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Experimental study of Effect of Process Parameter of GMAW Welding on Mechanical Properties and Microstructure of Steel (SAILMA 350 HI)

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Abstract

Welding is a multi-faceted procedure of manufacturing and can occur at any point during the creation of a product. The purpose of this research centers on resultant tensile strength, impact value, root bend and microstructure of a single-vee butt joint in low carbon steel. In this study, Sailma E 350 steel was bonded by GMAW welding with CO_2 as a shielding gas. Test samples were developed using GMAW welding process that remained consistent for all of the welds. Each sample was plasma cut into five pieces, which were machined to have a uniform cross section of the welded joint and surrounding parent material using a numerically controlled machining center. This paper aims at the investigation of the effect of current, voltage, root gap, welding rate, shielding gas flow rate on the mechanical properties (UTS, impact value, root bend, microstructure) of weldment. By changing the values of current, voltage, root gap, welding rate and shielding gas flow rate; the three sets of each weldment have been made and one set of parent metal also. Welding samples have been characterized by means of UTS test, Root bend test, Face bend test, microstructure test & Impact test. The results show that the UTS value of weldment varies significantly with change in welding parameters. Impact value and the microstructure also vary with change in welding parameters, but there is no change in the face bend test and root bend tests. It has been found that the UTS value and Impact value for weldment two are the higher in comparison with weldment one and three.

INTRODUCTION

Welding process plays important role in manufacturing industries. There are more than 100 processes within welding technology. The following are some of the variables that affect weld penetration, bead geometry, Overall weld quality and weld strength of the joint: The deposition rate, bead shape, and properties of the welded joint are controlled by the welding parameters. The parameters include the welding wire chemistry, wire size and extension, heat input, current, voltage, speed, and shielding gas. The purpose of this research centers on resultant tensile strength, impact value, root bend and microstructure of a single-vee butt joint in low carbon steel.

Knowledge and control of these variables is essential to consistently produce welds of satisfactory quality. These variables are not completely independent, and changing one generally requires changing one or more of the others to produce the desired results.

Ericsson and Sandstro (2003) investigated the influence of welding speed the fatigue strength of friction stir (FS) welds and also compared the fatigue results with results for conventional arc-welding methods: MIG-pulse and TIG.Liu et al. (2003) experimentally showed that the tensile properties and fracture locations of the joints are significantly affected by the welding process parameters. When the optimum revolutionary pitch is 0.07 mm/rev corresponding to the rotation speed of 1500 rpm and the welding speed of 100 mm/min, the maximum ultimate strength of the joints is equivalent to 82% that of the base material. Though the voids-free joints are fractured near or at the interface between the weld nugget and the thermo-mechanically affected zone (TMAZ) on the advancing side, the fracture occurs at the weld center when the void defects exist in the joints.Bayraktar et al. (2006) studied the objective of clarifying formability characteristics of welded thin sheet steels, such as Interstitial Free Steels (IFS) and Ferrite Stainless Steels (FSS) based on the LASER, TIG and resistance spot welding (RSW). The characterization of basic parameters influencing formability of homogeneous; base metal (BMs) and welded parts (WPs) has been carried out by hardness, impact tensile tests (ITT). Jang et al. (2005) carried out an experiment to study the toughness of Al5083-O aluminum alloy, to evaluate the variation of welding zone toughness as a function of the shielding gas composition and the testing temperature. Kanjilal et al. (2006) studied the combined effect of flux mixture and welding parameters on submerged arc weld metal chemical composition and mechanical properties. Amongst welding parameters, polarity is found to be important for all responses under study.Marzoli et al. (2006) established a friction stir welding (FSW) process parameters envelope for an AA 6061 alloy reinforced with

20% of Al_2O_3 particles, and determine properties of the obtained joints. The stirring of the tool has a substantial influence on the reinforcement particles distribution and shape. It breaks off the sharp edges of the bigger particles, rounding them up at the same time. This action results in smaller, round particles in the nugget.Cavaliere et al. (2006) investigated the effect of processing parameters on mechanical and micro structural properties of AA6056 joints produced by Friction Stir Welding. Different samples obtained by employing rotating speeds of 500, 800 and 1000 rpm and welding speeds of 40, 56 and 80 mm/min were produced. The mechanical properties of the joints were evaluated by means of micro hardness (HV) and tensile tests at room temperature. Fatigue tests on the welds were carried out by using a resonant electro-mechanical testing machine under constant loading control up to 250 Hz sine wave loading. The low cycle (LCF) and high cycle (HCF) fatigue tests were conducted in the axial total stress-amplitude control mode with $R = \sigma_{min}/\sigma_{max} = 0.1$, for all the welding and rotating speeds used in the present study. It was observed that the specimens welded at 56 mm/min showed the best behavior in the low cycle regime. Hana et al. (2011)carried out experimental work on AA5754 aluminum alloy resistance spot welded (RSW) to produce 27 different joint stack-ups with differing process parameters and corresponding weld quality. Quasi-static joint strength was evaluated for three test geometries; lap-shear, coach-peel and cross-tension. The results derived from over 1000 samples demonstrate various fundamental relationships.Squillace et al. (2012) studied the influence of welding speed and laser power on weld quality of 1.6 mm thick Ti − 6Al − 4V sheets autogenously laser beam welded in butt configuration using a Nd-YAG laser. The joint quality was characterized in terms of weld morphology, microstructure and mechanical properties. An under fill defect, controlling the whole weld geometry, was observed both at the weld face and root surface. In dependence of the specific heat input, this defect showed a maximum, which separates two different welding regimes: keyhole welding, at low heat input, and a welding regime where heat conduction around the keyhole is predominant, at high heat input.

Steel (IS 2062 E 350 generally called SAILMA 350 HI) is used for welding under different welding variable parameters. SAILMA 350 HI is the most common form of steel because its price is relatively low while it provides material properties that are acceptable for many applications. In this study an attempt has been made to investigate the effect of welding parameters on mechanical properties of weldments. Several test specimens have been welded with varying welding parameters.

EXPERIMENTAL SETUP

Six metal pieces of dimensions 400 mm × 200 mm ×12 mm are prepared for welding, then closed butt joint are made by these pieces. MIG welding process with CO_2 as inert gas is used for welding of specimen.The most common type of power source used for this process is the switched primary transformer rectifier with constant voltage characteristics from both 3-phase 415V and 1- phase 240V input supplies.

Specimen Preparation

In order to carry out the necessary tests to study the mechanical properties of the weld joints, specimens have been made with the shape shown below.

Fig. 1 specimen weldment(1, 2 & 3)

The specimen weldment 1, weldment 2 and weldment 3 shown in above figure from left to right have been prepared at different welding parameters which are given in table1.

Welding Parameters:

	WELDMENT 1	WELDMENT 2	WELDMENT 3
Current (I) in Amp.	196	208	240
Voltage (V) in Volts	24.8	28	31.2
CO_2 Regulation (L/min)	16	20	30
Root Gap (mm)	1	2	3
Welding Rate (mm/min)	175	200	250

Material Specification:

Material used in experiment:	SAILMA 350 HI.
UTS of SAILMA 350 HI :	540 MPa
Yield strength of SAILMA 350 HI:	400 MPa
Filler material with chemical composition:	Flux cored MIG roll (SFC- 71) Chemicalcomposition(C% - 0.12,Mn% - 1.75,Si% - 0.9,S% - 0.03,P% - 0.03,Cu%- 0.35)
Chemical composition of SAILMA 350 HI:	(C% - 0.13,Mn% - 1.28,Si% - 0.23,S% - 0.022, P% - 0.022,Al – 0.026).

RESULTS AND DISCUSSION

The following result outcomes we got from the testing of specimen.

Tensile test: The specimens undergone UTS test have been shown in figure 2. In figure 2, the top most specimen is of parent metal with dimensions 16.8 × 12.20 mm which breaks in the middle of the gauge length (80 mm) at the ultimate load of 112600 Newton showing ultimate tensile strength 549.4 MPa. The elongation has been measured over 23 mm.The 2nd specimen from the top in figure 2 is weldment 1 with the dimensions 16.00 × 11.70 mm which breaks from the heat affected zone i.e. the location of fractute is in the parent metal. The fracture occurs at ultimate load of 102300 N and the corresponding value of ultimate strength is 546.5 MPa.The 3rd specimen from the top in figure 2 is weldment 2 with the dimensions 16.60 × 11.80 mm which breaks at the start of gauge length i.e. the location of fractute is in the parent metal. The fracture occurs at ultimate load of 111800 N and the corresponding value of ultimate strength is 570.8 MPa.The 4th specimen at the bottom in figure 2 is weldment 3 with the dimensions 16.80 × 12.0 mm which breaks in the region near HAZ i.e. the location of fractute is in the parent metal. The fracture occurs at ultimate load of 109900 N and the corresponding value of ultimate strength is 545.1MPa.

Fig. 2 Specimens for UTS test

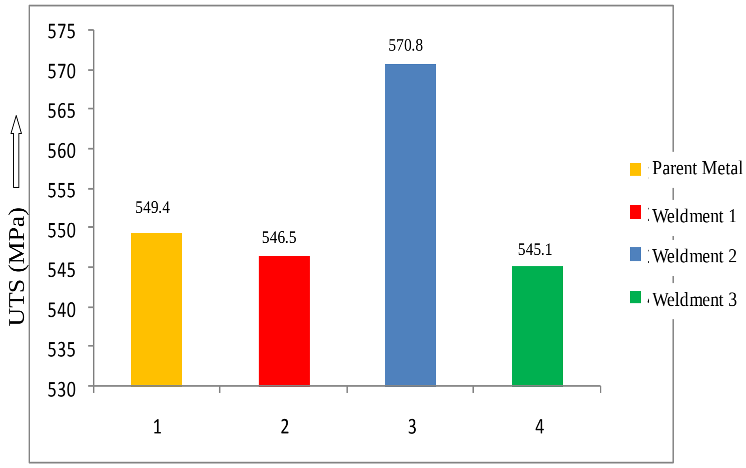

Fig. 3 UTS values of parent metal and weldments

From the above discussion it is observed that maximum UTS is obtained in weldment 2. In weldment 1 and weldment 3 the UTS value remain almost the same as in the parent metal. The comparison of ultimate tensile strength values for parent metal, weldment1, weldment 2 and weldment 3 has been shown in figure 3.

Charpy Impact Test

Charpy impact test is practical for the assessment of brittle fracture of metals and is also used as an indicator to determine suitable service temperatures. Charpy V-notch testing is used to measure the impact energy which is sometimes also termed the notch toughness (Callister, 1997). The Charpy test sample has 10 × 10 × 55 mm^3 dimensions, a 45° ‘V’ notch of 2 mm depth and a 0.25 mm root radius will be hit by a pendulum at the opposite end of the notch.

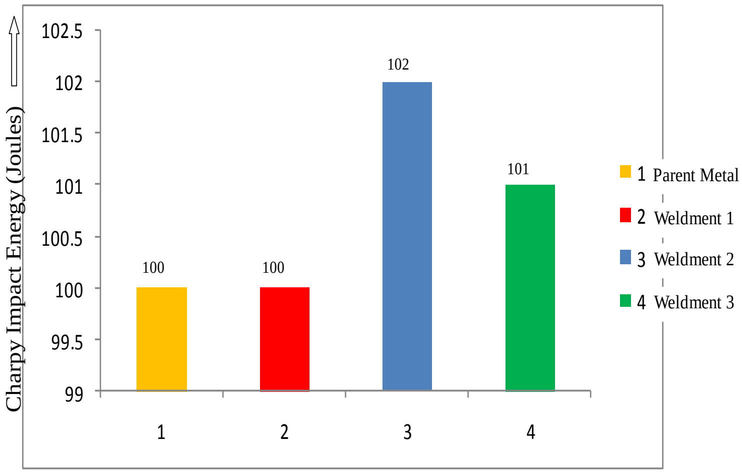

Fig. 4 Charpy Impact values of parent metal and weldments

Charpy Impact Test

The values of Charpy Impact Energy for parent metal, weldment 1, weldment 2 and weldment 3 are 100, 100, 102 and 101 respectively. The figure 4 shows that Charpy Impact Energy values do not significantly change with change in welding parameters. However, like tensile test the Charpy Impact Energy value for weldment 2 is higher in comparison to parent metal, weldment 1 and weldment 3.

Bend Test

The specimens after bend test are shown in figure 5. There are no surface cracks in the specimens in the welding region after bend test. The specimens show satisfactory results after bend test.

Fig 5. Specimens after bend test

Table 2. Results obtained from tests

	PLATE	WELDMENT 1	WELDMENT 2	WELDMENT 3
UTS (MPa)	549.4	546.5	570.8	545.1
IMPACT ENERGY (J)	100	100	102	101
ROOT BEND TEST	Satisfactory	Satisfactory	Satisfactory	Satisfactory
FACE BEND TEST	Satisfactory	Satisfactory	Satisfactory	Satisfactory

MICROSTRUCTURE TEST

The specimens for microstructure test are shown in figure 6. These specimens are super finished from one side for microstructure test. Microstructure of the parent material is given in Figure 6 (a). Since the steel contains low carbon (0.14 wt %), the structure primarily consists of equiaxed ferrite grains with presence of small amount of pearlite at ferrite grain boundaries.

The electrode used for welding in this study possesses a low carbon concentration (0.12 wt %). Accordingly the microstructure of all weldments also primarily consists of ferrite grains with small amount of pearlite. Due to rapid heat flow conditions, the grains are elongated in the heat flow directions. The grains in weldment two are fine and more elongated in comparison to weldment 1 and weldment 3. It is due to this reason that specimen of weldment two exhibits higher UTS in comparison to the other specimens. The microstructure of weldments is shown in figures 6 (b) to 6 (d). The results obtained from tensile test, impact test and bend test for parent metal, weldment1, weldment2 and weldment 3 have been tabulated in table 2.

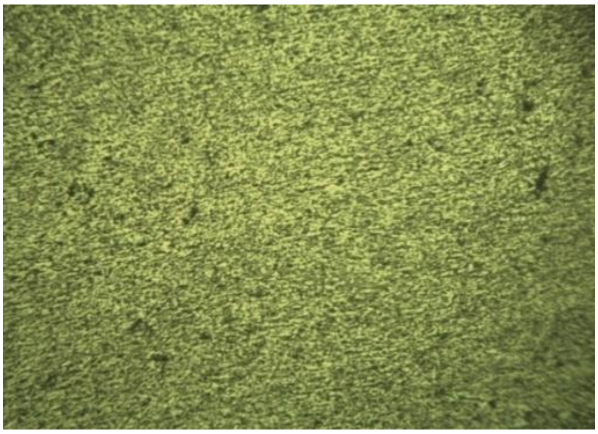

Fig.6 (a) Microstructure of parent metal

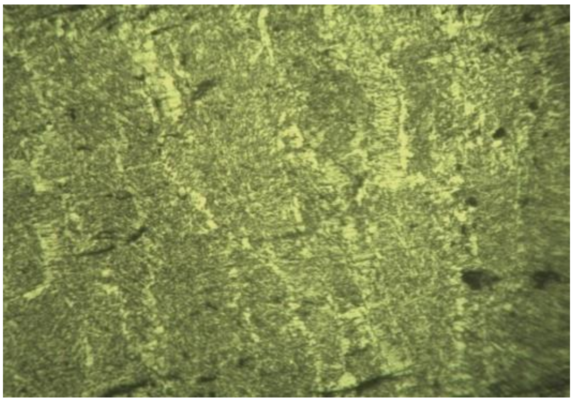

Fig.6 (b) Microstructure of weldment 1

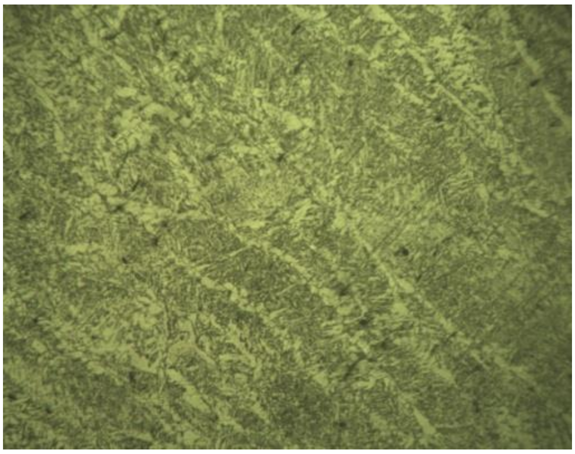

Fig.6 (c) Microstructure of weldment 2

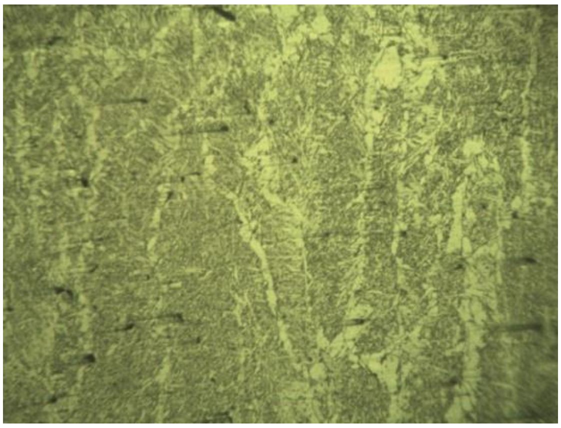

Fig.6 (d) Microstructure of weldment 3

CONCLUSIONS:

The Results of the present research work indicates that numerous process variables of GMAW and variety of possible joint configuration have profound effect on tensile strength of the weld joint. The important conclusions of the present research work are listed below:

- The results show that welding parameters used for the weldment 2 provide the most suitable conditions for the welding region in the structures. Every test shows a better result for weldment 2.
- Results show that at voltage 28 volts, current 208 Amp. CO_2 regulation 20 L/min, root gap 2 mm & welding speed 200 mm/min gives ultimate tensile stress 570.8 MPa which is maximum for weldment 2 as compared to that obtained for parent metal, weldment 1 and weldment 3.
- The Charpy Impact Energy 102 J is also maximum for weldment 2 for the above set of welding parameters. The change in Charpy Impact Energy is not substantial.
- Root bend test and face bend test have been found satisfactory for all the combinations of welding parameters and for parent metal as well as weldments.
- The microstructure tests also show that in these conditions or welding parameters for the material Sailma 350 HI the grains in weldment 2 are finer and more elongated in comparison to parent metal, weldment 1 and weldment 3.

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