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COMPARISON STUDY OF THE JOINT STRENGTH USING WELDING METHODS

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ABSTRACT

This paper shows the effects of manual metal arc welding (MMAW) and tungsten inert gas (TIG)welding processes on two types of joints (lap and butt joints) to evaluate the strength of welded joints of the specimens that is made of steel (ST52-3). Tensile and bending tests were executed to study the mechanical properties of welding joints. The experimental results prove that the welded joint could have more strength than the elements if a suitable welding procedure is utilized, and also if the filler metals used has physical specks superior to those of the elements. The results also show that MMA welded joints are more powerful than those produced by the TIG welding technique.

KEYWORDS: *Butt Joint, Lap Joint, MMAW, Tungsten Inert Gas (TIG), Tensile Test, Compression Test, Bending Test*

INTRODUCTION

Welding processes that are widely utilized in the industry include manual metal arc (MMA) or shielded metal arc (SMA), gas metal arc (GMA), submerged arc (SA), gas tungsten arc (GTA), oxy-acetylene, resistance welding, thermit welding, and cold pressure welding. Most of these techniques have specific fields of influence [1]. For instance, GMAW is mainly appropriate for joining the low carbon steel constructions as also joining the stainless steel and aluminium [2] while SAW is more popular for joining of thick steel plates such as ship building and large diameter pipes manufacturing [3]. GTAW is generally utilized for welding of thin plates [2] while resistance welding is commonly used within the automobile industry [4]. Thermit welding is suited for welding of rails in situ [5] while cold pressure welding is used by food processing industry [1]. However, MMAW and TIG welding techniques are the general purpose methods with a wide range of applications [1].

Welding can lead to weakness in the mechanical properties of the welded material. The welded joints might also face certain quality defects that reduce the joints' strength. Those defects are difficult to detect. Many researchers have studied the effects of welding process on the properties of welded joints. For instance, the strength of welded joints has been investigated by [6] when the Arc welding process was used. Another study was done based on Design of Experiment (DOE) to estimate the welded joints' strength by using traditional welding processes [7]. The authors in [8] performed experiments based on Bead-on-plate on austenitic stainless steel (AISI 316L (N)) consuming flux cored arc welding (FCAW) method. Some researchers have investigated the strength of welded joints within dissimilar metals. Khuder and Ebraheam (2011) [9] described the factors that influence the welding joint of Austenitic stainless steel (316L) that is welded to carbon steel by using GMAW. Alves *et al.* (2010) [10] evaluated the welded joints of aluminum (AA1050) and stainless steel (AISI 304) that can be used in pipes.

The main objective of this paper is to explore the effect of MMAW and TIG welding techniques on the properties of welded joints (butt and lap). MMAW used an electric arc between an electrode and a weldment or between two electrodes to heat the joint to be welded. MMAW is very widely used in the industry [1, 11&12].TIG welding method uses acetylene gas that is mixed with oxygen in the gas welding torch. These gases are then burnt at the torch tip to provide a temperature at the centre flame is about 3000 °C that is capable to melt metals and alloys [11]. This paper firstly describes the fundamental information of the experimental procedure. This is followed by analyses and discussions of the experimental results; and finally the conclusion of the work is presented.

Experimental Procedures

MMAW and TIG welding processes were chosen to weld the samples of steel (ST52-3). Tables (1) and (2) show the chemical composition and the mechanical characteristics of steel chosen, respectively. The steel samples were welded within two types of joints (butt and lap). In butt joint, the joined pieces lie in the same plane and are then welded at their ends while in the lap joint two overlapping parts are welded. The option of welding was a flat. In MMAW method, the electrode filler metal that was used in the experiment is J38.12 (AWS E6013) [13] of (2.5mm) diameter; this type comprises (C, Mn, S, P, and Si) as a deoxidize components that are added to achieve a high quality of welding (see Table 3). In TIG welding, the filler rod stainless steel ER316LSi x 1.6mm [14] is used. Table (4) shows the chemical composition of this filler [14].

Table1: Chemical Analysis of the Steel (ST52-3) [15]

Elements	C	Mn	Si	S	P
Wt%	0.22	1.60	0.55	0.04	0.04

Table 2: Mechanical Properties of the Steel (ST52-3) [15]

Yield Strength (ReH) (N/mm^2)	Ultimate Tensile Strength (Rm) (N/ mm^2)	Elongation (%)
335	490-630	21

Table:3 Chemical Composition of Arc Welding Rod Filler AWS E6013

Elements	C	Mn	Si	S	P
Wt%	0.06	0.32	0.23	0.013	0.012

Table 4: Chemical Composition of TIG Rod Fillerer316lsi

Elements	C	Si	Mn	p	S	Cu	Ni	Cr	Mo
Wt%	0.03	0.65-1	1-2.5	0.03	0.03	0.75	11-14	18-20	2-3

RESULTS AND DISCUSSIONS

The bending tests have been carried out to verify welded joints' strength and flexion. The strength of material is estimated by supplying an increasing load centrally on the specimen until failure 0ccurs. The equation (1) is used to determine the fracture stress (σ_f) [16]

$$\sigma_f = \frac{3LP_f}{2wt^2} \quad (1)$$

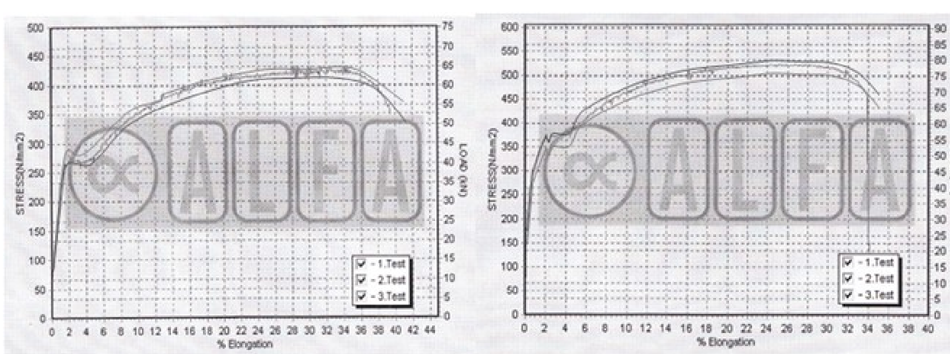
Where L is the long of the specimen P_f is the maximum load reachedin the test, w denotes the sample width, and t is the specimen's thickness. Table (5) shows the bending tests results. The bending tests showed that the strongest joint of steel (ST52-3) was also made within MMAW lap joint in comparison with other techniques. In this case, the maximum load that could be supplied on the steel samples was 3950N. As such, the maximum fracture stress was 1767.30 N/mm^2 for MMAW lap joint compared to (970.44, 940.22 and 646.11) N/mm^2 that occurred with MMAW butt and TIG lap and butt joints, respectively.

Table 5: The results of the Bending Test

Welding Type	MMAW						TIG					
Welding Joint Type	Butt			Lap			Butt			Lap		
Sample No.	1	2	3	1	2	3	1	2	3	1	2	3
Maximum load (N)	2100	1950	1700	3950	3600	3450	1400	1350	1200	2050	1900	1800
Fracture stress (N/mm^2)	970.44	878.17	755.66	1767.30	1660.51	1564.10	646.11	631.51	544.23	940.22	845.09	812.12

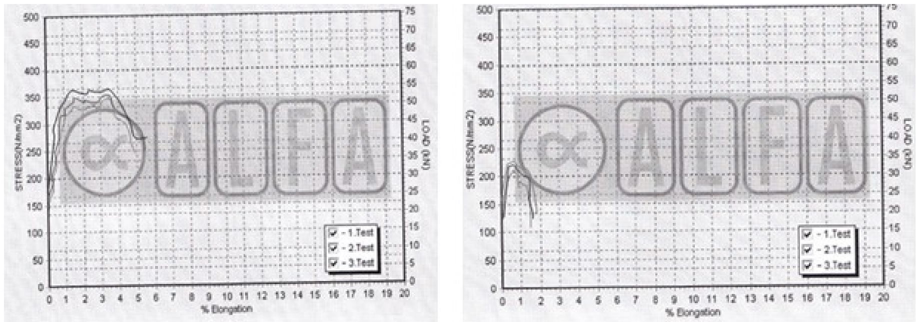
Tensile tests were performed using universal tensile and compression tester (UBCH-001) [17]. Table (6) demonstrates the results achieved from the tensile tests. The samples of steel (ST52-3) that were joined by MMAW have presented the highest ultimate tensile strength (UTS) in comparison with the TIG samples. In such a case, a strongest joint of steel (ST52-3) was produced by MMAW. The maximum UTS was 536.23 N/mm^2 for the MMAW lap joint, which means the UTS of MMAW lap joint was greater than the minimum base metal UTS (see Tables 2 and 5). The minimum UTS was 235.17 N/mm^2 that was achieved within the TIG lap joint. As such, the UTS of the lap joint reached only to 37 % of the base metal maximum UTS and therefore, the welded joints were weaker than the welded samples.

The yield strength of the lap joints that were made by MMAW was the highest compared with the welding joints that was created by the TIG welding, and that had the least yield strength. The MMAW joints of the specimens of steel (ST52-3)had the highest percentage elongation that showed ductility between 24% and 35% while the specimens that were joined by the TIG welding had failed without any elongation. Figures 1 and 2 show the stress-strain curves of tensile test for MMAW and Toweling, respectively.



(A) (B)

Figure 1: Actual Stress-Strain Curves for Steel (ST52-3) Sample using Manual Metal arc Welding (MMAW) within (A) Butt Joint and (B) Lap Joint.



(A) (B)

Figure 2: Actual Stress-Strain Curves for Steel (ST52-3) Sample using TIG Welding within (A) Butt Joint and (B) Lap Joint.

Table 6: The Tensile Tests' Parameters

Welding Type	Welding Joint Type	Sample No.	Ultimate Tensile Strength (Rm) (N/mm^2)	Yield Stress (ReH) (N/mm^2)	ReH /Rm	Yield Load (kN)	Maximum Load (kN)	Elongation %
MMAW	butt	1	445.62	356.05	0.800	54.15	67.21	31.10
		2	441.08	351.21	0.796	53.77	63.16	27.50
		3	430.28	348.08	0.809	51.79	62.77	24.10
	lap	1	536.23	389.18	0.726	57.55	80.18	35.04
		2	512.23	365.27	0.713	54.14	77.66	33.30
		3	488.45	352.67	0.721	53.24	75.32	31.60
TIG	butt	1	356.17	0.00		0.00	53.44	0.00
		2	355.41	0.00		0.00	51.64	0.00
		3	349.78	0.00		0.00	54.55	0.00
	lap	1	235.17	0.00		0.00	35.80	0.00
		2	238.15	0.00		0.00	32.33	0.00
		3	237.11	0.00		0.00	33.11	0.00

CONCLUSIONS

Specimens of steel (ST52-3) were joined using MMAW and TIGwelding processes. The tensile and bending tests were performed to examine the strength and ductility of joints. The selection of two types of joints (lap and butt) for welding represents a significant role in determining the characteristics of the weld. From the results, it was concluded that:

- A strong welded joint of steel (ST52-3) is made by MMAW procedure.
- The MMAW lap joints of steel (ST52-3) are presented maximum UTS.
- The Toweled joints of steel (ST52-3) have poor UTS for both lap and butt (see Table 6).

- The yield strength of MMAW welded joints of steel (ST52-3) are the best for both lap and butt joints (see Table 6).
- The joints of steel (ST52-3) have the best ductility for both lap and butt MMAW welded joints (see Table 6).
- The maximum fracture stress is produced by MMAW lap joint while the minimum stress is made in TIGbutt joints (see Table 5).
- The welded joint could be stronger than the welded work pieces if appropriate welding methods are used, and also if the filler used has mechanical characteristics superior to those of the workpieces.
- The welded joint might be suffering from quality defects that could reduce the joint's strength. Those defects are usually difficult to detect.

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