EXAMINATION OF HARDNESS VALUES FOR Ti-6Al-4V WELDED SPECIMENS AND MICRO STRUCTURAL CHARACTERIZATION OF FRACTURED SPECIMENS

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Abstract:- The main objective of the present investigation is to examine the viability of Ti6Al4V welded joints and evaluating hardness of different weld beads at different zones using Vickers hardness tester which shows impact on strength of the weld joint. Fractured specimens are made in to 10mm x10mm size to analyze the structure under Scanning Electron Microscope (SEM).the major observation after SEM analysis is large number of crack initiation sites are examined for more stress value.

Titanium welded joints are majorly used in industries like aeronautical because it is having good mechanical, physical and chemical properties. When compared to steel the weight to strength ration of ti6al4v is high. Temperature behavior and corrosion are two important good factors of titanium material application [1-2] Ti grade 5 are used in biomedical purpose because of light weight material and non corrosion Jing Liu et al [3]. Identified the importance of microstructure when

1. INTRODUCTION

Ti6al4v joint undergo fatigue loads, Torkamany et al. [4] observed that porosity of welded region is focused when titanium weld joints undergo pulse laser welding.

Xiao-Long Gao et al [5]. Examined microstructure and porosity of Laser welded sheets of Ti6Al4V and informed that presence of lamellar structure leads to increase in resistance of growth of fatigue crack and identified the presence of residual stress which are acting tensile mode. When compared to TIG or electron beam welding Q. Yunlian et al [6] observed more advantage in LBM because of thin line of weld and with fine grain micro structure. W.A. Baeslack et al practically observed that, Tungsten inert gas welding is best method for titanium alloy and in sheet form and micro structure observation is very clear [7].

Different combinations of process parameters were adopted. Bead geometry and micro hardness characterization of samples cross section were studied. Two tensile strength tests for each welding condition were performed in order to evaluate the mechanical properties of the welds. The mechanical properties of welds and the parent metal were compared. The fracture surfaces were studied by an electronic microscope.

2. EXPERIMENT PROCEDURE

The specimens consist of a main plate and two cross plates. Size of the main plate 100mm x24mmx 6mm and each cross plate 100mm x 24mm x 6mm. Subsequently, the Fillets were made between the flange plate and cross plate laying weld metal TIG welding process with corresponding weld metal consumable.

2.1 Ultrasonic testing

Ultra sonic testing was done to all specimens for knowing the defects in welded joints, few specimens were rejected as we identified the cracks in welded regions and specimens which are not having any defects are undergone tensile testing and fatigue testing.

Fig 1 .Ultrasonic Equipment

2.2 Hardness Measurement

Hardness is the measure of resistance offered by the material for the local compressive load. It consists of a diamond indenter, in the form of a right pyramid shape with a square base and angle between the opposite faces is 136^0. The indentation is shown in Fig. b. For calculating Vickers Hardness Value (HV), the distance between diagonal corners has to be measured. The Vickers hardness number is the ratio of the load applied in kg to the area of the sloping surface of indentation in square mm.

Fig 2. Vickers Hardness Equipment

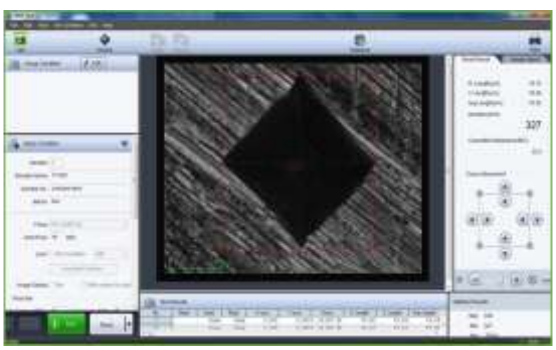

Fig.3 Profile of Vickers Hardness measurement

2.3 Hardness values for welded specimens

The Vickers method depends upon micro hardness test and macro analysis of specimen using optical measurement system, ASTM E-384 a range loads are used with help of diamond indenter to make an indentation and to obtain a hardness value for Measuring Vickers Hardness, Micro Hardness Tester is used Shimadzu Model: HMV-G is used as per ASTM E 340-15 & IS:1501-13. A load of 1 KG was applied on the specimens; A minimum of five indentation diameters was used as distance between the measurements. The hardness profiles presented are an average of 3 profiles across the welds at different depths as shown in Figure the micro hardness value of as received, as welded Ti-6Al-4V shown in. The value of micro-hardness for the base material of Ti-6Al-4V is nearer to 339 ± 2.1 HV. The change in the hardness is less at the BM area for the as welded specimen, while there was a small decrease in the hardness of the BM area after welding. It is observed that the hardness of the FZ and HAZ of the cruciform welded Ti-6Al-4V concave shape is around 365 ± 4 HV and 334 ± 5 HV.and hardness of the FZ and HAZ of the convex shape is around 438 ± 5 HV and 359 ± 6 HV. HAZ and FZ of the Flat shape is around 259 ± 3 HV and 280 ± 3 HV.

Table.1. The micro hardness values of the Ti6al4v of different weld bead shapes at different zones

	Distance from weld centre in mm	Concave Weld Specimen	Convex Weld Specimen	Flat weld specimen
BM	-8	300	320	340
	-7	314	341	342
	-6	315	336	335
	-5	366	435	279
HAZ	-4	363	443	284
	-3	358	438	280
	-2	327	359	259
FZ	-1	334	365	257
	0	315	355	263
	1	326	367	254
HAZ	2	334	361	256
	3	361	437	278
	4	369	441	281
BM	5	365	434	277
	6	335	336	332
	7	310	340	329
	8	298	318	337

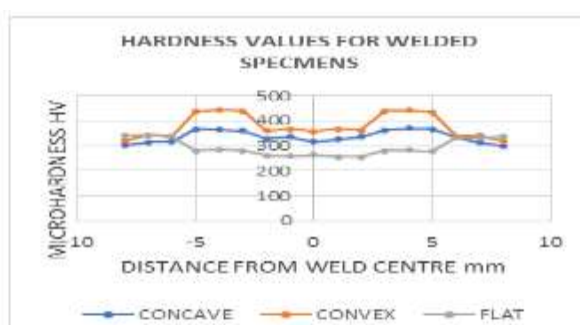

Fig 4. Distribution of hardness values

2.4. Tensile testing of specimens

The tensile strength of Welded material depends upon Hardness value at different region. This test was will help to predict the failure of welded joint priorly and there is necessity of testing of specimen.

Fig 5. Specimen loaded in UTM machine

Specimen was failed at ultimate point of 890 Mpa (i.e 133 KN and area of cross section 144mm^2) and the yield point is 820MPa. Stress is applied on specimen with a range of 80%, 60%, 50% and 30% of yield point. Specimen was broken out at outside of weld

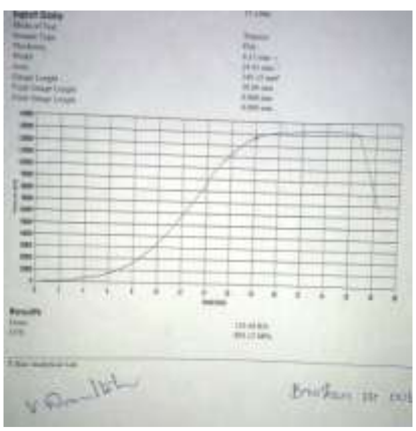

Fig 6. Computerized graph for Tensile Testing of specimen

3. OBSERVATION OF MICROSTRUCTURE OF SPECIMENS FAILED UNDER TENSILE TESTING

Etching procedures were used to expose the underlying micro structural features including grain boundaries, inclusions, cracks, and secondary phases. Solutions that can be used for etching titanium include: 100 ml water, 2 ml HF, 5 ml HNO3 (Krolls Etch)); or 20 ml water, 10 ml 40% KOH, 5ml 30% H2O2; or 30 ml glycerin, 10 ml Hf, 10 ml HNO3. The polished metallographic mount can be immersed or swab etched in the solution from 3 to10 seconds to reveal the micro structural features.

The fractured surfaces of fatigue specimens were viewed under SEM to identify fracture morphology. Scanning electron microscopy is done to examine the surfaces of fractured fatigue specimens and tensile specimens of different welded samples at various magnifications and to understand the mode of fracture. The fractured tensile and fatigue samples are first cut to required size of (10mm x10mm) and are then ultrasonically cleaned and degassed before loading then in the SEM chamber.

SEM is a powerful tool for examining and interpreting the microstructures of materials and is widely used in the field of material science. The principle of SEM is based on the interaction of an incident electron beam and the solid specimen. SEM images were used for the evaluation of the morphology of material.

Fig 7. Samples placed in SEM Equipment

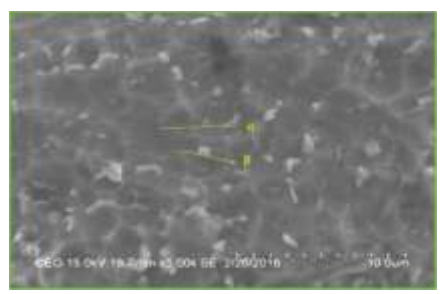

Fig 8. Micro structure of Base Metal(Ti64)

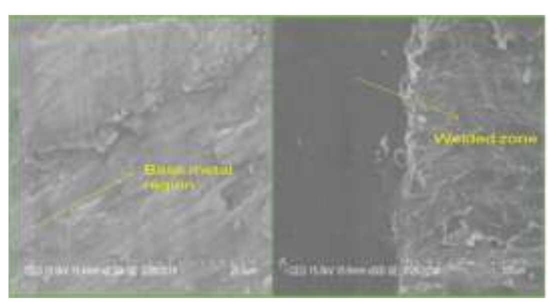

Fig.9 Welded region of specimens indicates that there are no under cuts, no crack initiation sites

In the present research micrographs were taken using a SEM. A scanning electron microscope (SEM) is a type of electron microscope that images a sample by scanning it with a beam of electrons in a raster scan pattern. The electrons interact with the atoms that make up the sample producing signals that contain information about the sample's surface topography, composition, and other properties such as electrical conductivity.

The electron beam, which typically has an energy ranging from 0.2 keV to 40 keV, is focused by one or two condenser lenses to a spot about 0.4 nm to 5 nm in diameter. The beam passes through pairs of scanning coils or pairs of deflector plates in the electron column, typically in the final lens, which deflect the beam in the *x* and *y* axes so that it scans in a raster fashion over a rectangular area of the sample surface

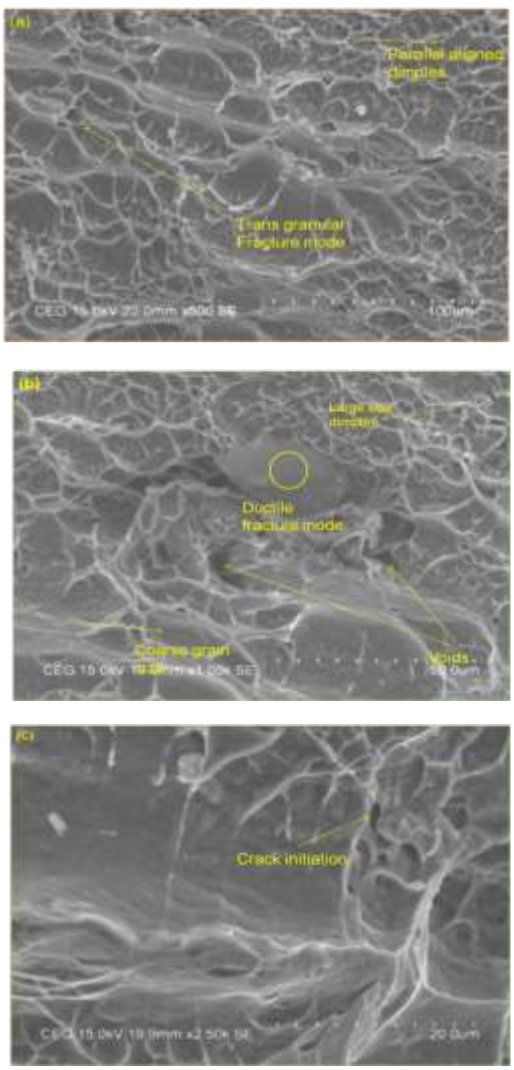

Fig 10.SEM analysis of fracture surfaces of different weld bead shapes under tensile testing

Figure 11 a reveals the formation of ductile mode failure with dimples of fine size and it is obvious that the fracture surfaces of tensile tested sample of concave weld joint show trans-granular fracture mode and the parallel aligned finer dimples with grain boundaries are observed.
A typical Stage I fatigue fracture is observed in welded joint (Fig 11 b). Stage I fatigue fracture surfaces are faceted and often look like cleavage, and do not display fatigue striations. Stage I fatigue is usually observed on high-cycle low-stress fractures and is often absent in low cycle high stress fatigue.

The direction of crack initiation is indicated by arrow mark (Fig.11 c) obviously reveals the presence of transgranular facets with some secondary cracking. The tensile fracture surfaces exhibited in above figure indicate crack in a ductile mode, coarse grain sizes are observed and Micro voids and micro cracks are identified.

4. CONCLUSION

Vickers hardness measurements found that convex specimens are having more hardness values. Hardness values of specimen shows more impact on tensile strength. In this work microstructure variation on fractured specimens obtained from tensile test is studied. Further, the fractured surfaces are checked through Scanning electron microscopy to identify the modes of failure/fracture. Porosities were observed in few specimens, which affect the elongation and leads to rupture of the specimen. Fracture analysis of the TIG welds exhibited ductile fracture modes, with the high proportion of ductile fracture in the presence of micro cavities and cleavage areas, Because of high heat input in TIG welding the formation fine grains is not possible which leads to inferior fatigue performances of cruciform shape welded joints, and convex weld specimens are exhibiting good performance under fatigue testing

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