To Study the Mechanical Properties of Aluminum Alloy AA-6061 Welded using TIG Welding Process at Different Welding Current

Ishteyaque Ahmad[1], Somvir Arya[2]

[1]Research Scholar, Mechanical Engineering Department, Indus Institute of Engineering & Technology, Kinana (Jind) Haryana India
[2]Assistant Professor & Head, Mechanical Engineering Department, Indus Institute of Engineering & Technology, Kinana (Jind) Haryana India

---***---

***Abstract**: Tungsten Inert Gas welding is the process in which heat is produced from an arc between the non-consumable tungsten electrode and the work piece.TIG welding is the widely used technique for the joining of ferrous and non-ferrous metals. The molten metal, tungsten electrode and the welding zone are shielded from the atmospheric air by a stream of inert gas through the welding torch. During the TIG welding the filler wire may or may not be use. The accuracy and quality of welded joints largely depends upon type of power supply, welding speed, type of inert gas used for shielding and also the gas flow rate. This paper deals with the study of Micro-structural and mechanical properties of the welded joints of the aluminum alloy AA-6061 welded by Tungsten Inert Gas(TIG) welding by using welding current as varying parameter.*

Keywords: Mechanical, Micro-structure, Properties, Welding, Al

1. Introduction:

Welding is a process of joining two similar or dissimilar metals by fusion with or without the applications of pressure and with or without the use of filler metal. Weld ability of a material depends on different factors like the metallurgical changes that occur during welding , changing in the hardness at the welding zone due to rapid solidification, extent of oxidation due to reaction of materials with the atmospheric oxygen and tendency of crack formation on the welding joint position.

The welding phenomenon comes in existence from “Bronze Age” about 2000 year ago. But the Egyptian people were started to weld the iron pieces together during the Iron Age. Mainly the TIG welding technique was demonstrated firstly by Russell Meredith in 1930 during the Second World War for the purpose of welding of aluminum and magnesium in air craft industry.TIG welding is mostly used in the modern industry, especially for aluminum stainless steel, titanium alloy and other materials for high quality weld. TIG welding process has some advantages including as high quality weld, easy control of welding parameters.

1.1 Different Types of Welding:

- Arc Welding
- Electric Resistance Welding
- Gas Welding
- Solid State Welding
- High Beam Energy Welding

1.2 Tungsten Inert Gas welding / TIG

TIG (Tungsten Inert Gas) welding is also known as GTA (Gas Tungsten Arc) in USA and WIG (Wolfram Inert Gas) in Germany is a welding process in which a non-consumable tungsten electrode is used to make a weld. TIG welding process used for high quality welding of a variety of materials, stainless steel, titanium and aluminum. During the TIG (as shown in the fig. 1) welding inert gas is used to shield the welding zone from the atmosphere.

An electric arc is produced between the work piece and the electrode with the continuous supply of current from the power source. During the TIG welding there may or may not be the use of a filler electrode. The filler rods are used to provide the welding bead during the joining two pieces of a metal together.

TIG welding also helps in the joining of the dissimilar metals with each other. The temperature of the electric arc exceeds 3600 °C. The intense heat is focused on a very small area. TIG welding is a quick, clean and free of slag and sputter.

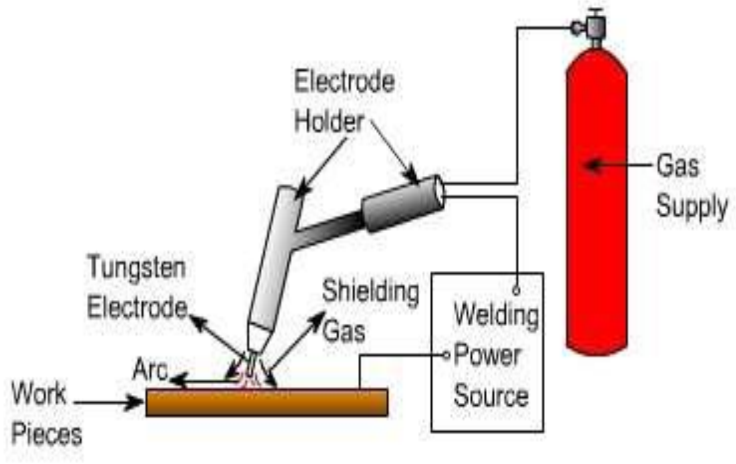

Figure 1: Dia. of TIG welding apparatus

1.3 Types of Welding Current Used During TIG Welding

Different types of welding current are used during the TIG welding:

a) DCSP (Direct Current Straight Polarity): During the direct current straight polarity the tungsten electrode is connected with the negative terminal. These types of connections are most widely used during the DC welding process. Due to the connection of tungsten with the negative terminal it will receive only 30% of welding energy. So the tungsten will run cooler than DCRP. And the welding results have good penetration and narrow profile.

b) DCRP (Direct Current Reverse Polarity): During this the tungsten electrode connected with the positive terminal. These types of connections are rarely used because most of the heat is on the tungsten electrode thus the tungsten can easily be over heat and burn away. DCRP is used mainly for very light materials at low amperes.

c) AC (Alternating Current): Alternating current is most widely preferred current for white metals such as aluminum and magnesium. The heat input to the tungsten electrode is average as the AC waves passes from one side of the wave to the other. During the half cycle tungsten electrode is positive due to this electron will flow from base material to the tungsten. This will produce any oxide skin on the base material. This side of the wave called cleaning half. And when the wave moves to the other point where tungsten becomes negative the electrons will flow from the welding tungsten to the base material. This cycle is called the penetration half of the AC wave forms.

d) Alternating Current with Square Wave: In the modern electricity AC welding machines can be produced with a wave form called square wave. The square wave have better control and side of the wave can gave a more cleaning half of the welding cycle and more penetration.

1.4 Advantages of TIG welding

The TIG welding is a highly controllable process that leaves a clean weld which usually needs little or no finishing. TIG welding can be used for both manual and automatic operations. TIG welding can be use on mostly all types of metals due to this the TIG welding have special advantages over the arc welding. These advantages are given below:

1) TIG can be used on ferrous and non-ferrous metals.
2) In the TIG welding there is no use of flux or leaves a slag.
3) During TIG welding there is the use of shielding gas to protect the weld pool from atmospheric air.
4) The TIG welding has no spatter.
5) There is the formation of narrow concentrated arc during TIG welding.

1.5 Aluminum:

Aluminum is light, ductile, readily worked metal with good thermal and electrical properties. It have tenacious oxide film on the surface which provides it good corrosion resistance. Aluminum is the most abundant metal on the earth. Aluminum alloys are sub-divided into main two groups-

1) Cast Alloys.
2) Wrought Alloys.

Cast Alloys: Aluminum alloys casting can be produced in metal moulds, sand moulds, and by pressure die casting. The casting processes providing good corrosion resistance and rigidity. Copper, silicon, magnesium, zinc, manganese and nickel are the alloying elements used in the casting of aluminum.
Wrought alloys- Wrought alloys having the cast material which has been work out by the process such as forging, extrusion, drawing or rolling. So the wrought alloys have enhanced mechanical properties. Wrought alloys are suitable for the welded construction.

Wrought alloys may be:

Forged to provide a variety of shapes, extruded to give bars, sections, tube, hot or cold rolled to produce plate, sheet, strip, and foil or drawn for making wire belts screw and rivets.
Wrought aluminum alloys are the mainly two types:

1) Heat treatable.
2) Non-heat treatable.

Heat treatable alloys are strengthening by the heat treatment process. Non-heat treatable alloys are strengthening by the cold working process.

2. Literature:

Mayur [1] investigated the structural and mechanical properties of aluminum alloy AA 5083 of size 125 mm x 60 mm x 3 mm after single pass Tungsten Inert Gas welding using the filler wire as AA-5356. The aluminum alloy plates were joined by TIG welding technique to examine optimal welding current. Welded specimens were investigated using optical microscopy, tensile and Vickers's micro-hardness tests. Optical microscopy was used to characterize transition sites of welded zone, HAZ and base metal. Results have shown that optimum weld current out of the three weld currents used (70A, 75A and 80A) is 75A.Better microstructure and mechanical properties were found in the welded joints for the weld current 75A.

Kareem [2] in this research the study of microstructure and mechanical properties of aluminum alloy AA-5052 having the thickness as 6 mm welded by MIG,TIG and friction stir welding processes was take place. From the investigation it was shown that the weldments processed by GTAW of aluminum alloy AA-5052 are mechanically more reliable than welded by GMAW. Perceivable porosity in the weldments done by GMAW was found. Friction stir welded samples have more strength than that of MIG welded samples. The weld metal microstructure of MIG welded specimen contains equiaxed dendrites as a result of solidifications process during MIG welding while friction stir welded specimen have wrought microstructure.

Hussain [3] investigated the effect of welding speed on the tensile strength of the welded joint. The experiments were conducted on specimens of single V butt joint having different bevel angle and bevel heights. The material selected for the specimens were aluminum alloy AA -6351. The tests were conducted on the universal testing machine. The results show that the depth of penetration of weld bed decreases with increase in bevel height of V butt joint. Maximum tensile strength was observed at weld speed of 0.6 cm/sec. It means strength of weldment is weaker than the base metal. The heat affected zone, strength increased with decreasing heat input rate.

Sivashanmugam [4] have investigated the mechanical properties and microstructure of the aluminum alloy AA-7075 having size 300 mm x 150 mm x 6 mm by using the different welding techniques GTAW and GMAW with argon as a shielding gas. A constant current AC power source with a continuous high frequency is used with water or air cooled GMAW torch. The torch must be maintained at an angle of 90 degree to the work piece and the filler material must enter the weld pool at an angle of typically 5 degree. Surface Mechanical properties of the joint like tensile strength, hardness and impact strength have been found out. Welded joints fabricated by GMAW process have lower strength than the GTAW process. Hardness is lower in the weld metal region compared to the HAZ and BM region. High hardness is recorded in the GTAW. The impact strength value is more in GTAW as 6 J than the GMAW as 4 J.

Naitik [5] have found out effect of TIG welding parameters such as welding current, gas flow rate, welding speed, that are influences on responsive output parameters such as hardness of welding , tensile strength of welding, by using optimization philosophy. The effort to investigate optimal machining parameters and their contribution on producing better wed quality and higher productivity.

Indira [6] have investigated the mechanical properties of the welded aluminum alloy AA-6351 during the Gas Tungsten Arc Welding (GTAW)/Tungsten Inert Gas (TIG) welding with non-pulsed and pulsed current welding at two different frequencies 3 Hz and 7 Hz. The specimens were selected of size 300 mm x 150 mm x 6 mm. The welding was performed with a current of 70A-74A and arc travel speed was 700-760 mm/min. AA-6351 have more ultimate tensile strength with the pulsed current welding frequency of 3 Hz. Pulse welding provide the better depth of penetration and fusion of filler material with parent metal is obtained and by this it improves strength and ductility of weldments.

Laksman [7] investigated the influence of welding parameters on the weld bead geometry such as front width and back width of the welded joint. The aluminum alloy selected for the experiment was AA-5083 and the specimen having the size 50 mm x 30 mm x 5 mm. The filler wire used during the welding was 5356. The welding parameters such as welding current, gas flow rate, and welding speed were being taken as the variables. The front width and back width of weld bead increases linearly for different values of welding current when gas flow kept constant. The front width and back width decrease linearly with increase in welding speed at constant current but there is the increase in depth of penetration. By changing the value of gas flow rates in increasing order then the front width and back width increase or decrease alternatively with keeping the welding current constant.

Czechowski [8] have made a research to found out the comparison of the stress corrodibility of the aluminum alloy AA-5083 with the aluminum alloy AA-5059 by the MIG and friction stir welding. Stress corrosion cracking was examined by the slow-strain-rate-testing (SSRT) according to EN ISO 7539-7. The tests were carried out on cylindrical notch-free specimens with diameter d=5 mm. The fractures were analyzed by electron scanning microscope of Philips XL 30 type. Tests were carried out in air and in a 3.5% water solution of NaCl. During the experiment the measured terms were: time-to-failure, obtained maximum load, strain energy, relative elongation of the specimen, tensile stress and reduction-in area. Aluminum alloy AA-5059 welded by friction stir welding have better strength properties as compared to the aluminum alloy AA-5083 welded by friction stir welding. Alloy AA-5083 has good resistance to stress corrosion on joining with the friction stir welding.

Miroslaw [9] investigated the results of low-cycle fatigue tests of welded joints of the aluminum alloy AA-5059 with the MIG welding under argon shield method. The low-cycle fatigue tests were performed in the air and in the 3.5% NaCl water solution having stress amplitude as constant. The resistance of the samples exposed in 3.5% NaCl water solution is lower than the resistance of the samples tested in the air. In the upper range of the low-cycle resistance with substantial strain, the cracking may initiate inside the cracked particles located on the sample's surface or on the borders with their matrixes.

Kora [10] Medium strength aluminum alloy (Al-Mg-Si alloy) has gathered wide acceptance in the fabrication of light weight structure requiring a high strength-to-weight ratio such as road tankers, military vehicles and railway transport system. In this research the investigation has been made about preparation of a weld joint of an aluminum alloy with exceptional properties and evaluate the mechanical and micro-structural properties by conducting tensile test, toughness test, % elongation test micro-structure and SEM imaging.

Duhan [11] have investigated the microstructure and effect of heat on hardness of base metal, weld bead and heat affected zone (HAZ) by welding of EN31 by the MIG (GMAW) welding process. The dimensions of the used specimen were 320 mm x 160 mm x 10 mm. And CO_2 was taken for the shielding gas purposes. And an electrode of 308 with diameter 1.2 mm was used with direct current electrode positive polarity. With the two variables as current and voltage the double-V butt joint was made at 90 degree. In the results the value of hardness was found higher at heat affected zone but the hardness at the welded portion was found minimum.

Lakshman [12] have made a research to find out the tensile strength of aluminum alloy AA-5083 welded with the TIG welding process by using the different grades of filler electrodes and with variable value of welding current. The specimen of aluminum alloy AA-5083 used having the size as 150 mm x 12.5 mm x 6 mm. The filler electrode used in the experiment with the different current were (Graded as 5356, 5556, 5183, 5554, 5083). The maximum tensile strength of the welded joint was found as 136 MPa obtained at the welding current of 240 Amp with the use of 5083 graded filler electrode.

3. Experimental Work:

3.1 Basic size of the selected material:

This is the first step that we have to select the basic size of the material for the experimental work. We have selected the material as aluminum alloy of grade AA-6061 T-651 and cut the pieces in the rectangular form of the size as 200 mm x 150 mm x 6 mm. And for the welding of aluminum alloy AA-6061 we have selected the filler wire of grade as AA-4047 having the diameter as 1.6 mm and length as 30 inches.

3.2 TIG welding preparation for the pieces:

After the cutting of the pieces we have to use the TIG welding on pieces at the different values of welding current for the experimental procedure. The TIG welding was done on the aluminum alloy at Kewal Welding Works Jawhar Nagar Hanuman Gang Ghar (Ludhiana). Before the welding the pieces are we have to prepare the pieces for the welding. The grinding was being done on the edges of the pieces to provide them a better smoothness for a proper welding joint. After that we have use the grit emery paper for the removal of the any kind of external material from the surface of the plate. Tungsten electrode with the diameter as 2.4 mm was taken. The end point of the electrode was prepared by reducing the tip diameter by the grinding process (as shown in figure 2).

Figure 2 : Fit the nozzle (cup) to the torch body

The TIG welding was being done manually on the work pieces. The Tungsten electrode in the welding torch kept as perpendicular to the work piece during the welding. There is the use of Argon gas during the welding and the gas flow rate is controlled with the help of gas regulator and valve. There is change of voltage takes place for its peak value during the change the value of current. Surface plate used to keep the pieces for the flat welding and heavy weights are used on the pieces to prevent from bending.

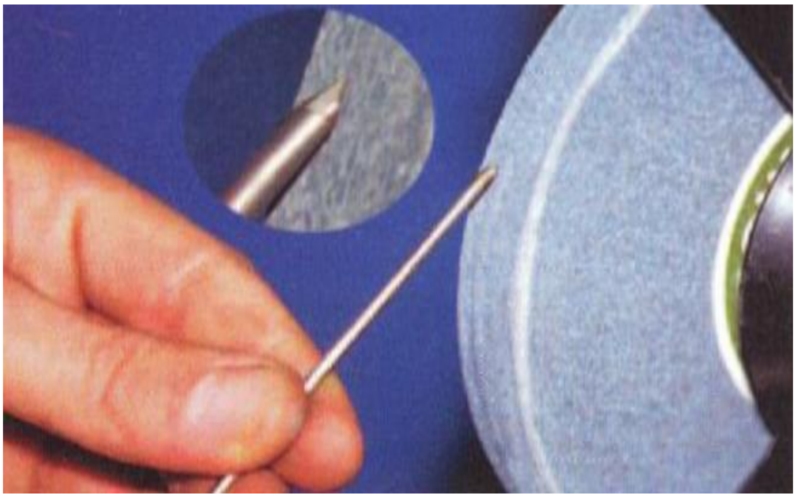

Figure 3 : Grinding the tungsten electrode

At the value of welding current as 140 ampere the welding joint between the two pieces take place. The gas flow rate was kept as10 liter/minute. During the TIG welding using alternating current as 140 ampere the value of voltage varies from 12.7 volts to 13.4 volts. During the welding the value of fixed current may also varies two or three points for example during the welding load the current may reach the value of approximately as 142 ampere. The welding was take place on the horizontal flat plate from the left end to the right end with a constant manually speed. The time taken during the welding was approximately 67 second. The welding type was the single pass welding as shown in figure 9 on the one side.

Figure 4 : Welding Plate after TIG Welding at the value of current as 140 ampere

TIG welding at the current value of 150 ampere:

Welding current during experiment = 150 ampere

Gas flow rate kept as = 10 liter/minute

4. Result & Discussion:

4.1 Testing of the welded specimen:

After the welding the welded specimen are passed through the microstructure testing and micro-hardness testing of the base material and of the welded portion. The micro-structure of the base material and the welded material and the micro-hardness testing of the welded material was being takes place at M/s Spectro Analytical Labs Limited (E-41, Okhla Industrial Area, Phase-II, New Delhi-20

Figure 5 : Specimen selected for the testing procedure

The micro-structural testing takes place by using the optical microscopy and micro-hardness examined by using the Vickers hardness tester. Specimens are to be cut in the lab with hand hacksaw for the testing having the size as 50 mm x 10 mm x 6 mm as shown in figure 14. After cutting the pieces these are to be passed through the different operations such as grinding, polishing with grit size emery paper and finally the etching process with the etching liquid solution. The surface roughness of the specimens was investigated at Jind Institute of Engineering &Technology Jind (India) by using Mitutoyo SJ-201 surface roughness tester. Surface roughness of the specimens was measured along the length of the weld bead.

4.2 What is Micro-structure:

Micro-structure refers to the surface structure of material such as thin foil that can be revealed under magnification higher than 25X. Micro-structure is the way in which a material comes together on a very small scale. An objects micro-structure is not visible by naked eye, although the patterns present at the microscopic level may replicate at a larger level. This larger level is the macroscopic level, it will give a basic impression of the underline design of the material to the observer. The microstructure of the object determine majority of its physical properties. Physical structure of the material to be changed depends how closely we look it.

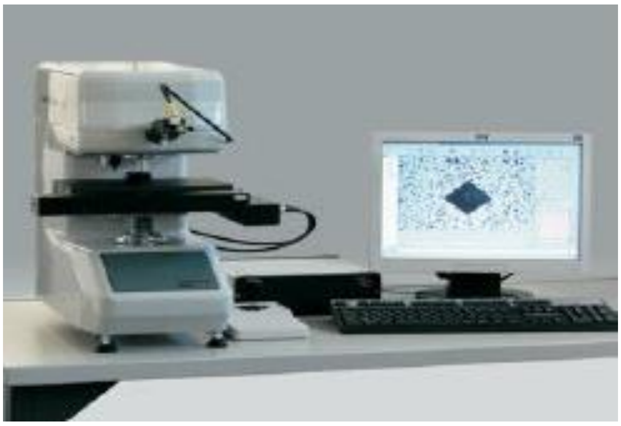

Figure 6: Vickers Hardness testing Equipment

Micro Structure of Base material of aluminum alloy AA-6061 T651:

The piece of the size as 50 mm x 10 mm 6 mm from the base material was prepared by the polishing and etching process for the microstructure testing. The piece was placed on the Versamet Unitorn 5463 optical microscope for the microstructure. The testing method used for the microstructure testing was ASM 9, 2004. The microstructure (as shown in the fig.7) of the base material specimen was captured on the microscope at 200 X magnification with help of camera along the weld.

Observed results after the microstructure testing:

The grain size	0.005-0.010 mm
Porosity	Few Sports (up to .02 mm)
Oxide/ Inclusions	Negligible
Silicon Eutectic	Satisfactory
Primary Silicon	Not Present

The grain size of the particles of the aluminium alloy AA-6061 was 0.005-0.010 mm in the microstructure. Oxide/Inclusions were negligible on the surface of the base material. Only few sports of porosity (up to .02 mm) were present. Primary Silicon was not present in the microstructure of the base material.

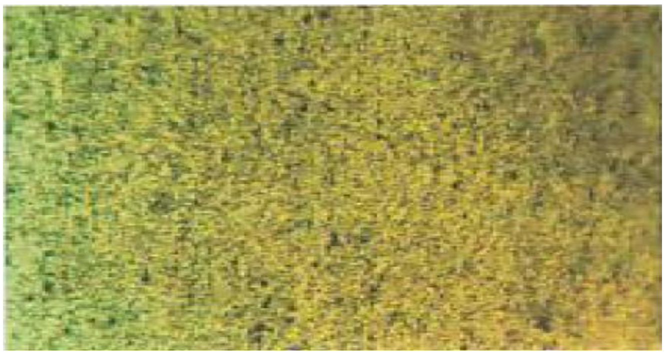

Figure 72 : Microstructure of the base material

4.3 Microstructure of the welded part of aluminium alloy AA-6061 T651 welded at the current as 140 ampere:

Now the cut welded piece of the size as 50 mm x 10 mm x 6 mm welding with 140 ampere current was placed on the optical microstructure for the testing. The method used for the testing of microstructure of the aluminium alloy was ASM 9, 2004. The microstructure was found out after the polishing and etching of the specimen. The microstructure of the welded part (as shown in the fig. 8) consists of interdendritic network of aluminium silicon in matrix of aluminium solid solution.

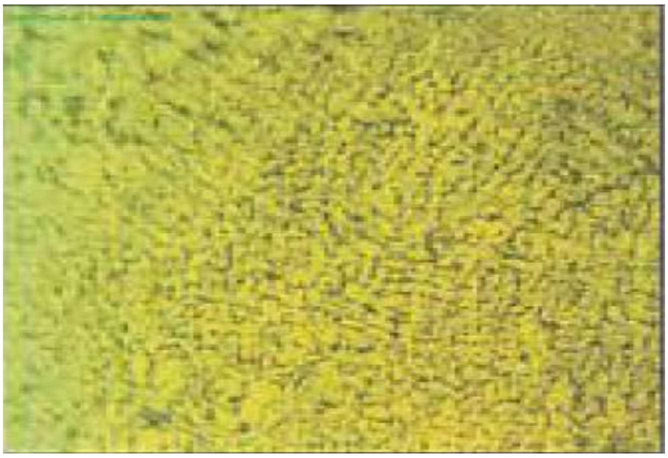

Figure 8: Microstructure of the welded part at welding current as 140 ampere

5. CONCLUSIONS:

From all these investigations the following conclusions have been outlined:-

The micro-hardness of the base material is more as compared to the hardness of the welded part. There is the alternative change in the micro-hardness value with the increasing of welding current during this experiment.

There is also the change of micro-structure of the different welded plates. The base material microstructure has the closely packed molecules atomic structure. There is the increase in the gap between the molecules as 100 μm.

REFERENCES:

[1] S. Mayur, K. M. Pavan, L. S. Sachin, A. Chandrashekar, and B. S. A. Kumar, “Effect of Welding Current on the Mechanical and Structural Properties of TIG Welded Aluminium Alloy AA-5083,” vol. 3, no. 2249, pp. 431–438, 2013.

2] A. A. Kareem and A. Jothilingam, “Study of Microstructure and Mechanical properties of 5052 aluminium alloy welded by MIG , TIG and friction stir welding processes,” pp. 313–321, 1991.

[3] A. K. Hussain, A. Lateef, M. Javed, and T. Pramesh, “Influence of Welding Speed on Tensile Strength of Welded Joint in TIG Welding Process,” vol. 1, no. 3, pp. 518–527, 2010.

[4] M. Sivashanmugam, C. Jothi Shanmugam, T. Kumar, and M. Sathishkumar, “Investigation of microstructure and mechanical properties of GTAW and GMAW joints on AA7075 aluminum alloy,” Proc. Int. Conf. Front. Automob. Mech. Eng. - 2010, FAME-2010, vol. 3, no. 2, pp. 241–246, 2010.

[5] N. S. Patel, “A Review on Parametric Optimization of Tig Welding Naitik S Patel , 2 Prof . Rahul B Patel,” pp. 27–31, 2014.

[6] I. R. M and R. N. Marpu, “Effect of Pulsed Current Tig Welding Parameters on Mechanical Properties of J-Joint Strength of Aa6351,” pp. 1–5, 2012.

[7] L. Singh, V. Shah, and N. K. Singh, “Study The Influence of TIG Welding Parameters On Weld Characteristics Of 5083 Aluminum Alloy,” vol. 2, no. 5, pp. 462–468, 2013.

[8] M. Czechowski, “Slow-strain-rate stress corrosion testing of welded joints of Al-Mg alloys,” vol. 20, pp. 219–222, 2007.

[9] S. Design, “LOW-CYCLE-FATIGUE TESTING OF AW 5059 ALLOY JOINTS,” pp. 1–7, 2004.

[10] K. T. Sunny, J. Joseph, G. S. Mangalathu, and J. Mathew, "a Review on Mechanical & Microstructural Property Evaluation of Aluminium 5083 Alloy Weldment," vol. 3, no. 4, pp. 119–128, 2013.

[11] R. Duhan and R. Nandal, "A Study of Microstructure and Hardness in AISI A ISI 50110 (EN 31) Welded Joints Using Gas Metal Arc (GMAW (G MAW) MAW) Welding," vol. 08, no. 01, 2013.

[12] L. Singh, J. Rana, A. Grewal, B. Singh, V. Biswal, and A. Prof, "Study Different Graded Electrode ' S Influence Over Tensile Strength of Tig Welded 5083 Al-Alloy," vol. 1, no. 12, pp. 1512–1517, 2014.