefied petroleum Gas; Tungsten inert gas

Abbrevations: BM: Base Metal; HAZ: Heat-Affected Zone; WM: Weld Metal; FZ: Fusion Zone; TIG: Tungsten Inerst Gas; LPG: Liquefied Petroleum Gas; EDS: Energy Dispersive Spectroscopy; HAZ: Heat Affected Zone; SEM: Scanning Electron Microscope

Introduction

Welding is a fabrication or sculptural process that joins materials, usually metals or thermoplastics, by using high heat to melt the parts together and allowing them to cool causing fusion. Welding is distinct from lower temperature metal-joining techniques such as brazing and soldering, which do not melt the base metal [1]. The main types of Fusion Welding are the arc welding which is the most popular type of fusion welding, the laser welding, induction welding, oxyfuel welding, and solid reactant welding. In general, fusion welding consists of three distinct zones, namely the base metal (BM), heat-affected zone (HAZ) and weld metal (WM) or fusion zone (FZ)[2]. Steels are generally welded by fusion welding and among these processes there is laser welding and tungsten inerst gas welding (TIG). TIG arc welding is the most popular method for welding steels. Laser beam welding is a fusion welding process in which two metal parts are joined together with the help of a laser. The laser beam provides a source of concentrated heat, focused in the cavity between the two metal parts to be assembled [3]. The welding process is used in manufacturing of liquefied petroleum gas (LPG) tanks. LPG tanks are generally made of welded steel, aluminum or composite materials. LPG tanks are used in the automotive industry to store fuel safely. Steel is by far the most common material, as it is the easiest to fabricate and it is an inexpensive material [4]. The steel used to create storage tanks falls into two broad categories: carbon steel and stainless steel. Carbon steel is preferred wherever possible as it is significantly cheaper than stainless steel. Low carbon, or mild, steel contains between 0.05% and 0.15% carbon. Because of this, it is quite malleable and can be easily bent, rolled, and welded into desired shapes. This flexible quality makes it easy to form the basic "disc and donut" assemblies that are used to create many finished storage tanks from carbon steel plates [5]. The objective of this study is to investigate the effect of the welding process on the metallurgical aspect of the low carbon used for the manufacturing of the liquefied petroleum gas (LPG) tanks. TIG and laser welding were used in this investigation.

Experimental Procedure

For the two-welding process (laser and TIG welding), the type of steel used is BS2 low carbon steel which the chemical composition is given in Table 1. The steel was obtained in the form of plates which had a warm rolled. The thickness of welded plats is equal to 3 mm (Figure 1). The TIG welding was done in the industrial company of metal equipment manufacture for storage of fuels. The main welding parameters by TIG process are Current I = 84 A, filler rod 2.4 mm, argon gas with pressure P = 18 Bar. The main welding parameters by laser process are laser power = 2 kW, continuous move mode, impulse frequency = 20000 Hz, shield gas = argon with pressure of 20 l/min. For the two welding processes, the thickness of the joint is 1 mm. Samples were cut to from the welded plates and then polished with abrasive papers. The samples are chemically etched by a reagent called Nital (Nitric acid + Ethanol), with 2% Nital (Figure 2). For microstructural observations, an optical microscopy was used, and scanning electron microscope (SEM) (Zeiss Gemini SEM 300) equipped with an energy dispersive spectroscopy (EDS) detector). Hardness measurements were performed by using Hardness tester (Type: INNOVATEST) with load of 2 Kg. Analysis of the phases was conducted using X-ray diffractometer, Siemens model (BRUKER D8 DISCOVER) with Cu Kα radiation, in 2θ range from 10° to 90°.

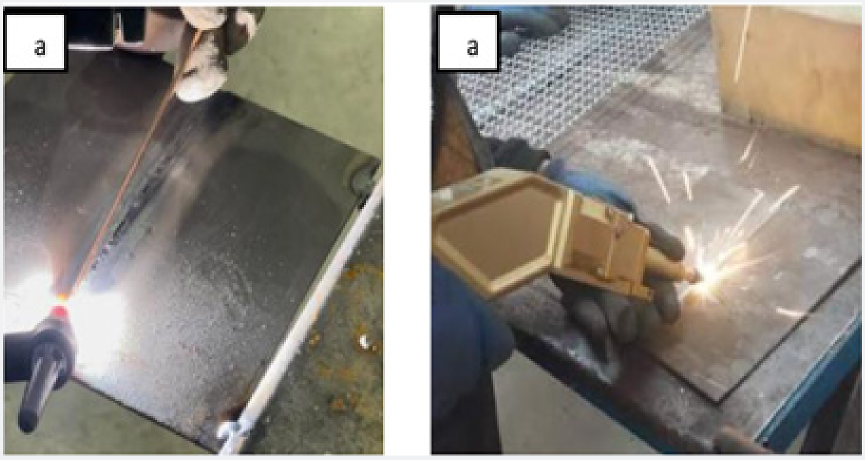

Figure 1: Welding of plats of low carbon steel by (a): TIG and (b): Laser welding processes.

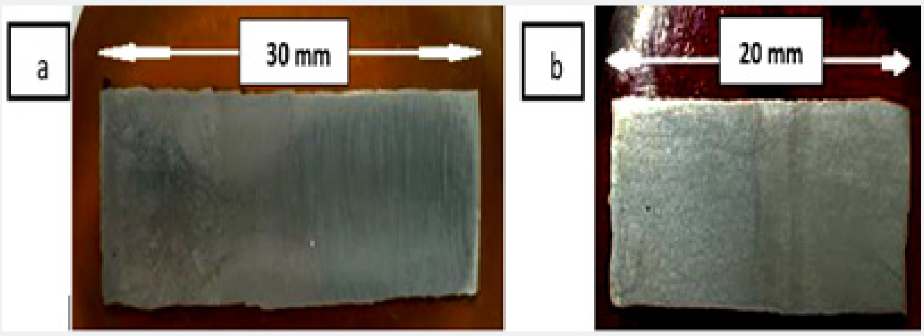

Figure 2: (a) TIG welded sample and (b) Laser welded sample after metallographic preparation.

Results and Discussion

Macrographic view

Figure 3a shows the two welded joints which were joined by the two processes (TIG Welding and laser welding in Figure 3b. The difference between the two joints is very visible because the TIG welded joint is very wide which has produced a larger heat affected zone. On the other hand, the laser welded joint formed a very thin joint which gave a narrower HAZ. The heat affected zone (HAZ) formed during welding is an area in which some structural changes in the welded material take place as the result of experienced temperature [6,7].

Microstructures observations

The microstructures of the two joints welded by TIG and laser are presented in (Figure 4,5) respectively. The three main zones (Base Meta, Heat Affected Zone and Fusion Zone) are illustrious. For the two welded joints, the microstructure of the base metal is the same, because it is formed of two phases (matrix in ferrite and colonies of pearlite). However, the difference is apparent between the heat affected zone in the two welded joints. The HAZ in the first TIG welded joint is characterized by a large amount of

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pearlite compared to the HAZ in the laser welded joint. This is due to the thermal effect produced by each type of welding process which confirms our previous studies [8,9] . For the fusion zone, the FZ in the TIG welded joint has a microstructure similar to a solidification microstructure and which is generally observed in arc welded steels. For example, a Widmanstätten ferrite (αw) was formed (Figure 4b). Widmanstatten ferrite develops from any allotriomorphic ferrite that may be present in the microstructure (Figure 6). Widmanstatten ferrite can form at temperatures close to theAe3 temperature and hence can occur at very low driving forces; the undercooling needed amounts to a free energy change of only 50 J mol-1. This is much less than required to sustain diffusion less transformation [10]. On the other hand, the FZ of the joint welded by laser is characterized by the formation of elongated bands and fine grains which is totally different from that observed in the joint welded by TIG. The observation by electron microscopy allowed us above all to confirm the observations made by optical microscopy and to observe other details such as the microstructure of the figure which shows that the size of the grains in the fusion zone of the joint welded by laser is of the order of 5μm.

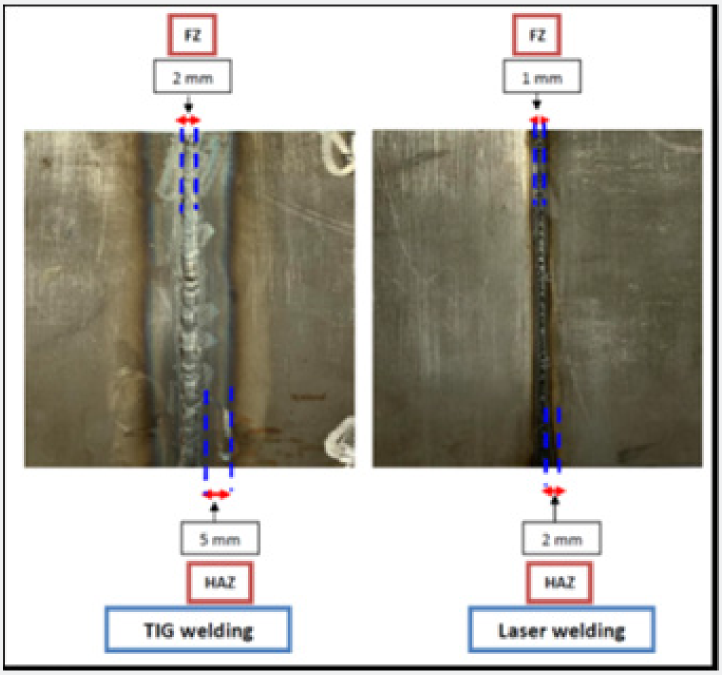

Figure 3: Welded plats of low carbon steel by TIG and Laser welding processes.

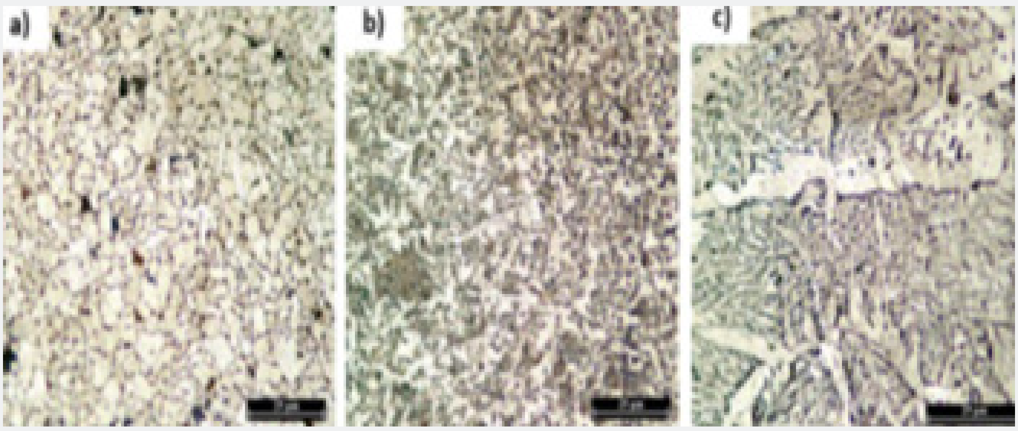

Figure 4: Microstructures of the joint welded by TIG process.
(a): Base metal (BM) (b): Heat Affected Zone (HAZ), and (c): Fusion Zone (FZ).

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X-ray diffraction

X-ray diffractograms of the base metal (Figure 7a), the TIG-welded joint (Figure 7b), and the laser-welded joint (Figure 7c) revealed the presence of ferrous phase peaks. This result indicates that there was no formation of new phases like martensite. However, the intensities of the peaks in the diffractogram obtained on the joint welded by laser are higher (Figure 7c), which confirms the small size of the grains in the fusion zone.

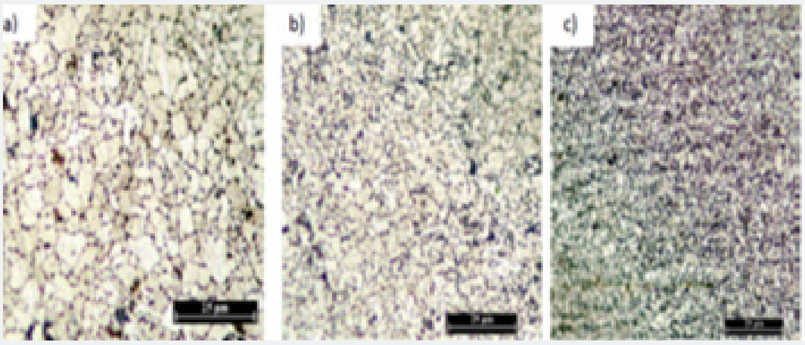

Figure 5. Microstructures of the joint welded by laser process.
(a): Base metal (BM) (b): Heat Affected Zone (HAZ), and (c): Fusion Zone (FZ).

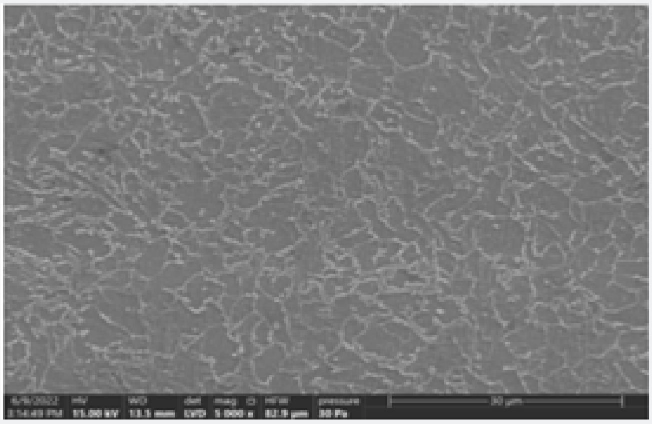

Figure 6: SEM observation of the FZ joint welded by laser process.

Hardness measurements

The microhardness profiles across the two welded joints are shown in Figure 8. The hardness profile in the TIG welded joint varies from point to point across the joint (Figure 8a). The hardness increases from the base metal to the boundary of the HAZ with the FZ and drops to the center of the FZ. However, the hardness across the joint welded by the laser process increases starting from the base metal then passing the HAZ and which registers the greatest value in the FZ (Figure 8b). This increase in hardness in the HAZ is due to its microstructure which contains fine grains as observed by optical microscopy.

Conclusion

Based on our results, the main following results were obtained

- The three main zones (BM, HAZ, FZ) were observed in the welded joint by the two processes.
- The fuzion zone in welded joint by laser process is different from the fusion zone in the welded joint by TIG process.
- X-ray diffraction analysis revealed no formation of new phases in the two welded joints.
- The hardness values in welded joint have confirmed

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the difference between the three zones from the microstructural aspect.

- The welded joint by laser welding is formed with finer grains than the welded joint by TIG process. This is confirmed by XRD.

- The welded joint by laser welding is different from the welded joint performed by TIG process in terms of hardness.

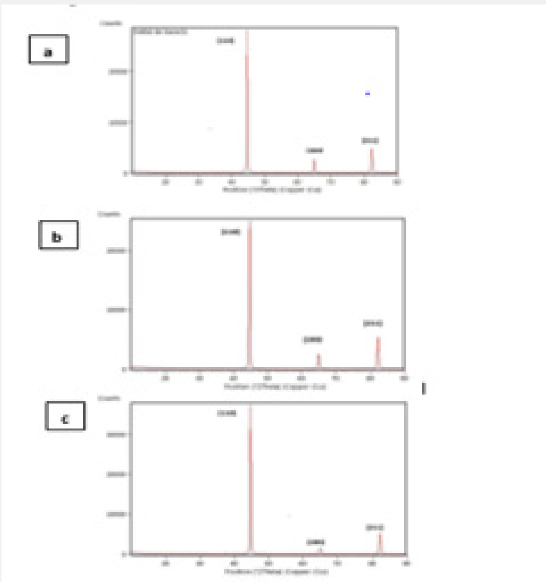

Figure 7: XRD diffractograms of the (a): BS2 low carbon steel, (b): of the welded joint of low carbon steel by TIG process and (c): of the welded joint of low carbon steel by laser process.

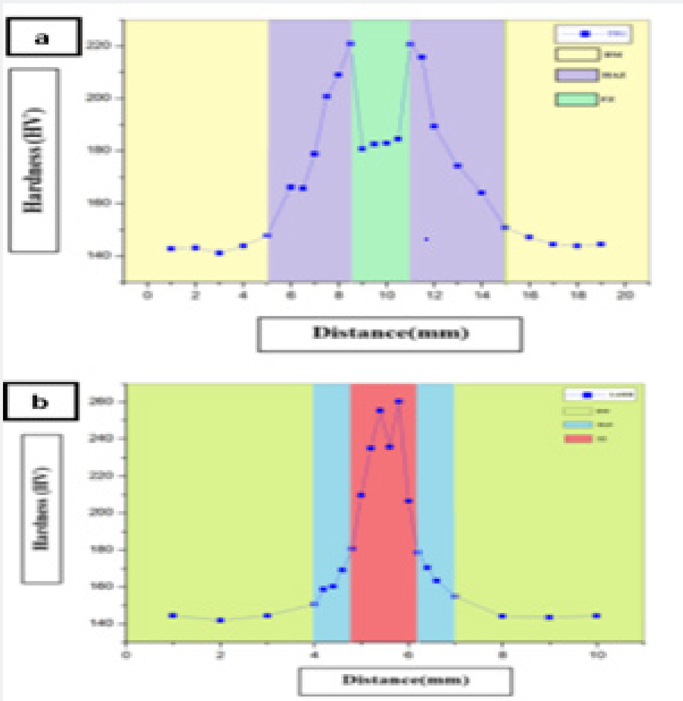

Figure 8: Microhardness profiles across the two welded joints by (a): TIG process, and (b): laser process

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Table 1: Chemical composition of BS2 steel (Wt.%).

C	Mn	Si	S	P	Al	Ti
0.15	0.63	0.19	0.01	0.02	0.04	0.01

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