Turkish Online Journal of Qualitative Inquiry (TOJQI)
Volume 12, Issue 9, August 2021: 2311-2318

Research Article

NON DESTRUCTIVE TESTING AND EVALUATION OF DISCONTINUITIES IN ALUMINUM 6082-T6 WELDMENTS DURING DYNAMIC LOAD CONDITIONS

Ramalinga Reddy M[1], Ranganayakulu S V[2], Samrat Goud Burra[3]

Abstract

The inspection of aluminium 6082-t6 weldments used in aircraft structures remains challenging for non-destructive testing techniques. Three longitudinal flat tensile samples were prepared, i.e., good (defect-free), defective (Lack of penetration), and without welding. Two aluminum plates of dimension 100 lengths, 120 widths, and a thickness of 8 mm were welded using Gas Tungsten Arc Welding (GTAW). Tensile samples of overall length 200, width of the grip 20, thickness 8 mm, and 57 mm gauge length using weld plate by CNC machining. We have experimentally calculated the maximum tensile load-bearing capacity of three categories of tensile samples. Defect-free samples are subjected to gradual, incremental load to initiate and propagate weld defects. The ultrasonic inspection was adopted to study the weld defects. It identified an initiation of the flaw at 6 KN by increasing the load to 14 N defect propagated 5mm internally, and the sample sustained a maximum 21 KN load before fracture. Inline in defect sample defect propagated 3.5 mm long at a load of 11KN and sustained 18 KN load before brittle fracture. Die liquid penetrant test is used to identify defects that are open to the surface. Reference standard and validation were performed using x-ray radiography. Microstructure examinations were carried out on parent material, heat affect zone (HEZ), and weld region.

INTRODUCTION

Aluminium alloys provide desired requirements that aerospace design required predominantly lightweight material with suitable specific strength, anti-erosion, conductivity [1]. Aluminum is a relatively ductile metal in its commercially pure state with lower tensile strength. Aluminum's tensile strength can be enhanced by adding minor volumes of alloying elements such as silicon, manganese, zinc, or copper with the proper cold working and heat treatment. In aluminum 6082, the grain structure is controlled by adding a large amount of manganese and silicon, ending in a more durable alloy. Welding becomes difficult in aluminum alloys because of the inherent oxide layer, low molten viscosity, and high surface reflectivity. Primary factors to consider that ensure the weld quality during the welding process are losses due to breaking, eliminating the oxide film, and limiting the new oxide's formation. To remove any oxide build-up in tig welding aluminum, it requires a tungsten non-consumable electrode, pure argon shielding gas, and preheating samples 40-80 c.

[1,2,3]Guru Nanak Institutions Technical Campus, Ibrahimpatnam, Hyderabad, India

ASTM B557 standards were adapted to experiment with tension testing of aluminum alloy samples [2]. The gradual dynamic longitudinal load is applied to tensile samples till fracture is encountered. X-ray radiography was performed on all three categories of samples to locate the defect's position and orientation. High-frequency, low wavelength sound waves are introduced using a transducer into the material to identify the propagation and intensity of flaws. An echo was generated as the sound returned due to acoustic impedance mismatch, and signal strength versus time is displayed. The time essential for a signal to travel is equal to the distance that the sign traveled. Dislocations found in the welds can be located, and their size orientation and other features can be studied by reflected sound signals easily. The exerted tensile strength and elongations are recorded to calculate material mechanical properties, weld defects initiation, and propagation during the test.

SAMPLE PREPARATION

A. Pulsed gas tungsten arc welding (PGTAW)

Two 6082 t6 aluminum alloy sample plates of dimension length 100mm, width 120 mm, and thickness 8 mm are clamped over vertical milling machine to machine 45 double v grooves on either side of the sample. Methyl ethyl ketone is used to clean pieces and hooked over a bench 2 mm distance apart using c clams for preheating to a temperature 80 c by a gas torch to remove any built-up oxide layer. 3 mm Tungsten non-consumable electrodes with pulse current characteristics were used to control the weld pool formation [3]. The pure form of Argon gas is used for shielding the weld pool from oxide build-up. Altering weld parameters lead to weld defect. The Altering pulsed current 200-230 Ampere is sturdily used to generate Defect-free samples. Low temperature preheating about 50°C, reducing the distance between weld plates to 2 mm, and changing Current to 180-220 Amperes leads to welding defects. The ER4043 Filler material is used as filler material for all weldments with two passes on each side. After welding, the plates acquired 200mm length, 120 mm width, 8 mm thickness.

B. CNC milling to prepare standard tensile sample

The weld Plate with dimensions 250 mm width, 120 mm length, and 8 mm thickness is programmed in CNC milling on MASTERCAM software. According to ASTM E 8:2004 standards, tensile samples are prepared with measurements, i.e., handle with 50length, 20 widths, 8 mm thickness, the reduced cross-section of 100mm in length, 12.5 widths, 8 mm thickness, and gauge length 57 mm[4].

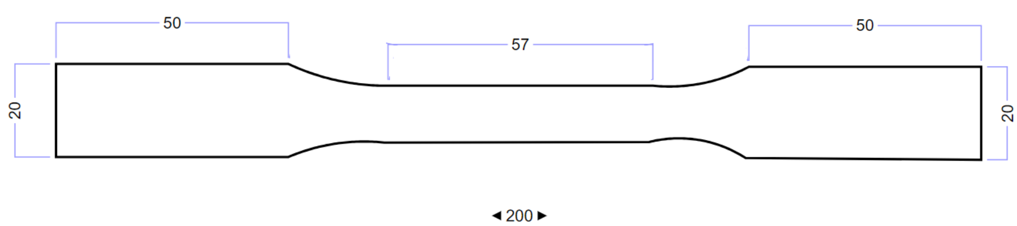


Fig. 1. Final Tensile Sample after CNC Milling.

EXPERIMENT SETUP

X-Ray Radiography

The samples are subjected to an X-ray Radiography test through 3 Mille Amperes current and 100 KV Voltage to establish defect location, magnitude, and orientation suitable for low-density aluminum material. Following ASTM SE 1815 standard test method, commercially available industrial radiography film is used [4]. Image quality indicators Wire and hole type are used for test correctness [5]. According to standards consecutively, all the tensile samples two pair of good and defects are tested with 70 cm source to film distance for one minute exposure time.

Tensile test

According to ASTM E8, the longitudinal tensile load is exerted on the samples to identify the weld's strength and ductility using a Computer interfaced universal testing machine [6]. Aluminum 6082 tensile sample without weld recorded A 28.4 KN of maximum tensile load, 29.8 % gauge elongation before fracture, which turns as a standard for further experiments. Good weld samples are subjected to tensile load it achieved a maximum tensile load of 21.6 KN. Two duplicate good weld samples are intermediately loaded to 7 KN with no elongation and 2 mm elongation employing 14 KN in gauge length. Likewise, defect weld samples are also subjected to tensile load attained maximum tensile load of 18 KN. Duplicated defect tensile are also exposed to an intermediate load of 11 KN, 6 KN with brittle fracture and no elongation in gauge length.

Liquid Penetrant Testing

One of the uncomplicated inspection techniques to identify defects open to the surface at the micron level is the Liquid Penetrant test. It follows a simple five-step procedure Precleaing the sample free from any foreign material that integer with defects that open to the surface. In this case, samples are welded and do not interfere with any contaminants still as a nominal of precleaning by volatile precleaning without leaving any mark[7]. The second stem to apply penetrant over precleaned samples, type-III duel Penetrant (MR 67), both visible and fluorescent, is applied at temperature 27 °C. As the penetrant is water-based, dwell time, i.e., the sufficient time required by the penetrant to seep into the flaw. Five minutes if dwell time is provided for the experiment[8].

Fig.2. Samples after putting on penetrant

The third step is to clean the excess penetrate applied throughout the sample. The penetrant has an inbuilt emulsifier, laminar flow of water pressure not as much as 40 psi are used and smoothly wiped in unidirectional with a lint-free tissue to remove moisture out of sample. The fourth step is to apply a tinny coating of the developer atomized spray evenly throughout the sample. The trapped penetrant in flaw is drawn out due to capillary action in 3 min, called developing time.

Interpretation of indications formed on the developer layer is studied under sufficient white light and UV Light. The final step is to post clan the sample and brings it to its original condition.

E. Ultrasonic Investigation

Digital Ultrasonic inspection brand by Modosonic and model Da Vinci alpha is adopted to investigate internal defect initiation and propagation in weldments during dynamic load conditions. As the weld region is uneven normal longitudinal probe is not suitable for inspection, 45 ° angle probe is preferred to introduce shear waves into Specimen[9]. In Pulse echo technique a single probe or transducer acts as a transmitter and receiver by using a pulzer. Calibration plays a very significant role in ultrasonic inspection, which varies from material to material. V 2 Block is used for angle probe calibration, and X off is found to be 10 mm with a tolerance of -1 or +1 on the sound path [10]. Sound
attenuates as it travels or interferes with other material that performances as the basic principle of ultrasonic inspection acoustic impedance mismatch. Distance Amplitude Correction Curve (DAC) is drawn in the instrument as ASTM standards [11] to compensate for the attenuation losses with time-controlled gain.

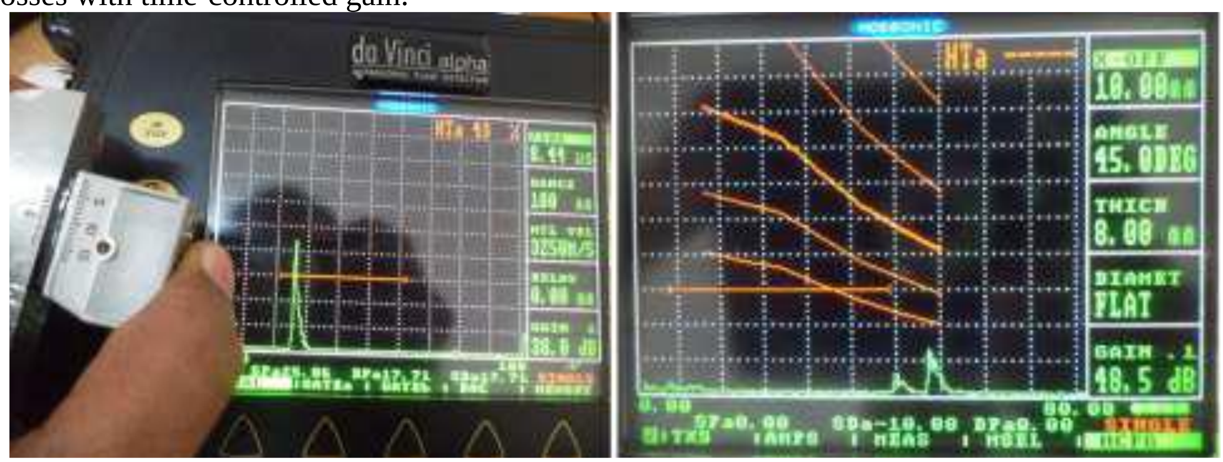


Fig. 3. Calibration and DAC curve developed for examination

RESULTS AND DISCUSSION

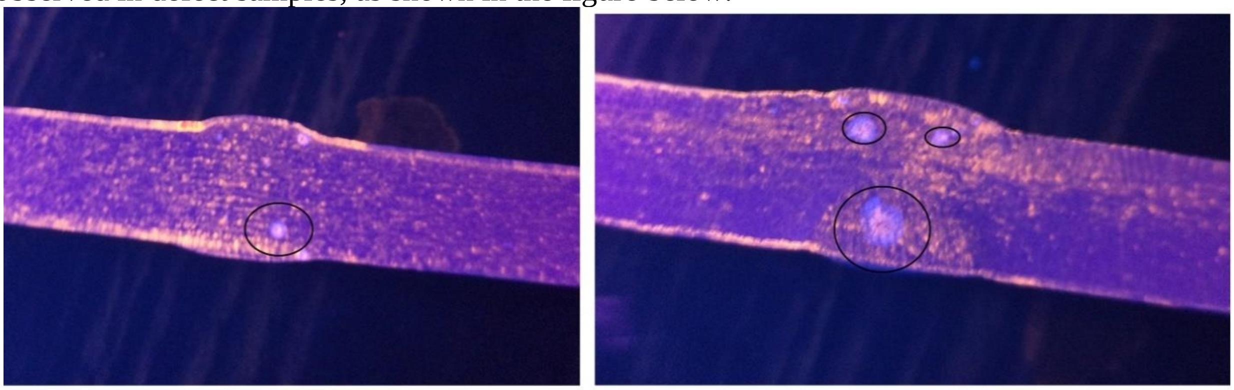
Radiography Film interpretation

X-ray Radiography film interpretation for good and defect weldments are carried out using good backlight. Defect orientation Lack of sidewall fusion was identified in the defect sample as shown in the figure, which acts as validation for other inspections.

Fig.4. Radiography film of Lack of sidewall fusion and defect-free samples.

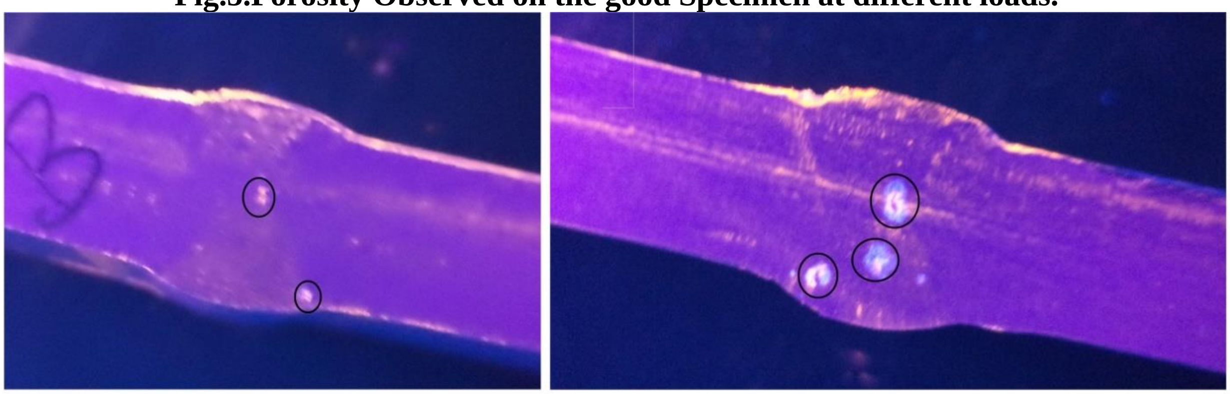
Liquid penetrant test

An adequate amount of blacklight or Ultraviolet Light is applied over the samples during the inspection. A small amount of porosity in good weld samples and a Lack of sidewall fusion is observed in defect samples, as shown in the figure below.



(A) (B)

Fig.5.Porosity Observed on the good Specimen at different loads.



(A) **(B)**

Fig.6. Porosity observed in the initial stage (A) and propagation in (B) Ultrasonic Examination

All the variable-loaded tensile samples are undergone ultrasonic inspection to identify defect location concerning depth, and propagation of defects due to loading is also measured. Ultrasonic signals are recorded and studied are recorded for different load conditions [13]. I significant increase in sound attenuation is noticed as the defects propagate due to loading, and a relationship is established between defect propagation and sound signal. During the initial load condition, no substantial signal attenuation is recorded. As the gradual load increase to 7 KN, 26 % amplitude acoustic echo is recorded at a depth of 0.23 mm. Defect propagated as the load increased to 14 KN with an echo of 53 % amplitude at a depth of 0.18 mm.

Fig.7. Increase in signal strength due to an increase in load in good weldment.

Artificial defect weldments are inherent with a lack of sidewall fusion defect till the 6 KN load sample did not show any significant ultrasonic echo. Around 6 KN, a sound amplitude of 26 % echo is recorded at a depth of 7.09 mm. A further increase in load to defect propagated 0.35 mm long internally to the depth of 7.41 mm with a 72 % sound echo.

Fig.8. Increase in signal strength due to an increase in load in defect weldments.

Microstructural Analysis

The microstructural analysis is carried out to understand additional information about the weldment's quality. Three samples welded region, heat affect zone, and parent material are prepared from the tensile specimen. Standard polishing, etching is performed over samples before microscopic examination. A Fine grain structure is present in the parent material, as shown in the figure. Due to the air colling heat effect zone, a fine grain structure is attained, but welding led to the needle-like arrangement is formed, illustrated in the figure. Cores grain structure is formed in the weld region visible grain boundaries are shown in figure.

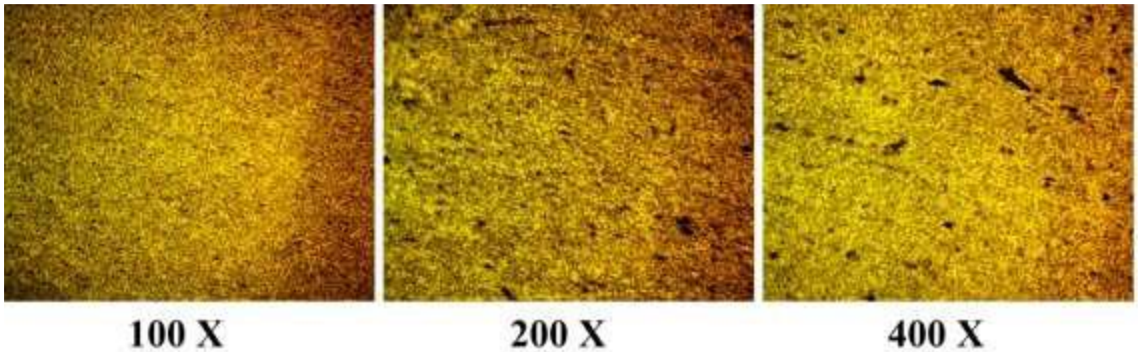


Fig. 9. Microstructure of parent material at 100X, 200X, 400X magnitude

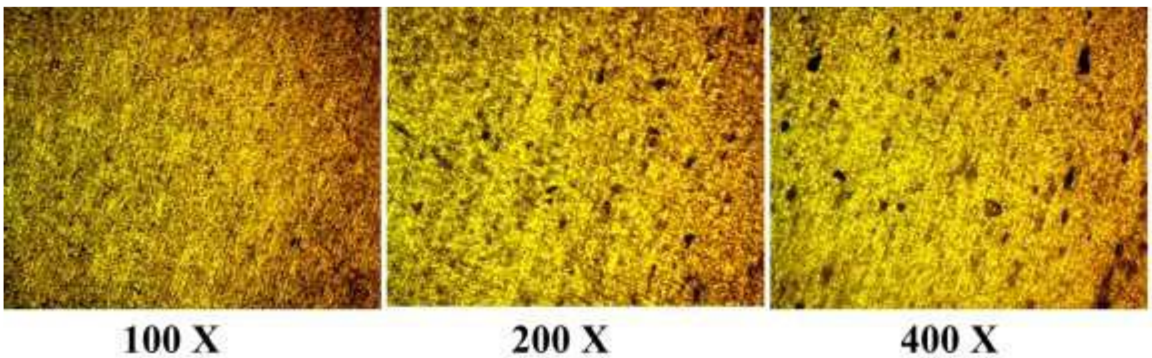


Fig.10. microstructure of HAZ material at 100X, 200X,400X magnitude

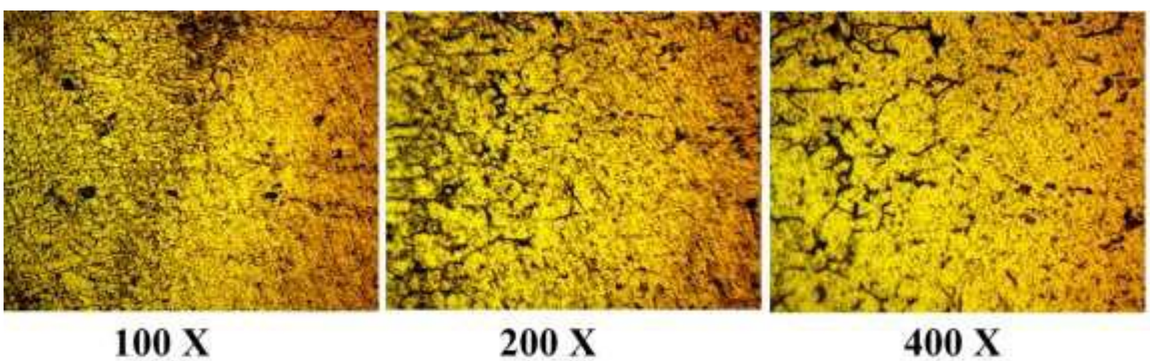


Fig.11. Microstructure of weld material at 100X, 200X, and 400X magnitude

CONCLUSION

Quality evaluation of weldments during structural loading is established by introducing weld defects artificially and good welding tensile samples designed with aluminum 6082 aero grade material. Scenarios that weldments phase during structural loading are created using a universal testing machine. How the good and defect weldments behave during load conditions are extensively examined by the liquid penetration test, Ultrasonic inspection, and validated by x-ray radiography results. Ultrasonic results provide internal defect information about weld defect propagation as load increased. Defect propagation is varied in good to defect weldments. Good weldments sustained a 21 KN of tensile load with an elongation of 8 mm. Defect weldments withstand 18 KN of tensile load with just 2 mm elongation and an encountered Brittle fracture.

Microstructural examination of parent material, Heat effect zone, and weld region with different magnitudes scale is studied for the grain structure and boundary changes due to welding.

ACKNOWLEDGEMENTS

The authors express their sincere thankfulness to "Shri Tavinder Singh Kohli, Chairman, Kohli G.S, Vice Chairman, and Dr. Harvinder Singh Saini, Managing Director, and Guru Nanak Institutions Technical Campus, Hyderabad.

REFERENCES

[1] Deekshant Varshney, Kaushal Kumar, "Application and use of different aluminium alloys with respect to workability, strength and welding parameter optimization", Ain Shams Engineering Journal, Volume 12, Issue 1, 2021,Pages 1143-1152, ISSN 2090-4479.

[2] Standard Test Methods of Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products [Metric], ASTM standard Designation: B 557M – 02a. Published 2003.

[3] P. K. Baghel,D. S. Nagesh. "Pulse TIG welding: Process, Automation and Control" Journal of Welding and Joining. 2017; 35(1): 43-48.

[4] Standard Test Method for Classification of Film Systems for Industrial Radiography.ASTM Standard Designation: E 1815 – 08, Published 2008.

[5] *Standard Practice for Design, Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI)* Used for Radiology, ASTM E 747-97, 1997.

[6] Introduction to Tensile Testing, Tensile Testing, Product code #05106G, ASM International, Published in 2004.

[7] Ranganayakulu S V, Samrat G B, et.al. "Quality Assurance of Structural Aluminum Aerospace Materials through Non Destructive Testing Techniques" *International Journal of Techanical Engineering and Technology*.,Volume 8, Issue 1, Jan 2017, pp. 44-52.

[8] Nielson D.C. and Thompson J.G.H., "Evaluation of Liquid Penetrant Systems, Materials Evaluation", *Applied mechanics review*, 33(12) (1975) 284-292.

[10] Nanekar P.P. and Shah B.K, "Characterization of Material Properties by Ultrasonic's" *BARC Newsletter Founder's Day Special Issue*, Issue no 249. 99 25-38.

[11] *Standard practice for ultrasonic Examination of longitudinal welded Pipe and tubing*, ASTM Designation: E273 – 10.Published 2005.

[12] M.V. Niranjan Reddy, M. Nikhil Reddy, K. Vijay Kumar and Parthasarathy Garre. Experimental Investigation of Tensile Strength on Al 6351 to the Aerospace Structural Applications, International Journal of Mechanical Engineering and Technology, 5(2), 2014, pp. 110–114

[13] Dr. S. Ravichandran. Ultrasonic Testing of Weldments, International Journal of Mechanical Engineering and Technology, 1, 2008, pp. 14–17