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EXPERIMENTAL INVESTIGATION ON MECHANICAL PROPERTIES OF TITANIUM / STEEL GTAW WELDED JOINTS

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ABSTRACT

Titanium and its alloys are widely used due to their unique combination of properties, viz, high strength to weight ratio, high corrosion resistance. In atomic power reactors, petroleum refineries and processing industries the titanium and steel are joined by welding to replace titanium with stainless steel plates [3, 6]. The stainless steel is replaced with the titanium due to high strength, low density and good corrosion resistance of titanium. Therefore there is need to study the weldability of titanium and steel. The mechanical properties of these joints greatly influence the application of these materials [1-2, 7-8]. The objective of this investigation is to study the mechanical properties of Gas Tungsten Welded (GTAW) titanium / stainless steel joints. The joints were fabricated using titanium (Grade 2)/stainless steel (202) plates. The 2 mm thick plates were cut by shearing to size of 150 × 100 mm. The welding was carried out by using GTAW process in the temperature range of 930 to 1000ºc. Since the iron present in the steel has very less solubility in titanium an electrode (filler rod) having composition of Cu-12Mn-2Ni was used to overcome this problem. The welded joints were subjected to tensile test, hardness survey and microstructural investigation. The microstructure analysis showed good grain structure and lack of any defects. The mechanical strength of the joint was good and this investigation proved that titanium could be welded to steel, provided suitable parameters and proper filler material are used.

***Keywords**: Titanium, Steel, GTAW, Microstructure, tensile strength, impact strength, microhardness.*

1. Introduction

There are several applications in which weld elements are made from metals of different compositions. The same is true for a mechanical wear problem, a high-temperature situation, or other conditions in which different properties are required from different parts of the same weld elements [10-12, 14]. This brings about the need for joining dissimilar metals, viz, titanium and steel [4-5]. The Commercially Pure (CP) alpha titanium is the Grade-2 (ASTM Grade) titanium. The Grade 2 titanium alloy is the most widely used in all product forms, primarily for its superior corrosion resistance [13]. Maximum of 0.030 percentage of nitrogen and 0.30 percentage of iron are allowable in titanium grade2. If the iron and oxygen concentration increase the tensile strength increases from 240 MPa to 345 MPa and yield strength increases from 170 MPa to 275 MPa, but the ductility reduces to around 20 percentage of elongation. Also higher iron and interstitial contents will degrade corrosion resistance. Also hydrogen content as low as 30 to 40 ppm can induce hydrogen embrittlement. Grade 2 Unalloyed Titanium (ASTM Grade 2, UNSR50400) can be welded, machined, cast and cold worked [9].

The Grade 2 titanium is used in airframe skin, airframe non-structural components, heat exchangers, cryogenic vessels, components for chemical processing and desalination equipment, condenser tubing, pickling baskets, anodes, shafting, pumps, vessels, piping systems and electrochemical processing equipments[9]. The typical composition of unalloyed titanium grade2 is show in the table .1.

The Stainless Steel (AISI 202) is a ferrous based alloy, in which Mn and N are added to lower the Ni content and maintained higher strength. The AISI 202 stainless steel is a widely available austenite grade. It is similar to the AISI 302 stainless steel, except that the nickel is replaced by manganese. It is mainly used in corrosive environment and in places where bright

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appearance is required The austenitic grade American Iron and Steel Institute (AISI) 200 series (Fe-Cr-Mn-Ni) are 201, 202, and 205[15-16].The typical chemical composition of AISI standard austenitic stainless steel (202) is shown in Table 2.

Table 1. Typical composition of unalloyed titanium Grade 2(by percentage of weight) [9]

C	Fe	H	N	O	Ti Balance
0.1	0.3	0.015	0.03	0.25	99.305

Table 2. Typical composition of stainless steel (AISI 202) (by percentage of weight) [15-16]

C	Mn	Si	Cr	Ni	P	S	N
0.15	7.5-10.0	1.0	17.0-19.0	4.0-6.0	0.06	0.03	0.25

The objective of this study is to fabricate joints from dissimilar materials, viz., titanium (Grade 2)/stainless steel (202) using GTAW process. The Study involved the hardness measurement at the fusion zone using Vickers hardness testing machine.

2. Application of Titanium / Stainless Steel Dissimilar Welding

1. It is used in petrochemical industries
2. It is used in power generation unit
3. It is used for transportation industry
4. It is used to acid storage tank

3. Advantage of Dissimilar Welding

1. It is reduce the amount of titanium materials need
2. Good corrosion and erosion control.
3. To with stand high pressure and temperature

4. Experimental Procedure

The titanium (Grade 2) and stainless steel (202) plates were cut to size of 150 × 100 mm by using shearing machine and then milled to the required size. The titanium and stainless steel plates were joined using single V-butt joint configuration so the one side of the plate is grinding at angle 45º by using grinding machine. These plates were joined by using GTAW process in the temperature range of 930 to 1000ºc.

The specimens are cleaned by acetone before welding to remove grease and contaminants from the weld surface. Welding steel with titanium is very difficult due to the low solubility of iron in alpha titanium at room temperature. When titanium is welded with stainless steel the filler metal composition and atmosphere are very important. Many kinds of filler metals such has Ag- based, Ti-based, Al-based and Cu-based filler metal are used, but generally copper is preferred due to its low cost and the high strength of the joints. The experiments were carried out by using purging with argon gas of 99.9 percent purity. The Ti / SS joints fabricated using GTAW process is shown in figure.1

Fig 1. GTAW Welded titanium (Grade 2) and stainless steel (202) plates

A standard tensile test specimen is cut from the welded joints by using abrasive jet machining process. The tensile strength measurement was performed by with the help of a UTM machine. The test was performed at room temperature and the displacement speed was 0.5mm/s. The Fig 2 shows the tensile specimen before testing and the fig 3 shows the tensile specimen after tensile testing.

Fig 2. Titanium (Grade 2) and stainless steel (202) GTAW welded plates before tensile testing

Fig 3. Titanium (Grade 2) and stainless steel (202) GTAW welded plates after tensile testing

Table 3. The tensile strength of the GTAW welded unalloyed titanium and stainless steel (AISI 202).

Welding Type	Tensile Strength (N/mm^2)
GTAW	72.50

The table 3 shows the tensile strength of the welded unalloyed titanium/stainless steel 202. The welded joint yielded a low value of tensile strength, may be caused due to contamination.

The cross sections of the welded titanium(Grade2)/stainless steel(202) joints were prepared for metallographic analysis by standard polishing techniques and then etched by 5% HF 20%HNO_3 and 75 % glycerol solution for titanium side and by 3% Nital solution for the steel side. The microstructures were investigated by using optical microscope. Figure 4 below shows a typical micro structure appearance of the specimen welded at temperature in the range of 930 ºc to 1000ºc. It is clearly visible from the micro structure that the joint was obtained with a homogeneous microstructure without cracks were observed. The two materials are joined by using GTWA welding, using copper based filler material.

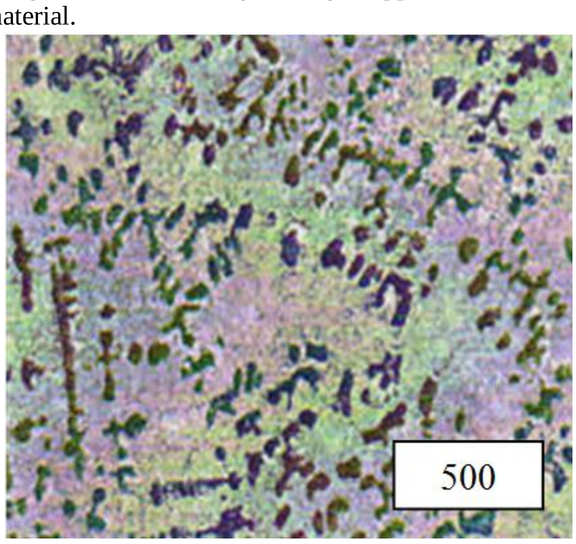

Fig 4. Microstructure of GTAW welding joint in fusion zone (FZ)

5. Hardness Measurement

Micro Vickers hardness test was conducted using the Vickers hardness testing machine with an indenter of a square based diamond pyramid having an angle of 136ºc between opposite faces. The specimen is carefully prepared and placed on the stages. It is raised upwards to make contact with indenter. A load of 500gm is selected according to the thickness and hardness of titanium /steel welded joints. Vickers test is very suitable for testing polished and hardened materials with greater precision in measurement.

Table 2. Vickers Hardness Measurement in Fusion zone

Welding process	Hardness in fusion zone (VHN)
GTAW	165.10

As shown in table 2, the Vickers hardness values in the fusion zone were measured with 500 gm load for 25 second impression time. The Vickers hardness value measurements showed an increase in the hardness value in the fusion zone of the GTAW joints. Since the hardness value of the joint causes an increase of strength and joint efficiency, therefore the GTAW joints are preferable.

6. Discussion

There are many instances where dissimilar metals need to be joined together. In this study the stainless steel (202) and grade 2 titanium plates were welded together using copper base filler alloys. The filler alloys were copper based with melting range of 970-1000ºc. The GTAW welding process was used in the joining process. The hardness measurement was performed with the help of a Vickers hardness testing machine with 25 seconds impressing time at 500 gm load. Even though the hardness value and the microstructure showed a sound joint, the tensile strength was low; this indicates an probability of an contamination of the weld pool or need for better filler material.

7. Conclusion

Dissimilar welding to produce joint between commercially pure titanium and stainless steel using copper based filler metal (Cu-12Mn-2Ni) in the temperature range of 930-1000°c.

1. Titanium/stainless steel joints were obtained with the copper based alloy at temperature at 930 to 1000ºc.
2. The use of copper based filler, which being an typical brazing filler material yielded an good fusion and the metallurgy showed that the joint was obtained with a homogeneous microstructure without cracks and any defects.

3. The average hardness of the dissimilar joint showed the highest values in the fusion zone of the GTAW joints.
4. The tensile strength was 72.5 N/mm^2 , which being an low value, therefore in the future investigations effort will be taken to improve the tensile strength of the welded joints.

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