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Experimental Investigation of Effect of TIG and MIG Welding Parameters on Ti6Al4V

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Abstract : *This paper reports on a study aiming at comparing mechanical and structural properties of Ti6Al4V titanium alloy of grade 5 welded by TIG and MIG welding. To achieve this motive titanium alloy plates of thickness 5mm were welded using tungsten inert gas welding (TIG) and metal Inert gas welding (MIG). Mechanical properties, microstructure, residual distortions and welded geometry of the joints produced with TIG and MIG welding were analyzed. TIG and MIG are generally two most commonly used welding on titanium alloy (Ti6Al4V). Welding is done by using filler material ERTi5. Tn all 18 specimens were tested for determining different properties of titanium alloy out of which 9 specimens were welded using TIG welding and the other 9 by using MIG welding. At the specimens were welded at different welding parameters such as by varying current, voltage, gas flow rate, depth of weld, welding speed, etc. and after testing each specimen for various mechanical properties results are obtained. Taguchi methodology was used to conduct the experiments and analysis of results obtained from welded joints.*

Keywords - *Ti6Al4V, ERTi5, TIG welding, MIG welding, Taguchi Methodology.*

I. INTRODUCTION

Titanium alloys have been used for aerospace, ship industries, desalination of sea water, chemical industries and biomechanics because of its good characteristics such as high specific strength, low thermal expansion rate, high corrosion resistance toughness and high temperature creep resistance. Strength to weight ratio of titanium is high and its joining methodology is crucial Ti6Al4V is the most commonly and widely used titanium alloy, more than half of all titanium tonnage in the world is titanium alloys. Ti6Al4V is commonly used in civil industries, nuclear engineering, military vehicles, road tankers, medically implanted materials, transportable bridge girders and space vehicles because of its significant properties. Mass chemical composition of ti6Al4V is aluminum (Al) 6.38%, vanadium (V) 4.07%, iron (Fe) 0.19%, oxygen (O) 0.17%, nitrogen (N) 0.008%, carbon (C) 0.012% and remaining amount of titanium (Ti). Ti6Al4V exists commonly in alpha state with HCP crystal structure and in beta state with BCC crystal structure. Titanium alloy (Ti6Al4V) is an alpha beta alloy.

Alloy of titanium are sensitive to heat treatment, ageing, and solution treatment and they can withstand high temperatures. Alpha phase stabilizes by alpha stabilizers such as tin, aluminum and zirconium whereas beta phase stabilizes by beta stabilizers such as iron, vanadium and molybdenum. Property enhancing techniques can increase strength by 50% compared to the annealed condition. During welding a small portion of Ti6Al4V is melted and cooled rapidly. These stabilizers while welding does not change their crystal structure rather, they increase the hardness and strength of material. During welding titanium temperature reaches above 550˚C and it becomes complicated to weld at this temperature especially at molten stage, it is commonly known to be very reactive towards atmospheric gases such as oxygen, carbon, nitrogen and hydrogen causing severe embrittlement if material. In order to minimize these issues, the entire weld area should be covered by an appropriate shielding medium. Porosity formation is also one of the major factors responsible for low fatigue life of the titanium alloy. Also, the chemical reactivity of the titanium alloy requires special attention. TIG welding of titanium alloy exhibits columnar grains, which deteriorates mechanical properties and may lead to hot cracking. It was observed that Heat Affected Zone (HAZ) was influenced by welding voltage, shielding gas type and welding speed. The attempt of this paper is to provide the optimum welding parameters for welding Ti6Al4V titanium alloy. For optimizing each output variable, the values of factors that should be used were determined and it was confirmed by testing the welding test specimens.

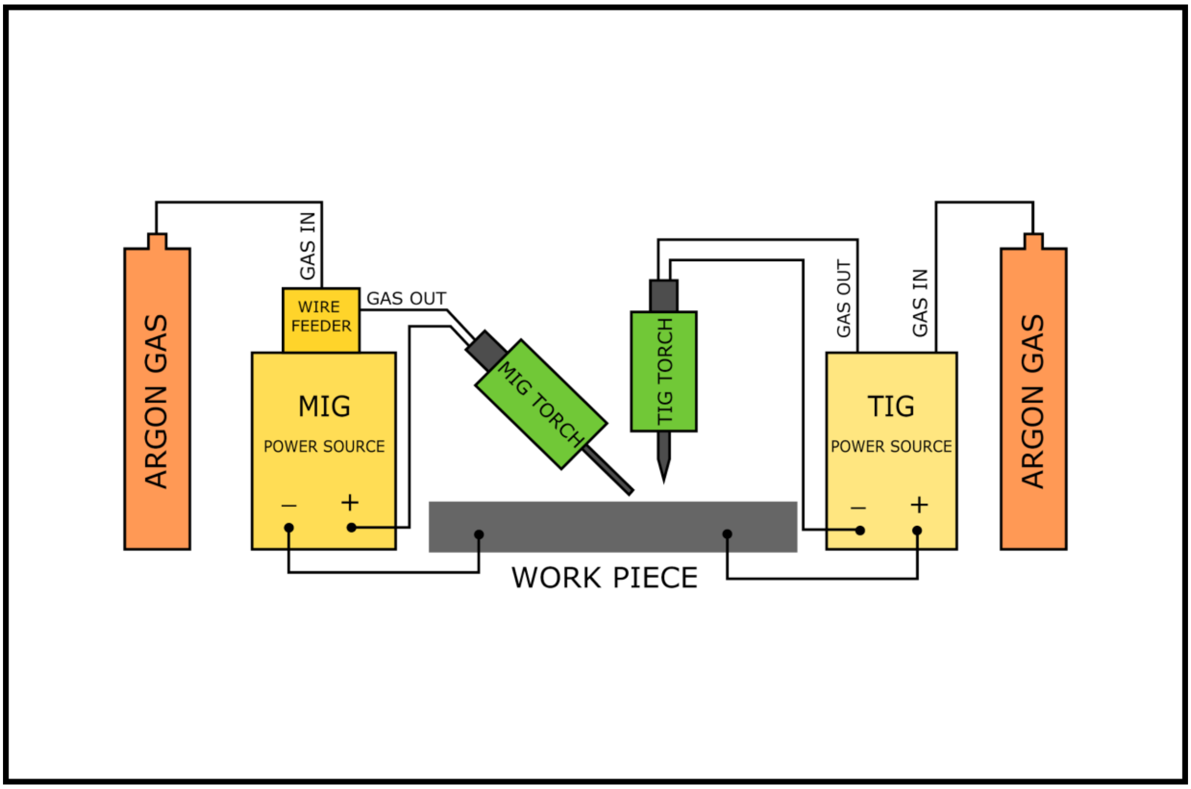

Fig. 1: Schematic diagram of TIG and MIG welding

II. PROBLEM STATEMENT AND OBJECTIVES

Titanium is most commonly used material in engineering application. Ti6Al4V is most widely used titanium alloy and thus it become very important to know about its joining processes. Many welding processes are carried out for welding but TIG and MIG are most commonly used as it gives quality weld. Due to highly reactive nature at elevated temperature, it become reactive to atmospheric gases thus decreasing weld efficiency and it is difficult to obtain sound weld quality. Since material is very expensive and hard to weld thus it becomes very important to know its optimum welding parameters. Titanium has high thermal conductivity due to which there is increase in HAZ of the weld, results into poor weld quality and increase in hardness and brittleness of the weld joint which is undesirable. Optimum welding speed minimises HAZ results into decrease in hardness and brittleness meanwhile increases the ductility of the material.

The main objective of the project is to investigate the best welding practice for the titanium alloy Ti6Al4V by carrying out TIG and MIG welding and to study the influence of various factors on the mechanical properties of welded joints as well as structural properties. Throughout the weld it was monitored that HAZ should be as minimum as possible and HAZ was also analysed in each case.

- Studying the influence of various factors affecting TIG and MIG welding.
- Performing TIG and MIG welding on titanium alloy Ti6Al4V sheets.
- Determining various properties of the welded joints in both the welding TIG and MIG.
- Determining the best welding parameter which gives sound weld quality in TIG and MIG welding.
  Comparing the results and discovering the best practice which results in minimal distortion of mechanical properties of the material.

TABLE 1 Composition of Grade 5 Ti6Al4V

ELEMENT	PERCENTAGE VALUE (%)
Aluminium	6
Vanadium	4
Iron	0.25(maximum)
Oxygen	0.2(maximum)
Titanium	Balance

III. METHODOLOGY

The Titanium alloy (Ti6Al4V) of grade 5 was welded by TIG and MIG welding processes. Total 18 specimens were prepared; each specimen is welded at different welding parameters such as by varying current, voltage and gas flow rate. The test specimen was made according to ISO standard of dimensions of each specimen is of thickness 5mm, length 75mm and width 20mm. V-groove was made in the plates before welding operation at an angle of 45˚ with the base. Argon gas is used as shield gas and filler material ERTi5 of diameter 2.0 mm in wire form is used for TIG welding and in rod form is used for MIG welding.

During TIG welding arc is generated between a non-consumable tungsten electrode and workpiece. The polarity used in TIG welding process in Direct Current Electrode Negative (DCEN) i.e., direct current straight polarity (DCSP). If the thickness of material to be welded is less than 5mm then filler material is not used but for welding metals of thickness above 5mm filler material is used. In this case weld bead obtained is comparatively of less thickness. In MIG welding arc is generated between a consumable electrode and a workpiece. This process is mostly suitable for metals of thickness between 5mm to 15mm. Electrode is in the form of wire which is continuously supplied to the workpiece through the movement of rollers. Movement of rollers are controlled by servomechanism. MIG welding uses Direct Current Electrode Positive (DCEP) i.e., direct current reverse polarity. Such polarity (DCRP) gives stable arc and high weld deposition rate. The distance between the workpiece and the contact tip was maintained about 10mm. Welding torch was held at the angle of 45˚ in relation with the vertical. After welding each specimen at different welding parameters, it was cut into the desired shape by Non-conventional metal cutting process EDM (Electric Discharge machining) and then further testing process was carried out, form each specimen different properties were tested.

For testing strength of the welded joint UTM (Universal Testing Machine) was used and the welded joint was prepared as per the standard dimensions required for testing. Similarly, other mechanical properties were tested such as hardness and toughness. Microstructures of welded joints were carefully studied and analyzed under the microscope and quality of weld was determined.

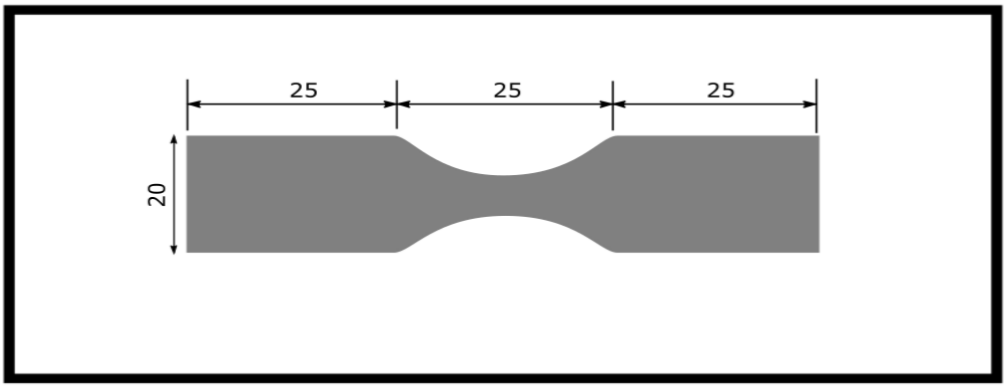

Fig. 2: Standard Dimensions of Specimen used

IV. CONCLUSION

Welding of Titanium alloy by using the method of TIG and MIG welding approach was successfully conducted by selecting different welding parameters. The welding parameters were selected on the basis of thorough research of the preferred material. The weld bead and heat affected zone obtained in both the welding was analysed and it was found that TIG welding gives sound welding quality. Mechanical properties and thermal properties of the TIG welding was better than MIG welding. Weld Geometry of MIG was preferred over TIG welding.

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