

Design and fabrication of special fixture for different weld configurations of commercial pure Titanium sheet in laser beam welding process

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Abstract. Titanium and its alloys have been used in several areas such as aerospace, automobile, marine and medical industries due to its several superior properties from other materials. In Laser Beam Welding (LBW) process, a variety of advantages such as very narrow heat affected zone, high depth to width ratio, high productivity and low residual stress are obtained. In the present study, trials were conducted in commercial pure titanium (Grade 2) material to ensure feasibility and to make different weld configuration such as lap joint and T joint in Nd: YAG single-sided during the laser beam welding process. Distortion and colorization of the welded joints were avoided by providing firm clamping and uniform shielding gas (99% pure industrial argon) using a custom-made fixtures arrangement. Hence, the quality of weld configurations of the lap joint and T joint are investigated in regard to weld morphology.

Keywords : Grade 2 Titanium; Laser beam welding; Macrostructure.

1. Introduction

In several grades of titanium, grade 2 titanium is widely utilized in medical and power plant sectors due to its properties of excellent corrosion resistance and high strength comes with low density. Even though grade 2 titanium has many superior properties, still it poses difficulty in fabrication due to its low oxidation resistance while operating at high temperature and its instability in cooling from high temperature. Due to these shortcomings of grade 2 titanium, it is imperative that more attention in fabrication is necessary especially for welding process. Number of welding techniques such as gas tungsten arc welding (GTAW), plasma arc welding (PAW), laser beam welding (LBW) and electron beam welding (EBW) have been used for welding of grade 2 titanium. Still concentrated heat input of LBW provides the ability to produce a high depth of penetration with minimum weld bead width with a very minimum heat affected zone (HAZ) compared to GTAW and PAW. In addition, ease of automation of LBW is comparatively more suitable for designing and providing proper shielding gas and clamping arrangements. It is more economical when compared to EBW in the aspects of operating cost and initial investment. Hence LBW is one of the best processes for welding of titanium and its alloys when compared to GTAW, PAW and EBW. Xiuyang fang, *et al.*[1] studied the laser beam welded titanium alloy Ti-2Al-1.5Mn and observed a notable angular distortion if the specific heat input exceeds 328 J/cm and reported that fracture positions of tensile test are affiliated to the under fill



rate. Thomas kramar, *et al.*[2] conducted experiments in commercial pure titanium and found that fusion zone and heat affected zone has to be perfectly inert gas shielded or should be in a vacuum if the temperature exceeds 450°C. Lisieckialeksander, *et al.*[3] reported that the Disk laser TRUMPF TRUDISK was used to conduct experiments and immediate joint failure occurred during bending test at the bend angle 20 - 25°. In addition, they found that probable causes for failure due to brittleness were the absorption of nitrogen, oxygen and hydrogen by the weld metal from the ambient as a result of disruption of shielding argon flow by the plasma plum formed over the key-hole. Nikolai kashaev, *et al.*[4] carried out experiments in Nd: YAG single-sided LBW process to study the weld morphology of Ti-6Al-4V by using filler wire to avoid undercuts and under fills. They also stated that fracture without any plastic deformation always appears on the base material in the welded sample. Luca boccarusso, *et al.*[5] examined the behaviour of fatigue life of laser beam welded Ti-6Al-4V butt joints. In addition to that, the number of fatigue life cycles decreases with increase in specific heat input. Bertrand, *et al.*[6] were analyzed the impact of various LBW parameters in grade 1 titanium. With the use, titanium filler will reduce distortion and improve the ductility of the welded specimen. Alexander buddery, *et al.*[7] have studied the effect of O, N and Fe in weld metallurgy of laser welded commercial pure titanium. And also the result shows that Fe suppressing the massive transformation and promotes the martensitic formation. Caterina casavola, *et al.*[8] have investigated the laser and electron beam butt welded titanium grade 2 and 5 in regard to residual stress. In addition, they reported that the causes of residual stresses are thermal stresses and non-elastic strain generated while subjected to welding. Also concluded that very narrow heat affected zone was achieved due to low thermal conductivity of the material and slow moving of heat over the plate during welding. Santhosh kumarsahoo, *et al.*[9] have studied microstructural and mechanical properties in commercially pure titanium by LBW and observed that the grain size of the samples increases along with the increase of laser power and shows decrement with the increase of welding speed and beam diameter. And also noticed that the fusion zone width decreases with the increase of welding speed and increases with the increase in laser power. Xinyang fang, *et al.*[10] investigated the effect of underfill defect on the distortion and tensile properties of Ti-2Al-1.5Mn LBW and noticed that the residual distortion is related to the specific heat input. Particularly, in their experimentation for 0.8mm thick plate the maximum angular distortion increases remarkably for the specific heat input higher than 328.5 J/cm, also their studies reveal that this is mainly due to the formation of underfill defect. Meanwhile, it is not affecting the maximum residual longitudinal bending distortion. Based on the literature survey, it shows that only few works have been carried out in achieving different configuration of weld in grade 2 titanium in LBW process. And still grade 2 titanium poses difficulty in welding different configurations of lap joint and T joint without colorization (i.e. oxidation) and distortion. Hence, an attempt is made in this research work to develop a fixture to provide firm gripping and efficient uniform shielding gas flow while welding to overcome colorization and distortion.

2. Material and methods

The material chosen for this work are 1.6mm and 2mm of grade 2 titanium because titanium usage in most of the applications is in sheet metal form. The chemical composition of titanium (Grade 2) material is shown in table 1. An attempt was made to manufacture different configurations of T- joint and lap joint in grade 2 titanium in LBW process. The LBW process has number parameters such as beam power, focal distance, beam angle, beam diameter, shielding gas flow rate, welding speed and shielding gas type.

Table 1 Chemical composition (in Wt. %) of Grade 2 Titanium

| Name of the element | C | Fe | H | N | O | Ti |
|---------------------|-----|-----|-------|------|------|---------|
| Composition (%) | 0.1 | 0.3 | 0.015 | 0.03 | 0.25 | Balance |

Hence a number of the bead on trials were made on 2mm grade 2 titanium and observed that the beam power and welding speed are comparatively important than other parameters in altering weld state in terms of depth of penetration(DOP) and bead width(BW) in LBW process. Initially, the grade

2 titanium plates were cleansed from dirt and oil using acetone on top and bottom surfaces of the plates. In the process of making bead on trails and joints, focal distance, gas flow rate and beam angle were kept as constant of 120 mm, 85 degrees, and 10 lpm respectively. And 99 % pure argon was used as a shielding medium. After conducting a sufficient number of bead on trials the desired range of parameter of LBW process were chosen with respect to the DOP of bead on trials. The welding speed of 200 mm/min and a beam power of 1300 watts were selected for manufacturing of different configuration of grade 2 titanium from the experience gained from results of bead on trials and the aid of expertise from WRI, BHEL Trichy. A 2000 watts Nd: YAG LBW system of continuous wave (CW) was used to conduct beat on plate trials and joints. The instability of grade 2 titanium at high temperature especially in oxidation resistance, usually leads the welding process into colorisation. Hence special custom-made fixture was made for lap joint and a separate fixture was made for T joint in order to achieve the silver-whitecolor (i.e. without oxidation) weld in LBW and to provide firm clamping to avoid any distortion while cooling.

3. Results and Discussions

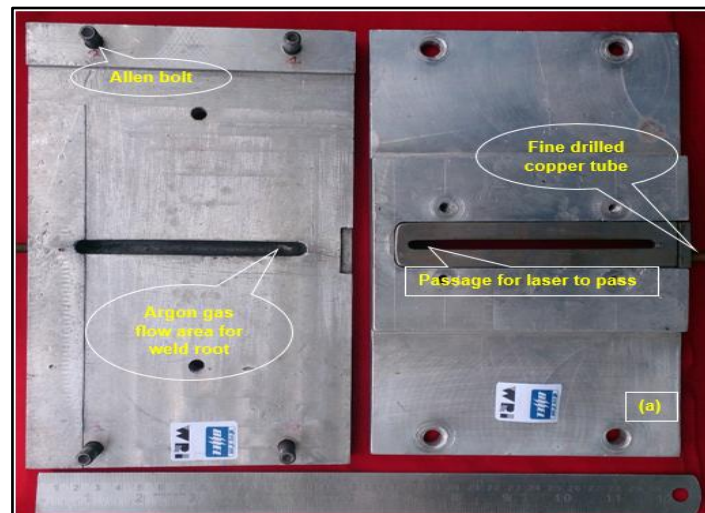


Figure 1 Custom made fixture for Lap joint

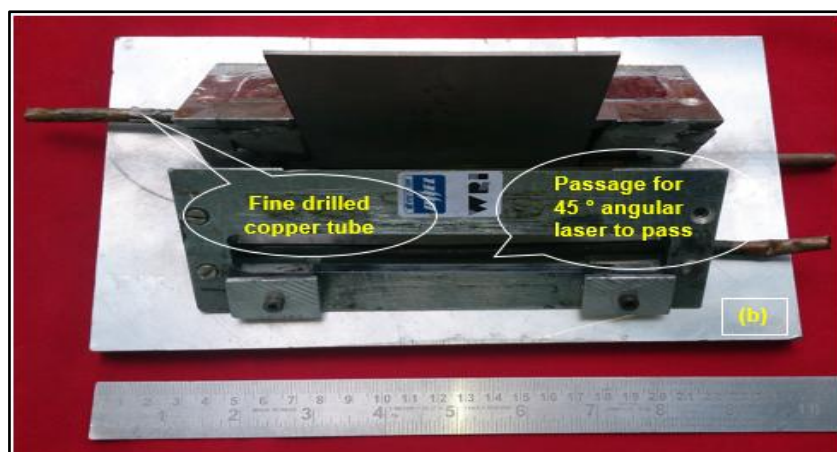


Figure 2 Custom made fixture for T joint

The custom-made fixture for lap joint consist of fine drilled copper tube and milled stainless steel plate to supply 10 lpm of shielding gas on face and root side of the weld joint and to maintain it which is shown in figure 1 and allen bolts were provided to apply pressure on plates while welding and during cooling Process. The T joint fixture was provided with three fine drilled copper tube to maintain 10

lpm shielding gas flow rate on two sides of T-joint and root side of it and milled stainless steel plate was used to maintain the shielding gas on the weld area which is shown in figure 2. The fixtures were used to manufacture the different configurations of grade 2 titanium. The selected parameters of welding speed 200mm/min and beam power 1300 watts were used. After the welding process, the welded specimens were visually evaluated. As shown in figure 3 and 4, the configurations of lap joint and T-joint are in silver white color with negligible distortion. Which indicates that the custom-made fixtures were successfully supplied sufficient shielding gas and maintained on all sides of the weld area.

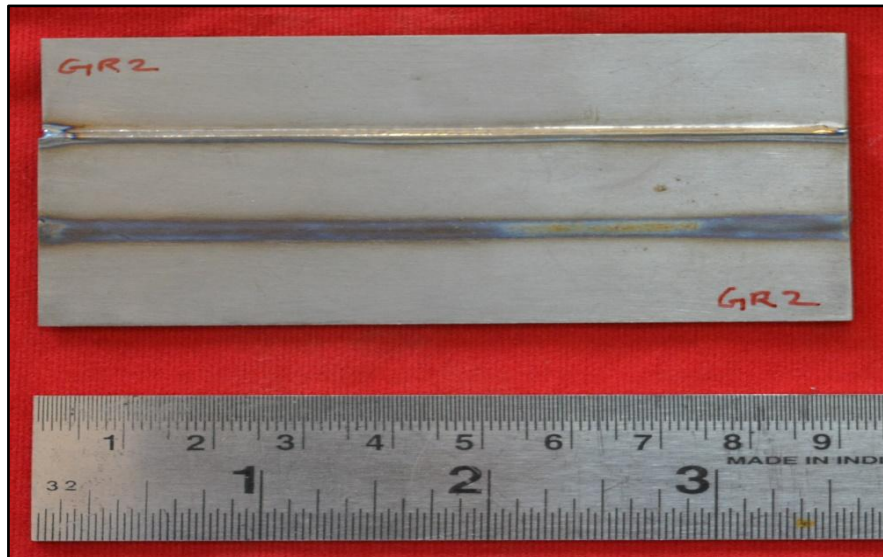


Figure 3 Laser welded lap joint configuration

Even though in lap joint configuration which shows some colorization on the root side of the weld which is shown in figure 3. It indicates that there was a predicament in shielding gas supply and in maintaining it which led to the oxidation.

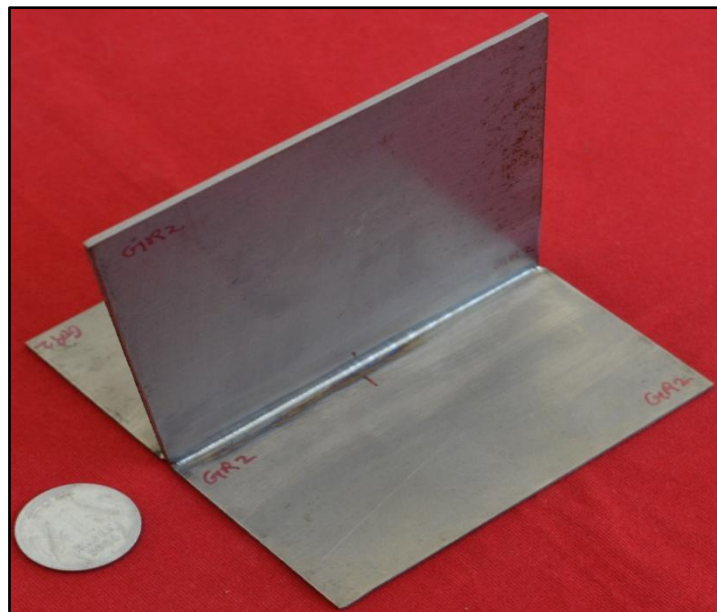


Figure 4 Laser welded T-joint configuration

The welded samples were sectioned using wire cut electro discharge machining process (WEDM). Normally, grade 2 titanium has low thermal conductivity which leads to metallurgical changes while

sectioning specimens. The ability of WEDM to maintain 0.2mm kerf width which minimizes the material wastage, high cutting accuracy and it has the tendency to avoid the localized heating of specimen, hence for specimen preparation the WEDM is one of the appropriate methods. After cutting, the specimens were metallographically polished in fine grained emery sheets to obtain mirror like finish. Kroll's reagent (92 % distilled water, 6 % nitric acid and 2 % hydrofluoric acid) was used for chemical etching and 18 seconds dwell time was maintained to reveal the grains and grain boundaries of the specimen. The etched specimens were viewed and characterized using struers make welding expert system and software, which has manual magnification controllable digital camera and a measurement system which was used to measure the DOP and BW. The morphology of the specimens was captured at 20 X magnification which is shown in figure 5.

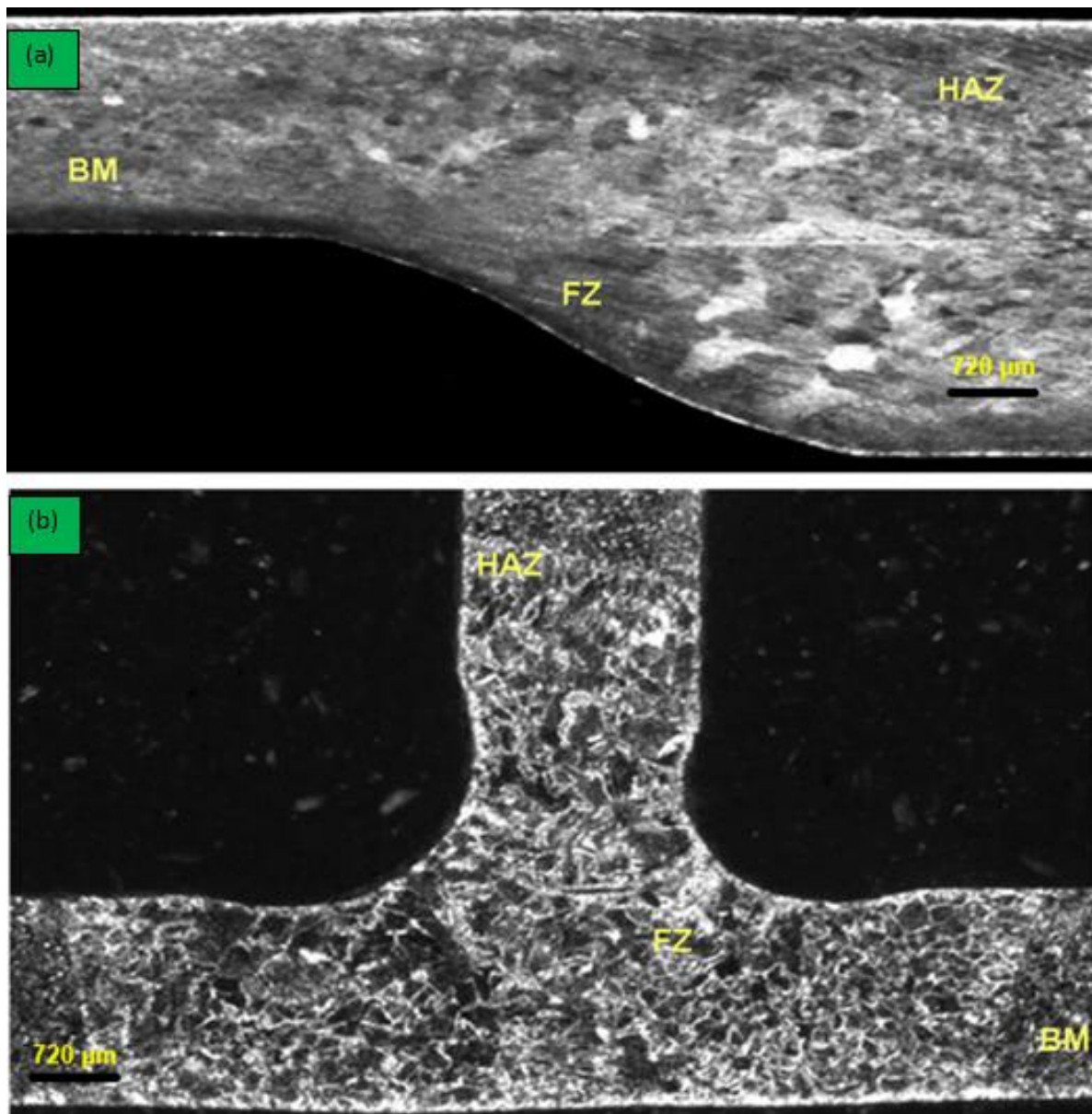


Figure 5 Macrograph of grade 2 Titanium (a) lap and (b) T-joint

4. Conclusion

The configurations of laser beam welded lap joint and T joint were subjected to visual and morphological characterization from those the following conclusion can be withdrawn. The high quality silver white color laser beam welded configurations of the lap joint, T-joint were made with the aid of custom-made fixture which shows that custom made fixture offers sufficient uniform shielding gas for face and root side of the weld zones and delivers effective clamping force.

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