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High Performance Steel Applications With Reference To Arc Welding

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ABSTRACT:
Welding process can be performed on similar or dissimilar metals. Welding of dissimilar metals involves different types of metals with distinct chemical composition. In this paper welding of similar and dissimilar metal joints of gas and Tungsten Inert Gas (TIG) welding are studied and their mechanical properties are evaluated. Recently joining of dissimilar materials are of great interest because of their wide spread application in engineering structural materials. The study of mechanical properties of welding is important because welded structure may be installed at highly sensitive and risky place. Problem of formation of inter-metallic compound may arise which affect the weld quality. In joining dissimilar materials having closer melting points, gas welding is the best choice however where melting point difference is high, sound welding can't performed by gas welding. Arc welding is a type of welding that uses a welding power supply to create an electric arc between an electrode and the base material to melt the metals at the welding point. They can use either direct (DC) or alternating (AC) current, and consumable or non-consumable electrodes. The process of arc welding is widely used because of its low capital and running costs. In this paper, arc welding parameters are determined for shielded metal arc welding method.

Key words: Arc welding, shielded metal, Effects of welding

1.0 INTRODUCTION:

In order to reduce CO2 emission, decreasing body weight is an urgent requirement in the automotive industry, and in this context, the need for application of thinner steel sheets of higher strength is increasing. While high-strength steel sheets of 440 and 590-MPa classes have been used mainly for chassis parts, use of 780-MPa class steel is looked for in response to the need for light car weight. On the other hand, for body parts, the use of steel sheets of yet higher strength, of a 1,470-MPa class, has already begun. Arc welding is widely used for chassis parts because of advantages such as the ease of continuous joining to secure high strength and rigidity of joints and wide freedom of joint shape to allow easy joining to pipes, brackets, or other accessories.1) Since chassis parts are composed of many components welded together, it is essential that weld joints are highly resistant to fatigue and corrosion. In addition, besides reducing spatter, welding methods and consumables must be able to deal with gaps often seen with press-formed sheets. In view of strengthening of chassis, specimens of arc-welded joints of steel sheets of tensile strengths up to 780 MPa were prepared, and their static strength, fatigue strength, and corrosion resistance were examined. In addition, new welding consumables aiming at suppressing spattering and improving gap weldability were developed. This paper reports the results of these studies and development activities. Besides these, because arc weldability changes depending on the chemical components of

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steel, this paper also describes the effects of steel chemistry over the forming mechanism of weld beads.

On the other hand, with respect to body parts, although arc welding is not widely applied, it is sometimes employed in place of resistance spot welding. Closed-section structure is advantageous for increasing the strength and reducing the weight of car bodies, but in this structure, resistance spot welding that needs access both from outside and inside is not applicable. When resistance spot welding must be applied to closed-section parts, working holes are required, which, in a great number, spoil the structural rigidity of the work.

2.0 LITERATURE REVIEW

Rohit and Jha (2014) investigated the effect of process parameter such as welding current on tensile strength of mild steel weldment by using welding current as varying parameter. In this work, mild steel alloy plates were joined by Shielded Metal Arc Welding (SMAW). The welding currents considered in this study were 100A, 110A, 120A, 130A, and 140 A. They showed that the maximum tensile strength was achieved when the welding current is 120A. With the increase in welding use, which were considered as a variable parameter, the ultimate tensile strength (UTS) of 515.185 MPa was recorded. Hence, it can be concluded that with the increase in welding current the UTS will increase until an optimum value. Increasing the current beyond this optimum value will result in decreasing UTS.

Mattoo and Kumar (2015) performed an experimental study to investigate the effect of using different filler rods via Shielded Metal Arc Welding. The filler rods used in this" work are austenitic stainless steel, ferritic stainless steel, and mild steel. The different welded samples have been tested and similar significant parameters like Tensile Strength and Brinell Hardness Number have been determined in order to be compared with the standards. They found that the tensile strength was a maximum when the Mild Steel 7018-filler rod was used and a maximum hardness was achieved when ferritic stainless steel 430-filler rod was used.

Abdulzara, (2011) used steel alloy instead of carbon steel for achieving of engineering industry requirements. Where in carbon steel, a tensile strength higher than 700 MPa with a suitable toughness and ductility, can't be recorded. It is also susceptible to mass effect and the low resistance to corrosion and oxidation… etc.

3.0 ANALYSIS:

Static strength of weld joints

Weld joints are designed, generally, so as to overmatch the base metal, that is, to have strength higher than that of the base metal, and for this reason, high-strength welding wires are often used for welding high-strength steel sheets. However, in the manufacture of auto parts, welding wires of a 490-MPa class for general applications are often used regardless of the strength of the base metal because using different welding wires for different parts is costly, and besides this, in welding of thin sheets, weld metal tends to harden because of dilution with the base metal. In consideration of this, steel sheets of different strengths were welded by changing the strength of the wires, and evaluated the mechanical properties of the joints.

Fig. 1 shows the static tensile shear strength of fillet lap joints of hot-rolled (HR) steel sheets with a thickness of 2.3 - 3.2 mm and tensile strength of 440, 590, and 780 MPa; here, the strength is expressed in terms of stress, which is obtained by dividing fracture load by the sectional area of the base metal. The joints were welded by pulsed metal active gas (MAG) arc welding using wires with a diameter of 1.2 mm and tensile strengths of 490 - 780 MPa at currents of 250 - 320 A and a welding speed of 100 cm/min. All the joints failed at the base metal or the weld toe, and the strength did not vary depending on the grade of welding wire Fig. 2 shows the hardness of the weld metals. From the graph shown in this figure, it can be seen that the hardness of the weld metals of the same base metal changes depending on the grade of welding wire, and the hardness of weld metals of the same welding wire increases

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with the strength of the base metal. Since welding of thin sheets is mostly done in a single pass, base metal accounts for a high proportion of the composition of weld metal; under usual welding conditions, 30 to 40% of weld metal comes from the base metal, and for this reason, the hardness of weld metal is strongly influenced by the base metal chemistry. In addition, because the heat input for welding thin sheets is comparatively low, the cooling rate is high, and weld metal tends to be hardened. This is the reason why high strength is secured with weld joints of high-strength steel sheets even when welding wire of lower grades is used. It has to be noted in this relation that, as will be mentioned in the following section, in the alloy design of many welding wires for automotive steel sheets, emphasis is placed on workability, and as a consequence, with different base metals, the hardness of weld metal is not always the same even when welding wire of a 490-MPa class is used.

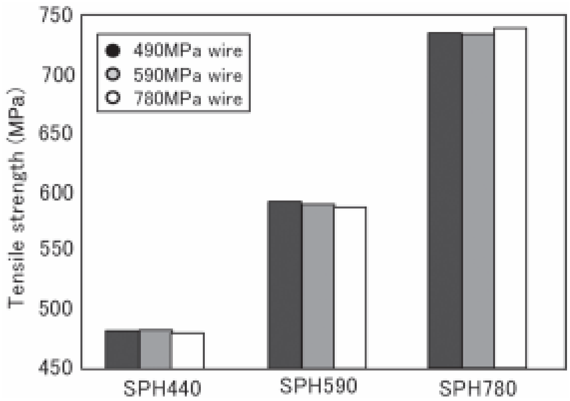

Fig. 1 Static strength of arc welded joints

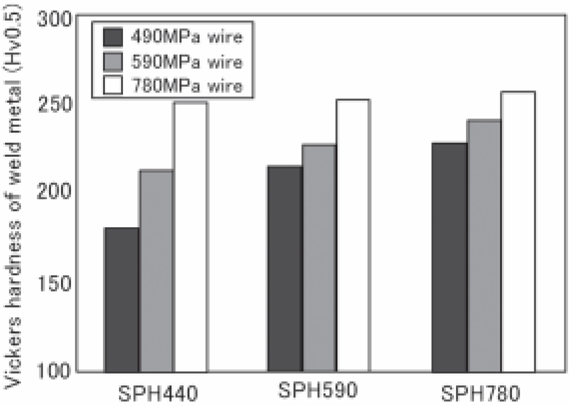

Fig. 2 Vickers hardness of arc welded joints

High performance steel

Another difficulty of HSS welding is the HAZ softening phenomenon. During welding of QTs, an area with softened microstructure is created in the HAZ, the so-called ‘soft layer,’ which has considerably lower strength properties. The presence of this reduced-hardness soft layer can have a significant effect on the strength of the joint and the integrity of the entire structure. This phenomenon is a characteristic derived from the welding process and the welding consumable used, since they determine the heat input and cooling time. With some types of UHSS, such as CP and TRIP, soft zones do not occur in the HAZ, due to their higher alloying content. Some very high strength steels (with high marten site content and strength levels above 800 MPa) may however suffer reduced strength in the joint, due to small soft layers in the HAZ, compared to the base metal strength, depending on the precise chemical composition of the steel HAZ

In similar metal welding, mild steel-mild steel and copper-copper joints were accomplished by gas welding. However, mild steel- copper joint is also develop by gas welding. In gas

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welding heat is required to melt the surfaces of metal which is supplied by a high temperature flame obtained by a mixture of acetylene ($C_2 H_2$) and oxygen gas. A flame is used to melt the metals at the joint, along with a filler rod to provide some extra material to fill the gap. The welding joint is lap joint. Tungsten Inert Gas equipment consists of welding torch in which a non-consumable tungsten alloy electrode is held rigidly in the collet. Al-Al samples are joined by the heat obtained from an electric arc struck between a non-consumable tungsten electrode in which Al alloy is mixed and the work piece in the presence of an inert gas atmosphere. The arc is struck by touching the tip of the tungsten electrode with the work piece. The high intensity of the arc melts the work piece metal forming a small molten metal pool. Filler metal in the form of a rod is added manually to the front end of the weld pool. Cu-Cu joint is also developed by the same process. For Al-Cu joint various alloy like zirconium, thorium, lanthanum etc., are alloyed with tungsten to improve arc stability, better current carrying capacity, resistance to contamination etc. The diameter of the electrode varies from 0.5- 6.4mm. Figure 3 shows the schematic diagram for the different welding zones; which include; the unaffected material or parent metal, the Heat-Affected Zone (HAZ), the Thermo-mechanically Affected Zone (TMAZ) and the weld nugget.

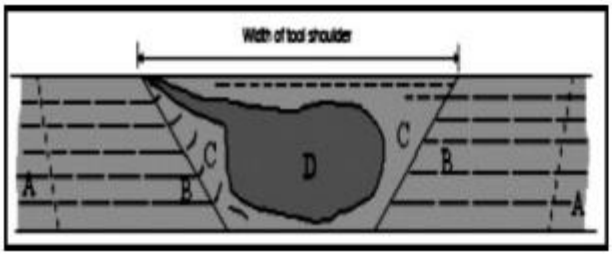

Figure.3. Illustration of different microstructural regions of a typical welded material. (A) Parent metal or unaffected material (B) heat-affected zone (C) thermomechanically affected zone (D) weld nugget

The heat-affected zone is the narrow region of the base metal adjacent to the weld bead, which is metallurgic ally altered by the heat of welding. It has a microstructure different from that of base metal prior to welding. The properties and microstructure of the HAZ depends on the rate of heat input and cooling and the temperature to which this zone was raised. A specific maximum underpass temperature in welding procedure is sometimes required e.g., in order to avoid hot cracking. In this case using a higher underpass temperature will increase the time spent in the critical temperature range. This is also an issue with high strength steel weld metals but using a high underpass temperature normally plays a more important role. Longer cooling times allows hydrogen diffusion from the weld and is a major factor when avoiding hydrogen cracking.

With high-strength steels, structures can be designed to have larger scales or thinner thicknesses due to the ability of sustaining larger applied stresses when compared with mild steel. Table 1 shows how the use of high-strength steel can make steel structures thinner or lighter. The use of 490-MPa high-tensile strength steel, for example, can reduce the weight of a steel structure by 25% in comparison with the use of mild steel under the same design stress. The weight ratios shown in Table 1.1 are calculated in accordance with the following formula

Weight ratio = $\frac{Minimum\ yield\ strength\ of\ mild\ steel}{Minimum\ yield\ strength\ of\ high-strength\ steel}$

Table 1. The possibility of weight reduction of steel structures by using high-strength steels in comparison with mild steel under the same design strength

Type of steel (1)	Min. yield strength (2) (MPa)	Weight ratio	Weight reduction ratio (%)

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Mild steel: JIS SM400A	235	1.00	0
490-MPa HT: JIS SM490A	315	0.75	25
570- MPa HT: JIS SM570	450	0.52	48
610- MPa HT: WES HW490	490	0.48	52
780- MPa HT: WES HW685	685	0.34	66

In the production of high-strength steels, the alloying elements (C, Mn, Ni, Cr, Mo, V, Nb, Cu, Ti, B, etc.) are added and heat treatment is applied in order to provide adequate tensile strengths, yield strengths, ductility, and notch toughness to the requirements of the relevant standards and specifications. The heat treatment includes normalizing, normalizing followed by tempering, and quenching followed by tempering. In addition, high-strength steels are often produced by using specially controlled thermal and rolling sequences known as the Thermo-Mechanical Control Process (TMCP). The TMCP steels offer higher strengths with lower carbon equivalent and superior weldability.

Weldability of high-strength steels

Weldability can be defined as the ease of obtaining satisfactory welding results. Satisfactory welding should result in sound welds with acceptable chemical and mechanical properties as well as reasonable welding costs. A sound weld should not contain welding defects such as hot and cold cracks, incomplete fusion, lack of fusion, overlap, excessive porosity, and undercut. An acceptable weld should have the sufficient tensile strength, yield strength, ductility, notch toughness, atmospheric corrosion resistance required for the intended application. Welding costs should be reasonable. In welding high-strength steels, the weld becomes hard with low ductility because of their inherent self-hardenability, contains diffusible hydrogen, and is subject to restraint stresses. These three factors of low ductility, diffusible hydrogen and restraint stress often cause cracks in the weld metal and the heat-affected zone. Therefore, the weldability of the high-strength steel and the welding consumable to be used should thoroughly be examined to establish the welding procedure

Welding processes and procedures

In order to get a satisfactory result in welding high-strength steels, suitable welding consumables should be selected and appropriate welding processes and procedures should be used. As shown in **Table 2**, applicable welding processes for 490- to 980-MPa high-tensile strength steels are those of shielded metal arc welding, submerged arc welding, gas shielded metal arc welding, and gas tungsten arc welding.

Table 2 — Welding processes for high-strength steels

Welding process	**Type of high-strength steel**				
	490-MPa HT	**610-MPa HT**	**690-MPa HT**	**780-MPa HT**	**980-MPa HT**
Shielded metal arc welding	◎	◎	◎	◎	○
Submerged arc welding	◎	◎	◎	◎	○
Gas shielded metal arc welding	◎	◎	◎	◎	◎
Gas tungsten arc welding	○	○	○	○	◎
Electroslag welding	○	△	—	—	—
Electrogas welding	○	△	—	—	—

Note: ◎: Widely used; ○: Used; △: Occasionally used; —: Not used

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Tensile Result

Tensile strength Shielded Metal Arc Welding (SMAW) welds of low carbon steel for each observation. Three tests coupons are cut and the average strength values are noted. One standard specimen without weld was tested and two specimens were welded by using electrodes (E7018) and E6013). Similarly, butt joints of two specimens were made and the average values are given. Ultimate tensile strengths of standard without weld test specimen is 426 MPa shown in the Fig. 4. The ultimate tensile strength specimen welded by E7018 is 419 MPa as shown in the Fig. 5. while the ultimate tensile strength of the last specimen welded by E6013 is 432 MPa as shown in the Fig. 6. The variety in the ultimate tensile strength of specimens due to the variation in welding conditions that mean the 10 mm thick with V groove .The tensile strength using V Groove surface preparation is due to high depth of penetration of molten metal in the joint. In both these processes, it is found that the increase in the plate thickness leads to increase the tensile strength moreover of depth of penetration is possible for higher thickness plates. In butt joint without surface preparation only the root joints on both sides are welded having unweld portion in the center, Hence the strength of weldment is poor .The Fig. 6. as shown explains the difference of comparing stress-strain curves

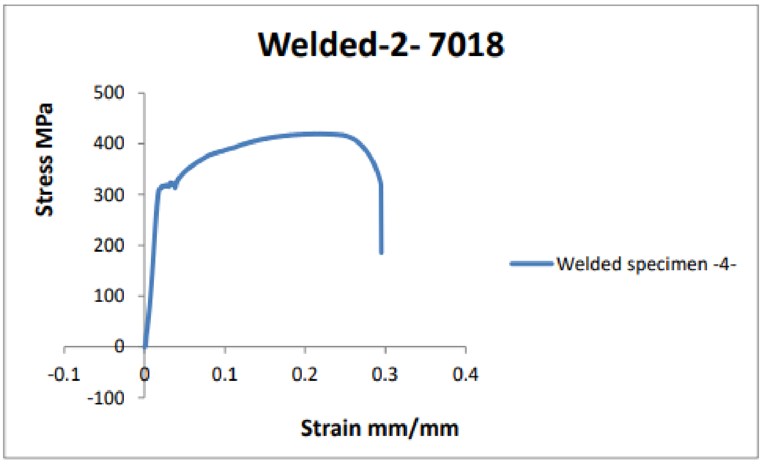

Fig. 4 Welded specimen 7018

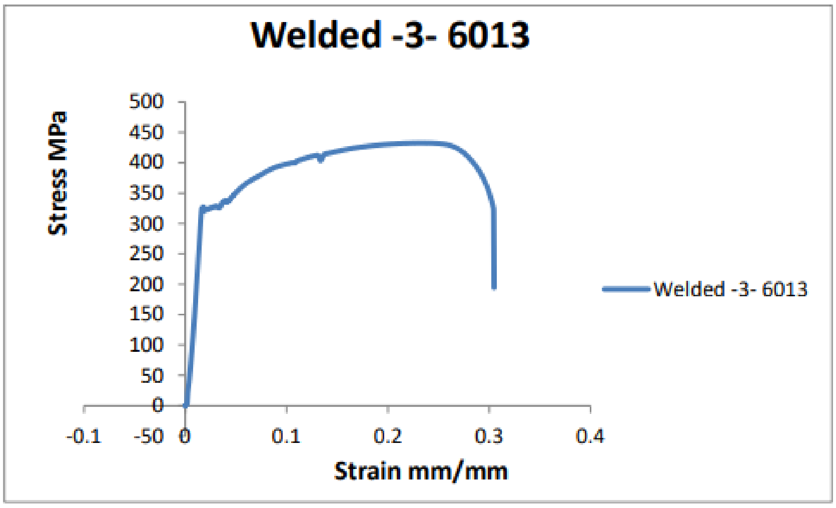

Fig. 5. Welded specimen 6013.

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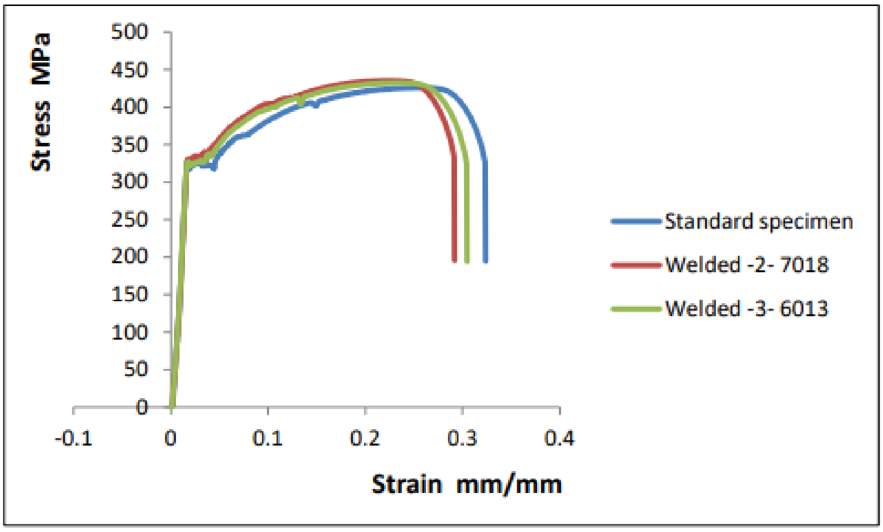

Fig. 6. Comparison lab curve Stress- strain curve.

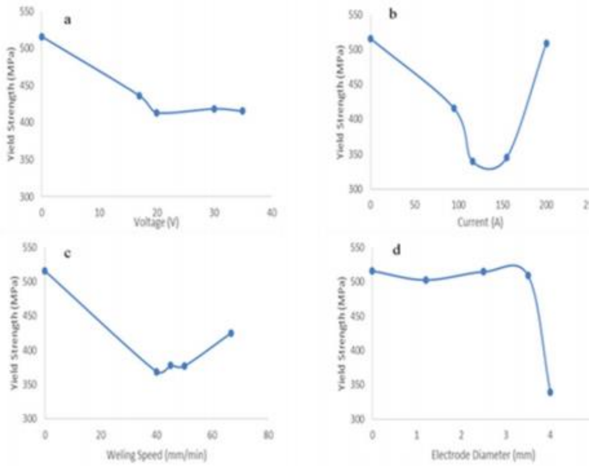

Fig. 7 Effect of welding parameters on the ultimate tensile strength of the welded joint

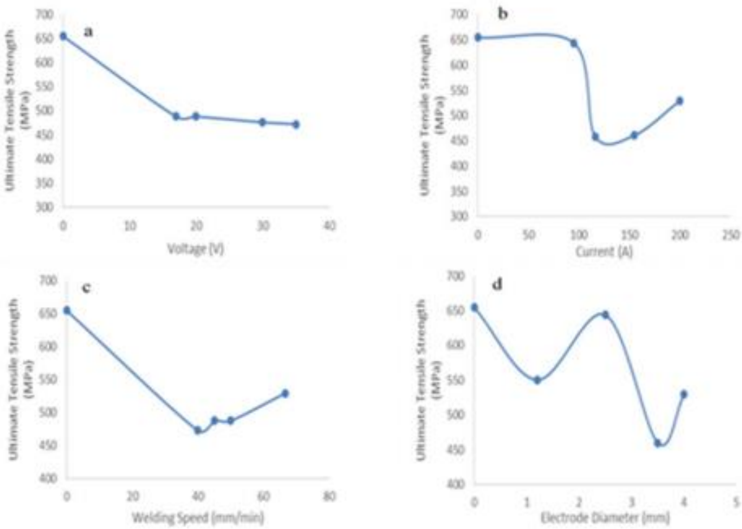

Fig. 8 Effect of welding parameters on the yield strength of the welded joint

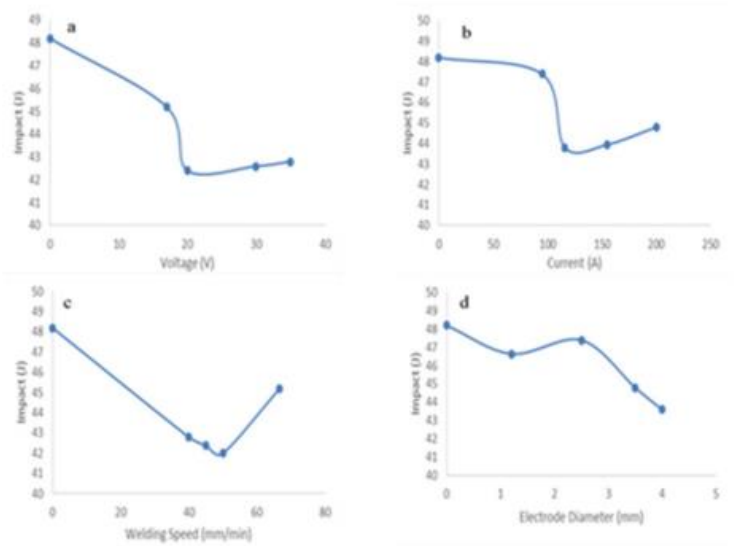

Fig. 9 Effect of the welding parameters on the Impact strength of the weld metal

4.0 CONCLUSION:

To effectively respond to the latest need for wider use of high-strength steel sheets of thinner gauges, it is necessary to enhance the reliability of weld joints of such materials through approaches from the material technology side. Arc welding is a versatile joining method applicable to a wide variety of joint configuration such as butt, lapping, and T joints. Another advantage of the method is that dimensional errors occurring at processes of cutting, pressing, and other working can be adjusted at assembly into structures as designed. The Nippon Steel Corporation intends to continue offering measures that realize these advantages of arc welding to the fullest extent to help obtain reliable joints; therefore, intends to support the automotive and other manufacturing industries.

From the results, the following can be concluded. The low carbon steel AISI1010 plates are joined using (SMAW) arc welding .The evidence that welding electrode type are important parameter that must be monitored in order to produce weld joints of enhanced mechanical properties .The tensile test properties such as ultimate tensile , yield stress , percentage of elongation and strength of welded joints are investigated. From the work, following are the conclusions. 1. The yield strength and ultimate tensile strength values of weld joints were lower than those of the base metal. 2. The specimens welded by E6013 has enhances in the ultimate tensile of the weld joint. 3. The fracture toughness of welded specimen in E6013 joint was found better than welded specimen in 7018 but T joint. 4. The percentage elongation of the base metal is higher than that of the weld joints.

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