EtI ENGINEERING AND TECHNOLOGY IN INDIA
Volume 4 | Issue 2 | Oct., 2013 | 30-35

RESEARCH ARTICLE

Finite element analysis of multipass GMAW butt joint for welding of AA 7020

K.P. KOLHE AND S. D. WAVALE

ABSTRACT : This study was conducted for analyzing the major failures of large metal inert gas arc welded structures of AA7020 aluminum alloy joined by using 5636 aluminium alloy electrode wire. The experimental study of two pass AA7020 aluminum alloys are carried out by preparing the standard welded samples as per British welding standard. The mechanical properties of the multiphase welded joint, like tensile strength, hardness and impact strength have been tested and reported. The analysis was carried out by using FEM solver ABACUS for identifying stress, strain and temperature distribution of welding. The number of nodes and elements selected for this study are 19,452 and 15, 840, respectively. Tie contact was used to connect molten and parent metal by using Ansys 6. By using Al-alloys lowering the mass by about 50 per cent can be obtained. However, it makes possible to increase and maintained ship buoyancy to increase its load carrying capacity and speed, as well as improve its stability. For these reasons Al-alloys are used for construction of ship hull and superstructures. Among weldable Al-alloys suitable to plastic working the group of Al-Mg alloys (of 5xxx- series) of good weldability and relatively good service conditions are still the most popular. Their relative insusceptibility to layer and stress corrosion is advantageous. Their disadvantage is low strength of welded joints of elements made of them, not exceeding 300 MPa. In order to more intensive craft of weight Al-Zn-Mg alloys (7xxx series) became more interesting. They are characteristic of higher strength properties as compared with those of Al-Mg alloys. Aluminum alloy 7020 [AA7020] a higher strength aluminum alloy, is widely used in welded engineering structural components, military applications, food processing industries and in aerospace applications.

KEY WORDS : AA7020, Finite element method, Heat affected zone, GMAW

Article Chronicle : Received : 05.07.2013; **Revised :** 04.08.2013; **Accepted :** 10.09.2013

How to cite this Article : Kolhe, K.P. and Wavale, S.D. (2013). Finite element analysis of multipass GMAW butt joint for welding of AA 7020. *Engg. & Tech. in India*, **4** (2) : 30-35.

INTRODUCTION

Aluminium alloys were generally believed to immune to hydrogen embrittlement. However, it is realized that many high-strength aluminium alloys are prone to environment-assisted cracking and hydrogen embrittlement could be a possible mechanism for the same. Today's aluminum alloys together with their various tempers, comprise a wide welding procedure development. It is important to understand the differences between the many alloys available and their various performances and weldability characteristics. When developing arc weld procedure for these alloys, consideration must be given to the specific alloy being welded. It is often said that arc welding of aluminum is not difficult, it is just different. It is believed that an important part of understanding in differences is to become familiar with the various alloys.

The effect of arc voltage and welding current on mechanical and microstructure properties of 5083 aluminum alloy joints used in marine applications was investigated by Mohd Noor *et al.*, 2011. The mechanical characteristics of the welded alloy were carried out for tensile and hardness tests. Further, metallographic examination was conducted to identify and observe the various zones. As a conclusion, the increasing of arc welding current in 5083 aluminum alloy will

MEMBERS OF RESEARCH FORUM

Address for correspondence :
K.P. KOLHE, Department of Mechanical Engineering, Imperial College of Engineering and Research, Wagholi, PUNE (M.S.) INDIA
Email: skishor75@gmail.com

Coopted Authors :
S.D. WAVALE, Department of Mechanical Engineering, Imperial College of Engineering and Research, Wagholi, PUNE (M.S.) INDIA

increase the welding heat input. Accordingly, the chance of defect formation such as burns in welded metal also increases. This will affect on mechanical properties and quality of welded metal badly. Besides that the high welding current also reduces the yield strength, ultimate tensile strength and toughness value of 5083 aluminum alloy welded metal.

Many researchers reported the effect of welding parameters for SMAW, SAW, MIG and TIG welding for ferrous and non ferrous metals, however, aluminum welding, the flow parameters are all concerned, because the large influence of small welding current welds causing changes in the microstructure and mechanical properties of weld area (Kolhe and Datta, 2007; Kumar *et al*., 2010 and Ghazvinloo *et al*., 2010).Variable flow effects to microstructure and hardness on aluminum 5083 by GTAW process by Akhmad Haris (Dept. of Defence 1966; Park *et al*., 2000; Litle, 1975; Kumar *et al*., 2009; Herring, 2005 and Rajkumar *et al*., 2010). Variable flow used was 110A, 130A and 150A, of the three variations of the flow testing of microstructure and hardness, higher welding current (150A) showed highest hardness value weldment region comparatively. The microstructure examination showed that the higher currents used in the welding process, the greater the grain size produced, in particular in weldment regions. While at small grain HAZ region resulted in the welding current 110A and the weldment region not undergo much change Rajkumar *et al*., 2010; Arunkumar *et al*., 2011; Srinivasarao *et al*., 2007; Sindo, 2003; Kashyap and Chandrashekar, 2001; Indira Rani and Marpu, 2012 and Park *et al*., 2008 The objective of present paper is to report the theoretical and experimental study observations and provide information about the mechanical properties such as tensile test, impact test, etc. for obtaining robust weld structure of 7020 aluminum alloy by using gas metal arc welding.

EXPERIMENTAL PROCEDURE

Gas metal arc welding GMAW welding is widely used for welding aluminium and it produces weld of good appearance and quality. Experiment were performed by using semiautomatic fully thyristorised 6 pulse CO_2 MIG welding machine having maximum current carrying capacity of 600 Amps. The material used in this study was AA7020 aluminum alloy. The chemical composition of 7020 aluminum alloy is as shown in Table A.

Butt joint of 10 mm thickness was made using MIG arc welding by following British welding society standard for joint preparation. The single "V" butt joint configuration is prepared by cutting and beveling the edges of an aluminum alloy 7020 – at Y by an angle of 45^0 is performed by mechanical processing. The surfaces of the groove and lying in its immediate vicinity, before welding is cleaned by means of rotating stainless steel brushes and then skimmed petroleum ether. Preparation for welding and weld joint was made in a closed position to protect against weather and other atmospheric conditions. To avoid distortion weld joint was performed in an arrangement, and the relief was after the terminal connector has cooled down. Installation of the joints was carried out using the bonding joints. In case of 7020 alloy welds after the stitches were cut finishes bottom of the weld face and then put a layer of root pass. The welding was carried out by using semiautomatic fully thyristorised 6 pulse CO_2 MIG welding machine in two passes. For the 7020 aluminum alloy, welding electrode wire used was 5356 aluminum alloy (AlMg5)– FSH. The chemical composition of 5356 aluminum alloy is as shown in Table B.

The argon shielding gas was used with the purity of 99.99 per cent. Welding parameters used to joining 7020 alloy are shown in Table C.

The other important welding parameters are pressure = 2.5 kg/cm², wire feed rate 3.5 to 4m /min. and welding speed = 0.4m /min.

The joint type used is single V butt welding joint with the following particulars :

Thickness of plate (T) = 10 mm, root gap (G) = 1.5 mm,

Table A: chemical composition of 7020 aluminum alloy (in wt %)

Chemical composition (%)									
Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Zr	Al
0.298	0.35	0.10	0.25	1.30	0.14	4.70	0.08	0.07	The rest

Table B : Chemical composition of 5356 aluminum alloy (in wt %)

Chemical composition (%)							
Mg	Zn	Cu	Si	Fe	Mn	Ti	Al
5.0	Max. 0.10	0.10	Max. 0.25	0.40	0.15	0.10	The rest

Table C : MIG welding parameters of 7020 aluminum alloy

Diameter of welding wire [mm]	Welding current [Amp]	Voltage [V]	Number of layers	Argon consumption [m³/h]
1.6	200	20	4 + prewelding	12

root face (R) =1.5 mm, bevel angle = 45º.

Tensile testing :

The rolled plates of AA7020 aluminum alloy were machined to the required dimensions (199 mm×30 mm). Single 'V' butt joint configuration, as shown in Fig. B (1), was prepared to fabricate GMAW welded joints. The initial joint configuration was obtained by securing the plates in position using tack welding for GMAW welds. The direction of welding was normal to the rolling direction. All necessary care was taken to avoid joint distortion, and the joints were made with suitable clamps Single pass welding was used to fabricate the joints. 5356AA grade filler rod and wire were used for GMAW welding processes, respectively. High purity (99.99%) argon gas was the shielding gas.

Square butt joint configuration as shown in Fig.A was prepared to fabricate GMAW Butt joints. After the GMAW Weld Butt joint model were completed on AA7020 aluminum Base weld metal were prepared for the tensile specimen according to ASTM E8M-04 standard, AA7020 aluminum alloy the tensile specimen were prepared for as per Fig. B (2), ASTM E8M-04 standard for the tensile test was carried

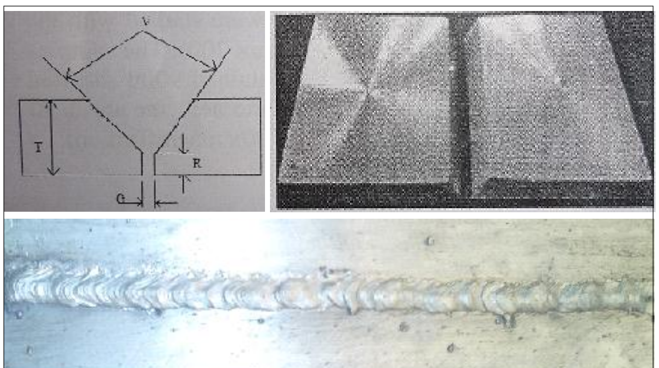


Fig. A : Plate edge, joint preparation and welded joint

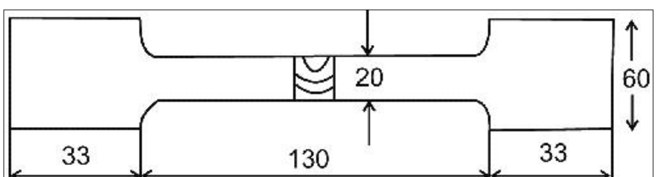


Fig. B (1) : Dimensions of flat tensile specimen (ASTM E8M-04)

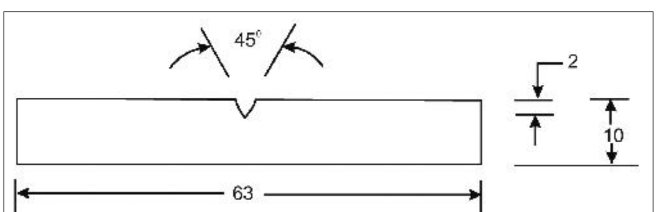


Fig. B (2) : Dimensions of flat impact specimen

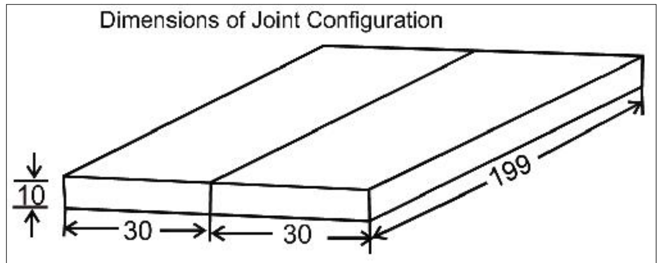


Fig. C : Scheme of welding with respect to rolling direction and extraction of tensile specimen

out using universal testing machine(UTM). The results are noted that Tensile strength is 21.21N/mm², yield stress 8.61N/mm² and the per cent elongation was 9.17 per cent.

Hardness testing :

Hardness test was carried out using Rockwell hardness testing machine. Three readings were taken and the average value has been reported. Measurement were taken along a line at half of the depth of fusion zone across the entire weld region at an interval of four times the indenter's size to avoid the effects of localized strain hardening in the vicinity of the indentation attributed to the dissolution of precipitates' into solution and subsequently.

Impact testing :

Impact testing was done using Charpy impact testing method IS: 1757- 1973. The Charpy impact test used a sample notched in the center of the one face. A standard length of 60 mm (+/- 0.1mm) sample was used. The V-notch was 2mm deep and of angle 45º. The energy absorbed in breaking the test piece is measured in joules. The ability of the materials to withstand the applied load is referred to as toughness.

FEM study of AA 7020 weld joint :

The theoretical analysis was carried out by using FEM solver ABACUS the maximum temperature towards the minimum temperature at various temperature ranges. Vons Mises stress distribution technique is selected for the stress analysis of the weld specimen using Ansis software. Finite element analysis is the basic theme to make the calculations at only (finite) number of points and then interpolate the results for entire domain **(**surface or volume**).** Any continuous object has infinite degrees of freedom and its just not possible to solve the problem in this format. Finite element analysis reduces the degrees of freedom from infinite to finite with the help of discretization *i.e.* meshing (nodes and elements). All the calculations are made at limited number of points known as nodes. Entity joining nodes and forming a specific shape, such as quadrilateral or triangular etc. is known as element. To get value of variable (say displacement) anywhere in between the calculation points, interpolate function (as per the shape of element) is used. Finite element analysis belongs to numerical method category. Applications of FEM are for linear, nonlinear, buckling, thermal, dynamic and fatigue analysis. In this case thermal analysis is applied for studying the parameters of welded joints. Thermal analysis of the part or a system was done to calculate heat transfer rate and temperature distribution by different approaches as, Theoretical (Analytical), Experimental, Numerical and Graphical. It is observed especially for the welding of large structures the failures always takes place on the welded sections, due the severe defect during welding or improper selections of welding parameters. In this analysis, it useful to predict the defects occurred in the welded section due to inadequate heat transfer in welding from the electrode tip towards the base metal.

EXPERIMENTAL FINDINGS AND ANALYSIS

The FEM results for the aluminum alloy 7020 by using Von Mises stress distribution, strain distribution and temperature distribution are as explained below.

Temperature distribution :

From Fig. 1, it is observed that during welding when electrode gets melted and its first drop of melted electrode is filled in a V groove of base metal, it produced approximately 1350^0 C at fusion zone. However, the temperature of base metal recorded for this section noted at room temperature was 20^0 C. The similar results were recorded at weld vertical axis from weld centre. The temperature of this section gets from weld vertical axis towards the base metal from left or right hand side of the vertical weld axis. The three dimensional section of the weld is presented in Fig. 2(a) and (b).

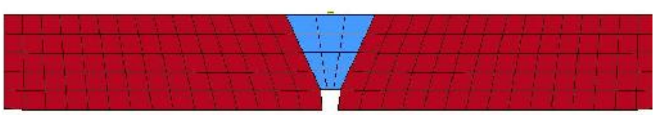


Fig. 1: Weld section details

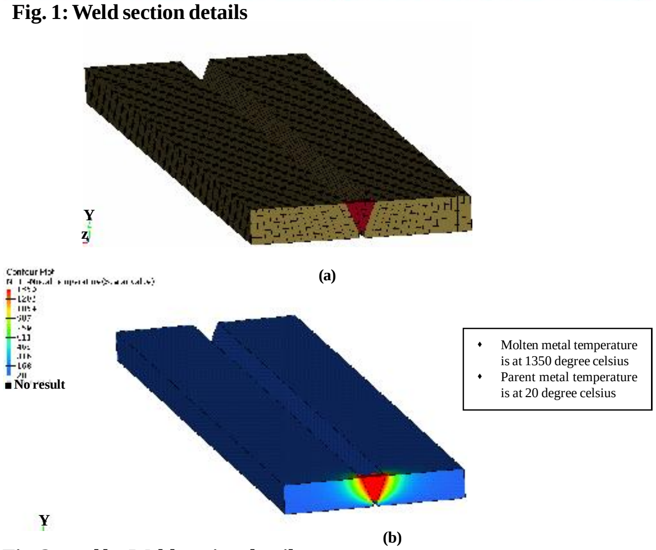


Fig. 2a and b : Weld section details

Von Mises stress distribution :

From Fig. 3 (a) (b) (c) and (d) it is observed that when weld is deposited towards the base metal the maximum stress from 9.1 mm from front face and bottom side recored was 287 Mpa. Neverthleness, if distance from vertical axis decreased In this figure the maximum stress when taken from face at a 9.1 mm from front face and from bottom side *i.e.*

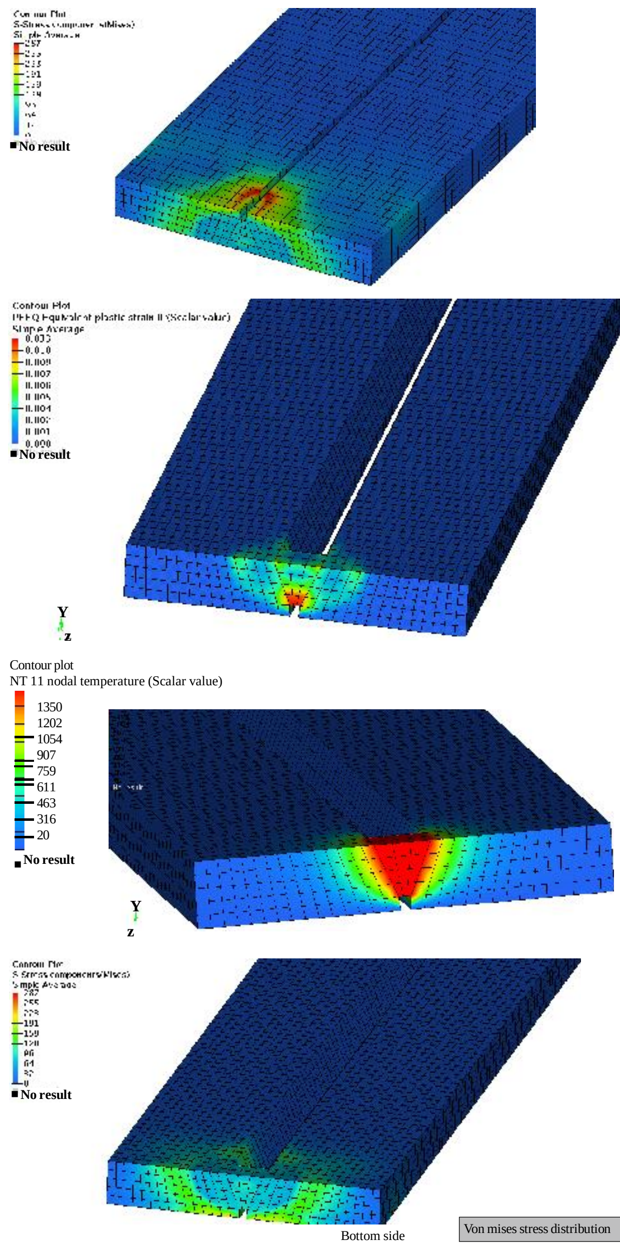


Fig. 3 (a, b, c and d) : Von mises stress distribution

287 MPa and as move away from vertical axis the decreased stress was recorded. As molten metal temperature is at 1350^0C and parent metal temperature is at 20^0 C, results appeared are symmetric in nature about vertical axis.

Strain distribution :

In this Figure the maximum strain distribution of 3.3 per cent at extreme bottom of molten metal, when we move from centre at 4.2 mm we get 0.8 per cent on edge. Fig. 4 (a and b) presents the results of strain distribution of the weld section for AA 7020 weld joint. Moreover, during weld deposition towards the base metal the maximum strain occurred will be at the bottom towards the root pass, as there is a void from which an atmospheric air comes in direct contact with the deposited molten weld material. The maximum strain distribution of 3.3 per cent at extreme bottom of the molten metal was recorded. However, towards 4.2 mm distance from weld centerline the 0.8 per cent strain was recorded.

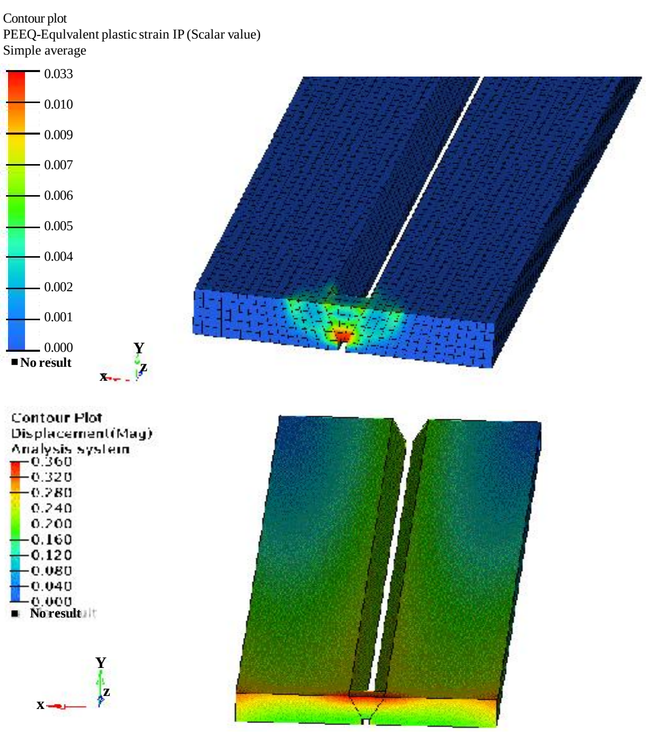
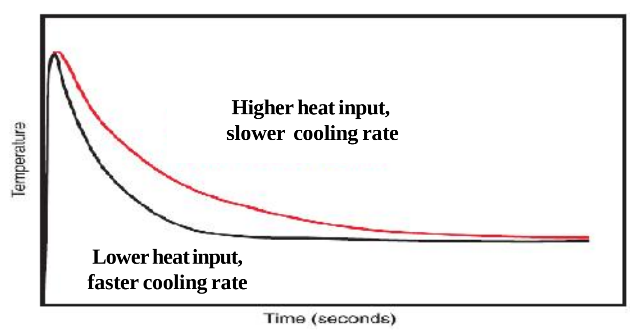


Fig. 4 : Strain distribution

In the Fig. 1, it is observed that the molten metal temperature of a welded specimen is 1350 ^{0}C for the welding of AA 7020 aluminum alloy. While the base metal temperature was 20 ^{0}C. The region presented by red colour in Fig. 2, 3, 4 elaborate the critical temperature region of a weld specimen. Whereas the region marked by green colour is a intermediate temperature region. The temperature flows from the weld centre line towards the end of base metal which affects the mechanical properties of a weld specimen on fusion zone heat-affected zone and base metal for different temperature and cooling cycles. When welding passes are deposited from the top side the maximum stress are developed are on the region toward the root pass of a weld joint. However, for faster cooling rates the region towards the weld bottom surface of a weld joint of a structural material becomes brittle, that reduces the tensile strength, impact strength and hardness. Nevertheless, the maximum failures were recorded for this region of the welded joint. From the bottom surface of a weld joints, however, the results recorded by bulk tensile strength, CVN test and brinell hardness are very poor. Hence, for improving these properties of AA 7020 aluminum alloy can be reduced by severe post heat treatment cycles of the welded sections are recommended. During the post heat treatment process the stresses, which are developed during welding gets recrystallization and refined and the mechanical properties gets improved. During post heat treatment of a welding the stresses which are developed in a region towards the heat affected region gets refined and the recasting in a region takes place. This also supports the improvements in the metallurgy of the weld region. Also this method helps to increase the weld strength of large weld structures, reduces the failures and also save the overall weld economy of large weld structures.

Effect of heat input for welding of AA7020 Al alloy :

In metal inert gas Arc welding, energy is transferred from the welding electrode to the base metal by an electric arc. When the welder starts welding, both the base metal and the filler metal are melted to create the weld.



This melting is possible because a sufficient amount of power (energy transferred per unit time) and energy density is supplied to the electrode. Heat input is a relative measure of the energy transferred per unit length of weld. It is an important characteristic because, like preheat and inter pass temperature, it influences the cooling rate, which may affect the mechanical properties and metallurgical structure of the weld and the HAZ. Heat input cannot be measured directly. It can, however, is calculated from the measured values of arc voltage, current and travel speed. Heat input is typically calculated as the ratio of the power (*i.e.*, voltage x current) to the velocity of the heat source (*i.e.*, the arc) as follows:

$$H = \frac{60\,EI}{1000\,S}$$

where,

H = Heat input (kJ/in or kJ/mm)

E = Arc voltage (volts)

I = Current (amps)

S = Travel speed (in/min or mm/min)

This equation is very useful for welding of AA7020 aluminium alloy by using gmaw. Heat input is a sole variable to control the mechanical and metallurgical properties of AA 7020 aluminum alloy.

Conclusion :

From above study, following conclusions were made:

–From the FEM analysis the maximum stress recorded for a multipass AA 7020 aluminum alloy was 287 Mpa. Moreover, the maximum strain distribution of 3.3 per cent at extreme bottom of weld metal deposition.

–From this study it is observed that increased heat input increases grain sizes that reduces the tensile strength, impact strength and micro hardness, however, post heat treatment is very essential for aluminum alloy joining that can avoid the abrupt failures of large welded structures.

–From the experiment study it is observed that for power supply of 100 amp, 22 volt and 100 Hz, the better properties of the weld joint were noted for welding of 10 mm AA 7020 base metal.

REFERENCES

Arunkumar, N., Nirmal, L.K.and Ananthapadmanaban, D. (2011). Effect of parameters involved in MIG welding of OHNS steel. *J. Modern Manufact. Technol.,* **3**(2): 111-127.

Herring, Daniel, H. (2005). Grain size and its influence on materials properties. *Materials Sci. & Engg.,* 22 August 2005: 29-32.

Ghazvinloo, H.R., Honarbakhsh-Raouf, A. and Shadfar, N. (2010). Effect of arc voltage, welding current and welding speed on fatigue life, impact energy and bead penetration ofAA6061 joints produced by robotic MIG welding. *Indian J. Sci. & Technol.,***3**(2): 25-28.

Indira Rani, M. and Marpu, R.N. (2012). Effect of pulsed current tig welding parameters on mechanical properties of J-joint strength of Aa6351. *Internat. J. Engg. & Sci. (IJES),* **1**(1): 1-5.

Kashyap, K.T. and Chandrashekar, T. (2001). Effects and mechanisms of grain refinement in aluminium alloys. *Bull. Mater. Sci.,* **24**(4): 345–353.

Kodgire, V.D. and Kodgire, S.V. *Material science and metallurgy for engineers.* Everest Publication House, 2.

Kolhe, K.P. and Datta, C.K. (2007). Prediction of microstructure and mechanical properties of multipass SAW. *J. Material Proc. Technol.,* **197**(1-3): 241-249.

Kumar, Pawan, Kolhe, Kishor P., Kolhe, Prakash R. and Datta, C.K. (2009). Optimization pulsed GTAW process parameters for bead geometry of titanium alloy using Taguchi method.*Asian Sci.,***4** (1&2): 78-82.

Kumar, Pawan, Kolhe, K.P. and Datta, C.K. (2010). Optimization of weld bead geometry for pulsed GTA welding of aluminum alloy 6061 by taguchi method. *Internat. J. Manufact. Technol.& Indus. Engg.,* **1**(1) : 39-44.

Military standardization handbook of aluminium and aluminium alloy (1966).Department of Defence Washington 25,D.C.15 December 1966.

Park, H.J., Kim, D.C., Kang, M.J. and Rheem, S. (2008). Optimisation of the wire feed rate during pulse MIG welding of Al sheets. *J. Achiev. Materials & Manufact. Engg.,***27** (1): 45-50.

Park, H.J., Kim, D.C., Kang, M.J. and Rhee, S. (2000). Recent development in aluminium alloys for the automotive industry. *Materials Sci.& Engg.,* **280** (1) : 37–49.

Prakash, Jyoti, Tewari, S.P. amd Srivastavain, Bipin Kumar. Shielding gas for welding of aluminium alloys by TIG/MIG welding-A review. *Internat. J. Modern Engg. Res. (IJMER),* **1**(2): 690-699.

Rajakumar, S., Muralidharan, C. and Balasubramanianin, V. (2010). Establishing empirical relationships to predict grain size and tensile strength of friction stir welded AA 6061-T6 aluminium alloy joints. *Trans. Nonferrous Metals Society China,* **20** (10) : 1863-1872.

Richard, L. Litle (1976). *A text book of welding and welding technology.* TATA Mach-Graw Hill, Ed 22.

Sindo Kou (2003). *Welding metallurgy.* Wiley-Interscience. Ed 2.

Srinivasarao, B., Del Valle, J.A., Ruano, O.A. and Pérez-Prado, M.T. (2007). Influence of thermo mechanical processing on the grain size, texture and mechanical properties of Mg-Al alloys. *Metallic Materials,* **50** (1) : 1-23.