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Studies on weldment structure in Ti/Al dissimilar metal joints using Laser beam welding

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ABSTRACT: Laser beam welding is a non-conventional welding process with high applicability to produce quality welds. An attempt is made to weld TI6AL4V (Ti) and AA2024 (Al) dissimilar sheet metal joints and studies have been made to analyze the structure in the weldment. Structural studies such as macrostructure and micro studies are undertaken. The extend of a metal mix in the fusion zone is also studied using Energy Dispersive Spectroscopy (EDS). Micro studies using Scanning Electron Microscope (SEM) reveal that higher weld speed brings grain refinement leading to the enhanced strength. SEM and EDS analysis further reveal that laser beam focusing from Ti side instead of Al side brings good quality weldment.

KEYWORDS: Laser beam welding; Ti/Al; Weldment structure; SEM; EDS.

1 INTRODUCTION

Laser beam welding (LBW) is a new generation welding process, widely adopted for joining sheet metals due to high energy density, focalization, deep penetration, high efficiency and strong applicability. Applications include aviation and space flights, automobile, microelectronics, light industry, medical treatment and nuclear industry [1-4]. As laser welding is fast in operation, larger temperature distribution appears around the weld. Also residual stress and deformation appear in the post welding structure. These are important factors, influencing the quality of welding structure and the usable capability. Understanding heat transfer in welding is essential to analyze the mechanical properties of welding and microstructure for obtaining good quality weld. LBW is used for welding steel, copper, titanium and magnesium alloys [5-14]. Also, it is used for welding dissimilar metals [15-18].

Many variables such as laser power, welding speed, focusing distance and types of shielding gas are important to analyze the heat and mass flow in the weldment. These factors are necessary to analyze the depth of penetration, shape and microstructure [19-21]. The present investigation is carried out to study the effect of weld speeds on structure and properties of fusion zone (FZ), heat affected zone (HAZ) and base metal (BM). Also proper mixing of dissimilar metals namely TI6AL4VA (Ti) and AA2024 (Al) in the fusion zone has been investigated using Energy Dispersive Spectroscopy (EDS) attached with Scanning Electron Microscope (SEM).

2 EXPERIMENTAL DETAILS

For the investigation, Ti and Al alloy sheets are taken and cut to the size of 150 x 75 x 1mm. Laser beam welding is carried out using Nd: YAG Pulsed laser welding unit and is shown in Fig. 1. The parameters used for the investigation are as follows: Energy: 25J; Laser focus distance: 200mm; gas flow rate: 10 lit/min and Pulse rate: 25Hz. The chemical compositions of parent metals on the weight basis are as follows. Ti alloy sheet (TI6AL4V): Al 5.5-6.75%; V 3.3-4.5%; remaining Ti. Al alloy sheet (AA2024): Cu 3.8-5.0%; Mg 0.2-0.8%; Mn 0.3-1.2%; Si 0.5-1.2% and remaining Al.

Fig. 1. Laser beam welding unit

Before welding, Ti and Al sheets are kept together on a workstation with a gap of 0.1mm and rigidly fixed using backup plates as shown in Fig. 2. The laser beam is focused both from Ti and Al side with offset distance of 0.3mm being thin sheet. Laser offset distance has a great influence on the formation of joints. To study the structure variation using offset distance focusing from Ti as well as Al sides. Welded joints are made by varying the speed from 200mm/min to 240mm/min with an interval of 10mm/min.

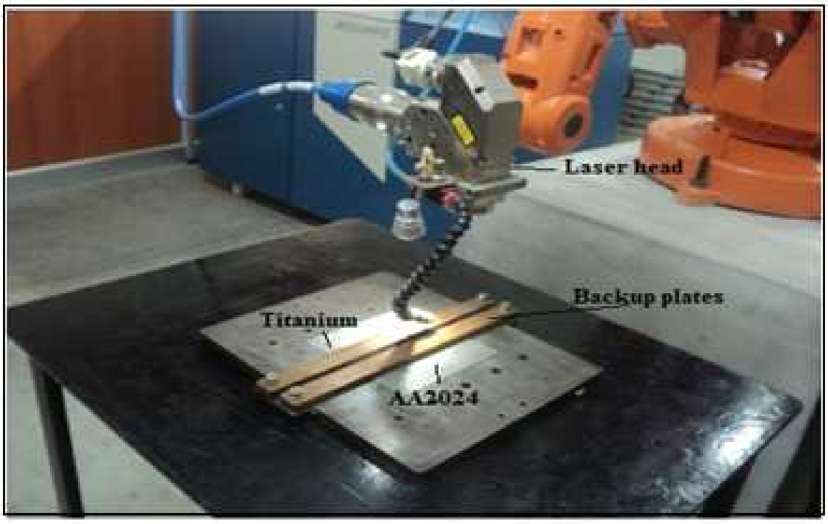

Fig. 2. Clamping device with backup plates

The parameters investigated are macrostructure and microstructure of weldment using Scanning Electron Microscope (SEM) as shown in Fig. 3. Also, EDS is used to find the chemical composition of fusion zone at 240mm/min.

Fig. 3. Hitachi SU6600 Scanning Electron Microscope

3 RESULTS AND DISCUSSIONS

Several tests have been carried using laser beam focusing both from Ti and Al sides, to study the macrostructure, microstructure and EDS on weldments and the results are reported.

3.1 MACROSTRUCTURE

Macrostructure study is taken to check the surface morphology of weldments including defects. Being thin sheets, only top sides are welded at various speeds. The macrostructure views of top weldment surface for three speeds are given in Fig. 4(a) and 4(b) represents the bottom views. From the figures, it is found that laser beam welding produces good welds without defects on a macro scale, and distortion is not seen even by varying the weld speed. Hence, it is clear that laser welding is very much suitable for Ti/Al dissimilar thin sheet joints.

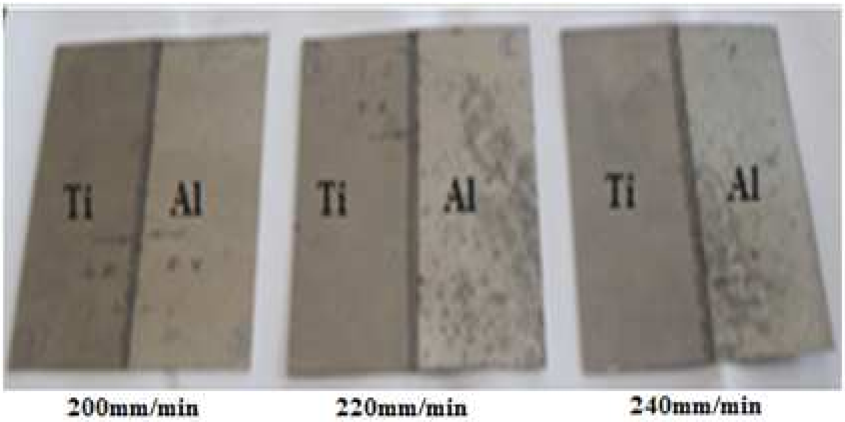

Fig. 4(a). Macrostructure of welds on top side

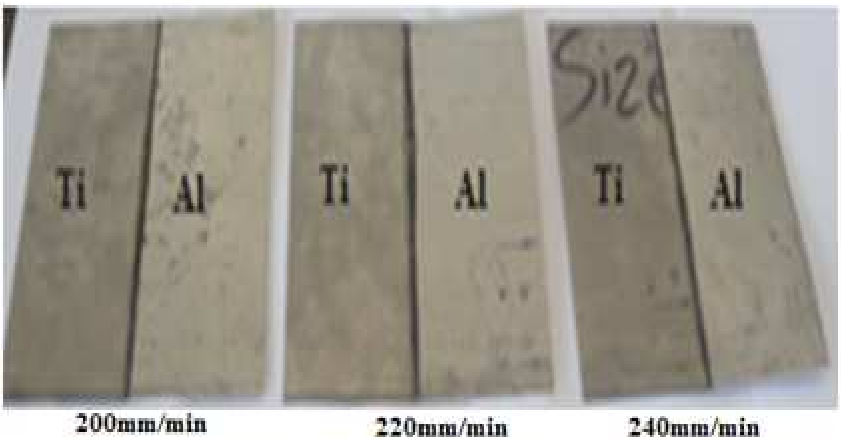

Fig. 4(b). Macrostructure of welds on bottom side

3.2 MICROSTRUCTURE

The effect of weld speeds on microstructure at various zones of welments has been studied. The various zones such as Fusion Zone (FZ), Heat Affected Zone (HAZ) and Base Metal Zone (BM) are identified and are shown in Fig. 5.

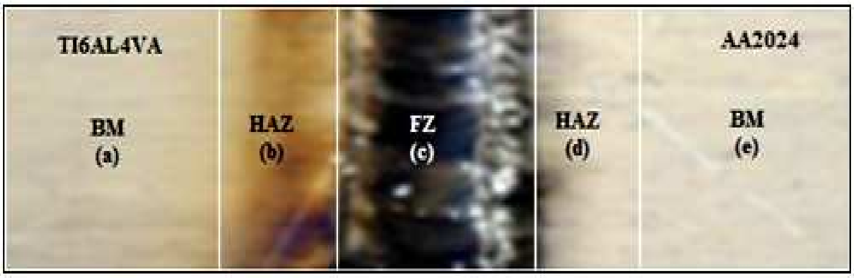

Fig. 5. Various zone at weldment both Ti/Al sides

3.2.1 LASER BEAM FOCUSED FROM TI SIDE:

The laser beam is focused from Ti side at an offset distance of 0.3mm and the structure distribution at various weld speeds such as 200mm/min, 220mm/min and 240mm/min are discussed. Fig. 6 shows the SEM microstructure of various zones at 200mm/min. In the present study, the magnification of all figures is maintained at 5000 (X5000). Due to higher heat concentration on fusion zone at low speed, the rapid metal transfer is seen from Al side resulting. However, coarse grains are seen in HAZ of Ti indicating higher heat addition.

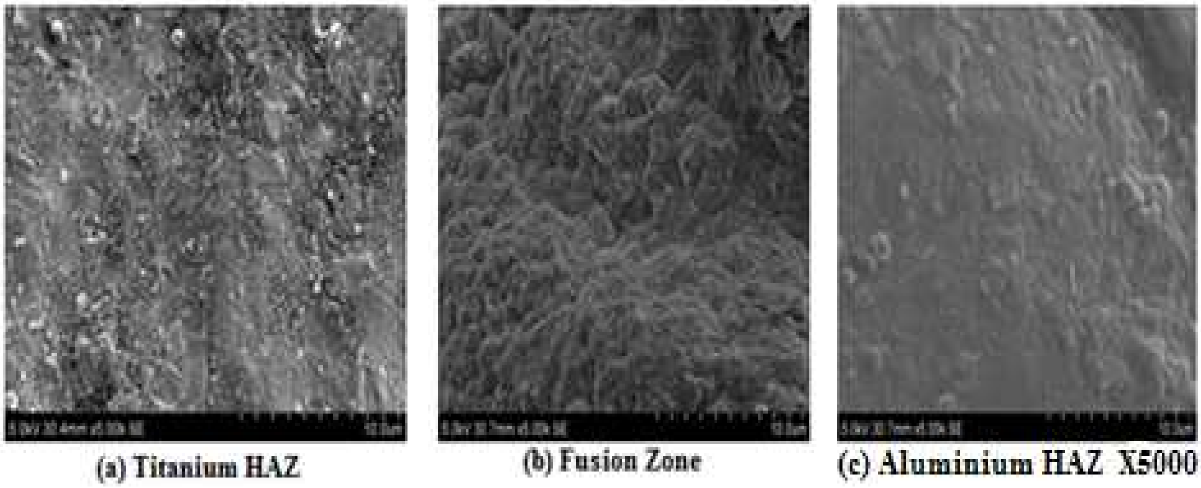

Fig. 6. Microstructure at 200mm/min, laser beam focused from Ti side (a) Ti HAZ, (b) Fusion Zone and (c) Al HAZ

The grain structures are changed to smooth texture at the speed of 220mm/min that is evident as seen in Fig. 7(a), (b) and (c). The heat energy is focused from Ti side, and the FZ may be attributed to the alternation of metal flow. This depends on the welding speed and would be an important factor affecting the evolution process of microstructure in dissimilar joints produced by laser beam welding.

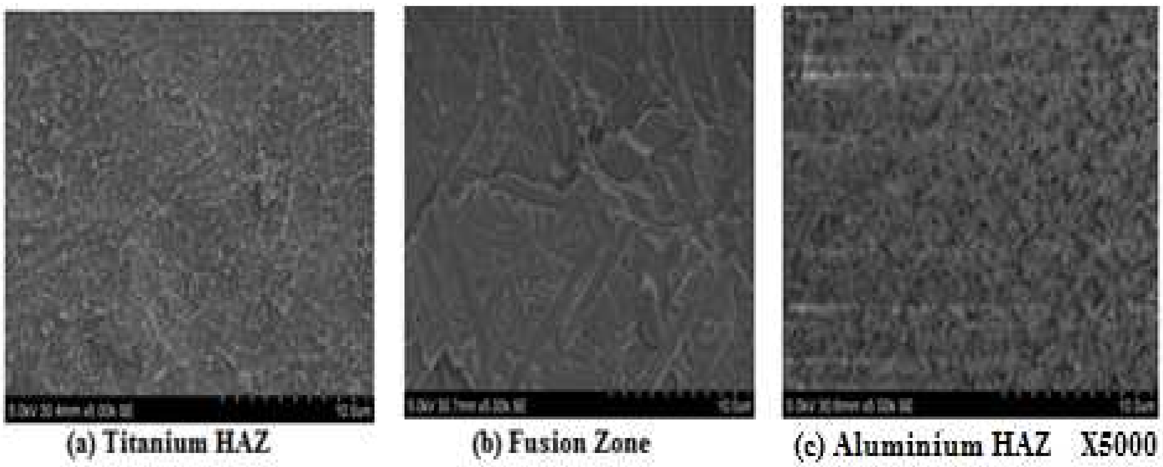

Fig. 7. Microstructure at 220mm/min, laser beam focused from Ti side (a) Ti HAZ, (b) Fusion Zone and (c) Al HAZ

Fig. 8 (a), (b) and (c) represents typical microstructures observed in the weld joint at a welding speed of 240mm/ min. The microstructure of Ti alloy HAZ is seen elongated grains with a random distribution. However, smooth texture is maintained in HAZ of Al. In welding finer and homogeneous distribution of particles are noted infusion zone. Comparing to 200mm/min and 220mm/min speed, it gives better grain structure in fusion zone. Hence, the structure in weldment is better than at lower weld speeds.

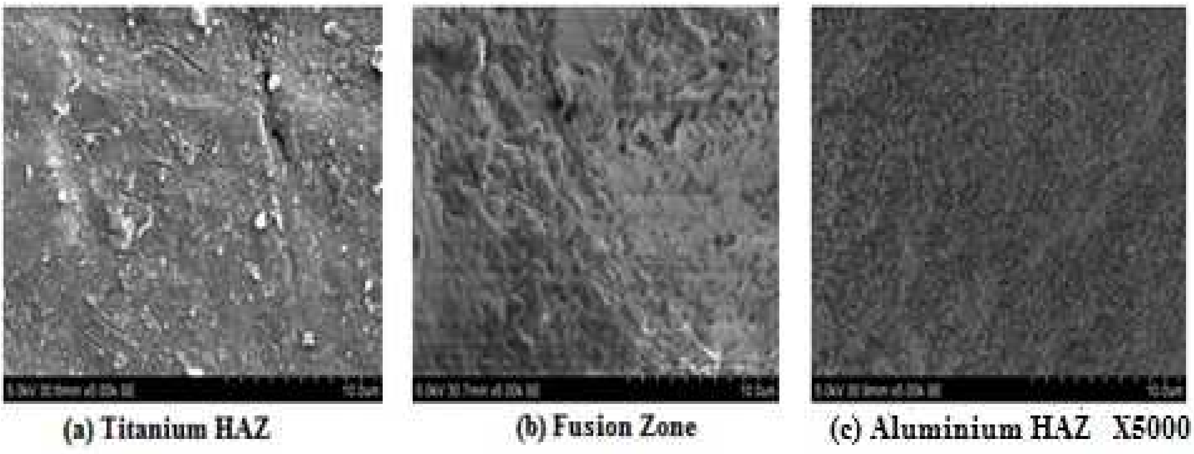

Fig. 8. Microstructure at 240mm/min, laser beam focused from Ti side (a) Ti HAZ, (b) Fusion Zone and (c) Al HAZ

3.2.2 LASER BEAM FOCUSED FROM AL SIDE

The changes of structure focused from Al side have been studied after focusing from Ti side for comparison. The laser beam is focused from Al side with an offset distance of 0.3mm, and the microstructure changes are observed at weld speeds 200mm/min, 220mm/min and 240mm/min. The grains structure at weld speed 200mm/min is shown in Fig. 9 (a), (b) and (c). Due to higher heat input associated with lower welding speed, the HAZ close to fusion zone are noted as below.

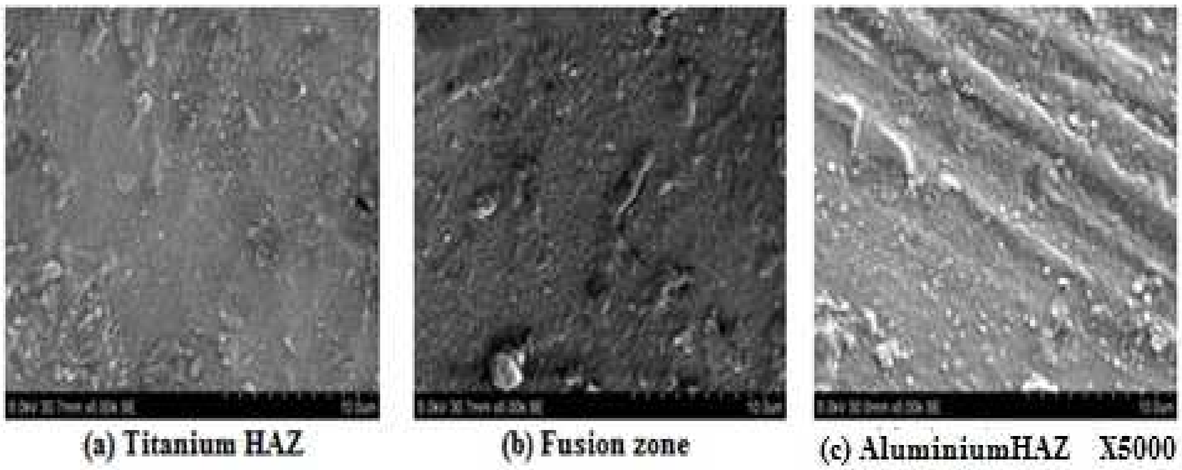

Fig. 9. Microstructure at 200mm/min, laser beam focused from Al side (a) Ti HAZ, (b) Fusion Zone and (c) Al HAZ

The interlaced structure is formed both in Ti and Al HAZ side, and it shows that the dissimilar sheets are bonded together. Fig. 10(a), (b) and (c) show the structural changes at weld speed 220mm/min coarse grains are seen at fusion zone.

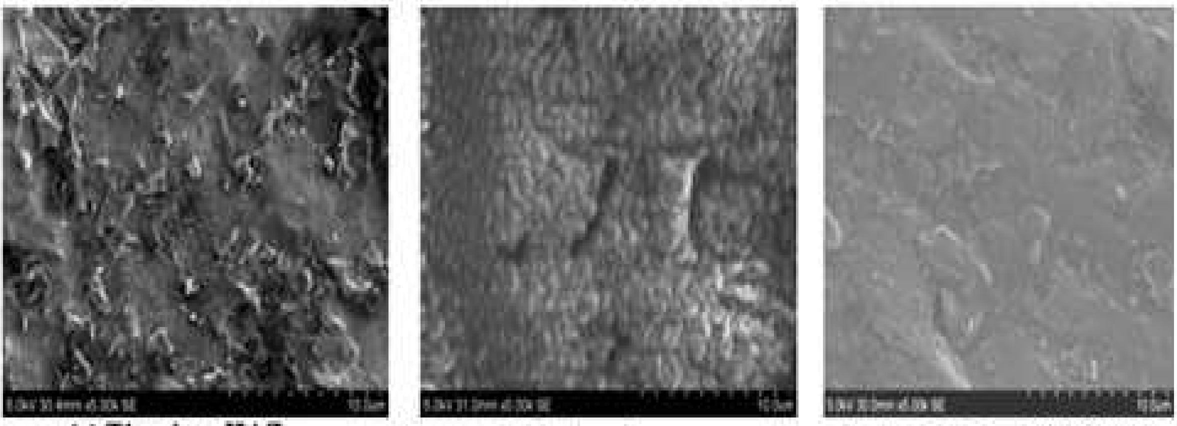

Fig.10. Microstructure at 220mm/min, laser beam focused from Al side (a) Ti HAZ, (b) Fusion Zone and (c) Al HAZ

Fig. 11 (a), (b) and (c) show the structures at the speed of 240mm/min. While comparing with fusion zone at 220mm/min, the fusion zone at 240mm/min gives coarse grains with bigger size indicating low strength at the fusion zone. Hence, it is concluded that laser beam is focusing from Ti side gives finer grain comparing with Al side indicating better mechanical properties.

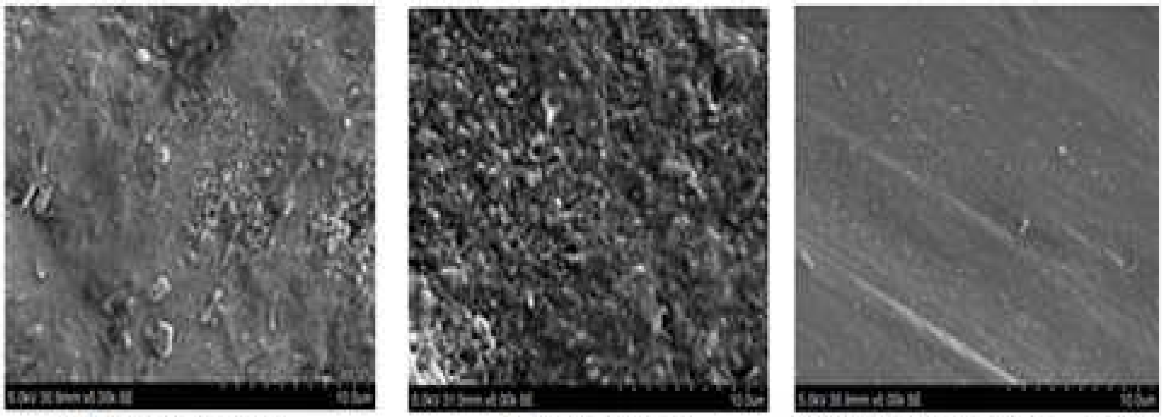

Fig. 11 Microstructure at 240mm/min laser beam focused from Al side (a) Ti HAZ, (b) Fusion Zone and (c) Al HAZ

3.3 Energy Dispersive Spectroscopy (EDS) Analysis

In Ti/Al dissimilar welding an attempt is made to evaluate the mixing of the alloys infusion zone, the laser beam is focusing on both Ti side as well as Al side at one particular welding speed. The optimum speed in the particular work is noted as 240mm/min, being the highest speed available in the LBW machine. The chemical composition of fusion zone at the optimum speed is found using Energy Dispersive Spectroscopy (EDS) analysis. The results of EDS data obtained by focusing laser beam from Ti side is given in Table 1 along with corresponding photo image in Fig. 12.

Table.1 Spectrum Processing of fusion zone at 240mm/min, laser beam focused from Ti side

Element	Series	Weight%	Atomic
M_g	K series	10.22	12.53
Al	K series	67.12	74.17
T_i	K series	16.13	10.04
V	K series	1.64	0.96
C_u	K series	4.88	2.29
Total 100%			

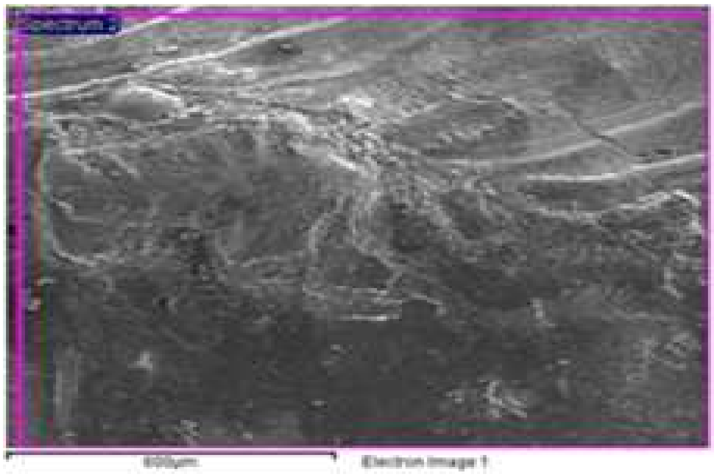

Fig. 12. EDS Fusion Zone image at 240mm/min, laser beam focused from Ti side

Similarly, the spectrum processing data obtained by focusing laser beam from Al side is given in Table 2 with corresponding spectrum image at 240mm/min weld speed, given in Fig. 13. While comparing with laser beam focusing from Ti side, Al side focus (Table 2) gives more amount of Al deposition 80.91% infusion zone and less amount of Ti 4.76%. In the case of focusing on Ti side, Al deposition is 67.12% (Table 1) and Ti-16.13%. The EDS image gives a smooth appearance at the weld zone as per Fig. 12 whereas in Fig. 13, due to the heavy mass flow of Al, pores are seen along with smooth texture.

Table.2 Spectrum Processing of fusion zone at 240mm/min laser beam focused from Al side

Element	Series	Weight%	Atomic
M_g	K series	6.40	7.55
Al	K series	80.91	85.96
T_i	K series	4.76	2.85
V	K series	0.63	0.35
C_u	K series	7.31	3.30
Total 100%			

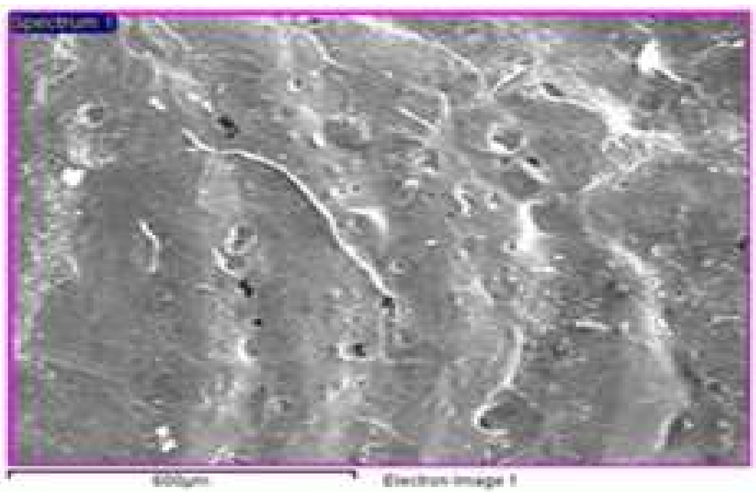

Fig. 13. EDS fusion zone image at 240mm/min, laser beam focused from Al side

Spectrum Table 2 indicates that Al content is enhanced to 80.91% whereas Ti content is reduced to 4.76% that may cause the lower strength of joint. Hence focusing on Ti side is suggested to get a high-Ti percentage, which in turn produce good strength in the joint.

4 CONCLUSIONS

Based on Macrostructure, SEM and EDS findings, the following are the conclusions:

1. Macrostructure analysis reveals that laser beam welding is a good choice suitable for Ti/Al dissimilar thin sheet joints without distortion at any welding speed within a range of 200mm/min to 240mm/min.
2. SEM analysis reveals that the weldment structure is much better at 240mm/min comparing with low welding speeds.
3. During welding laser beam focusing from Ti, side brings grain refinement compared with Al side, resulting higher mechanical properties.
4. EDS analysis specifically reveals that mass transfer of Ti is more by Laser beam focusing from Ti side indicating a choice of focusing laser beam from Ti side in dissimilar welding.
5. EDS spectrum also indicates that laser beam is focusing from Al side cause the presence of pores infusion zone supporting the choice of directing welding laser beam focusing from Ti side.

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