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Verification on Quality of Structural Aluminum Aerospace through Non-Destructive Testing Techniques

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Abstract: *In this work, another technique was produced for auxiliary uprightness of welded Aluminum 6082 air grade material by the methods for elastic burden as wellspring of commencement and engendering of imperfection through ultrasonic assessment. Three sort of elastic examples great/no-deformity, imperfection (Lack of penetrant) and un-welded with measurement shoulder 50*20*8 mm and 57 mm as check length have been decided for reasons of their dimensional adequacy and accessibility. The tractable examples of both great and flawed class were Gas tungsten bend welded (GTAW) which have experienced have experienced X-beam radiography for their reference portrayal. Three sorts of tractable examples were exposed to most extreme pliable burden which set back as referenced for additional assessment.*

Keywords: *Aerospace,*

I. Introduction

Aluminum alloys are used in engineering design dominantly for their light weight, high strength-to-weight ratio, corrosion resistance, and relatively low cost [1]. In its commercially pure state, aluminum is relatively ductile metal, having a lower tensile strength of approximately 57 KN. However, with the addition of small amounts of such alloying elements as manganese, silicon, copper, magnesium, or zinc and with the proper heat treatment and cold working, it's tensile strength can be enhanced up to 68 KN. The addition of a large amount of manganese and silicon controls the grain structure which in turn results in a stronger alloy as in case of aluminum 6082. In this experimentation, ASTM B557 standards are used for Tension Testing wrought, Cast Aluminum and magnesium Alloy Products [2]. Aluminum alloys are one of the most challenging metals to be welded because of their high surface reflectivity, low molten viscosity and inherent oxide layer. In addition, minimizing the HAZ in aluminum is more important than in other metals, in order to retain the mechanical properties of the parent material [3]. For these materials, the most common commercial welding methods use an electric arc with continuously fed wire electrode. The arc is protected by argon gas to shield the weld pool and the electrode from the surrounding atmosphere. To ensure an acceptable weld quality, there are two basic factors to consider - breaking loose and removing the oxide film, and preventing the formation of new oxide during the weld process. TIG welding aluminum requires a pure argon shielding gas, a tungsten non-consumable electrode and a clean surface to remove any oxide build-up by preheating the aluminum samples 30º-50º C.. Ultrasonic investigation is carried out for identifying the intensity and propagation of flaw, in which high frequency sound waves are introduced into a material and are reflected back from surfaces or structural defects. The reflected sound wave signal from the transducer is displayed on a screen. The reflected signal strength versus time is displayed from signal generation to when an echo was received. Signal travel time can be directly related to the distance that the signal travelled. From the signal, information about the reflector location, size, orientation and other features can sometimes be gained. If any dislocation is found in welds, it is located easily by using ultrasonic testing. The applied tensile load and elongations are recorded during the test for the calculations of stress-strain, achieve material parameters, initiation and propagation of defects.

Table 1 Calculated Mechanical Properties of material.

Aluminum 6082 material	Tensile strength	Yield load	Elongation	Brinell Hardness
Parent material	28 KN	20.6 KN	29.825 %	50 HB
Good welded	21 KN	6.5 KN	4.561%	55 HB
Defect welded	18 KN	3.5 KN	8.77%	56 HB

II. Sample Preparation

2.1. Gas Tungsten Arc Welding (GTAW)

The most common commercial aluminum and aluminum alloy welding methods use an electric arc with either a continuously fed wire electrode or a permanent tungsten electrode plus filler wire. The arc is protected by argon gas to shield the weld pool and the electrode from the surrounding atmosphere. Aluminum 6082 four plates of dimension 100*120*8 mm are "V" Groove either sides with 45° taper angle on milling machine. Two plates of width 100 mm are cleaned well with MEK (Methyl Ethyl Ketone) for but joined with 2-4 mm distance apart clamping over the bench, the Heat Effect Zone (HAZ) and weld region of plate are preheated to 30º-50° C with a gas torch as shown in figure 1. TIG welding aluminum requires a shielding gas (usually argon), a tungsten non-consumable electrode and a clean surface to remove any oxide build-up. Gas Tungsten Arc Welding is carried out with fallowing weld parameters

Table 2 Gas Tungsten Arc Welding (GTAW) parameters.

Weldment	Preheating	Electrode	Filler Materia l	Shield Gas	Current	Passes
Good/ Defect free	Two sides preheated 50°.	Tungsten Rod (White) 3 mm thickness	ER:404 3	99.9% Pure Argon gas	200-230 Ampere	2 passes each side
Defect	Preheated ones 30º-50°	Tungsten Rod (White) 3 mm thickness	ER:404 3	99.9% Pure Argon gas	180-220 Ampere	3 Passes each side

Two pair of weld plates are joined as good weld and another incorporating with lack of penetration defect by altering weld parameters as current to 180-200 A and distance between weld samples is reduced to less than 2 mm. Plates after welding have dimension of 200mm length, 120 mm width, 8 mm thickness.

Figure 1 Aluminum plates are preheating and welded.

2.2. CNC Milling to Standard Tensile Sample

The final dimension of samples after weld 250*120*8 mm are programmed for CNC milling on software MASTERCAM, Tensile samples are prepared according to ASTM E 8:2004 standards with measurements handle with 50*20*8 mm, with an 55.5 mm radius reduced cross-section of 100*12.5*8 mm and gauge length 57 mm as depicted in Figure 2 with operating time of 90 minutes using 10 mm milling tool.

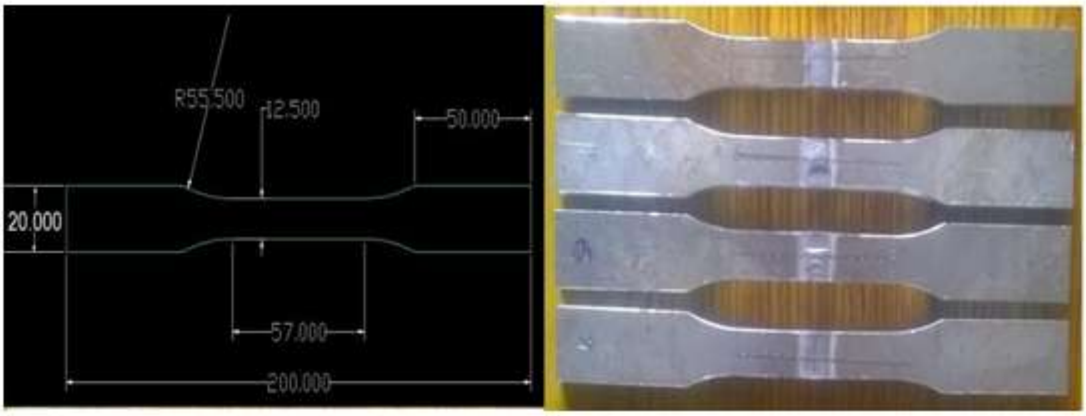

Figure 2 Final Tensile Sample After CNC Milling.

III. Experimental Setup

3.1. X-Ray Radiography

Defect location, Orientation and Magnitude are established by subjecting the samples to X-ray Radiography test with 100 KV Voltage and 3 Mille Amperes current which is suitable for low density materials like aluminum. Commercially available industrial radiography film is used in accordance with ASTM SE 1815 standard test method [3]. Using wire type Image quality indicators for test accuracy [4] sequentially all the eight tensile sample four good and four defect are tested according ASTM E1815-08 standards [5] with source to film distance as 70 cm and calculated one minute exposure time.

3.2. Tensile test

Tension test provide information on the strength and ductility of materials under uniaxial tensile stresses. This information may be useful in comparison of materials, alloy development, quality control [6]. The tensile testing is carried out by applying longitudinal or axial load at a specific extension rate to a standard tensile specimen with known dimensions (gauge length of 57 mm with cross sectional area 12.5*60*8 mm and the handle with 50*20*8 mm) according to ASTM E8 over computed Tensile test equipment. As the tensile samples are with flat surface flat jaws are installed. Initially tensile test is conducted on aluminum 6082 material without weld to calculate actual tensile strength of material and found to be 28.4 KN, with an elongation of 29.825%**.** With this reference of actual material, tests are further conducted on one good weld sample to maximum tensile load and found to be 21.680 KN. Another duplicate of good tensile samples is subjected to intermediate load of 14 KN with elongation 2 mm and 7.3 KN with no elongation. Similarly one defect tensile sample is gradually on load till fracture, sustained maximum tensile load of 18.0KN and another two defect samples are subjected to intermediate loads of 11 KN and 6 KN with no elongation noticed

3.3. Brinell Hardness Test

Hardness properties include varied attributes such as resistance to abrasives, resistance to plastic deformation, high modulus of elasticity, high yield point, high strength, absence of elastic damping and brittleness or lack of ductility [7]. Micro Brinell hardness measurement were conducted on the variably loaded good and defect weldments at 10mm interval entirely over tensile sample by portable dynamic hardness testing machines [8] (Make: Fasne Test equipment PVT. LTD.; Model: DHT-6).

3.4. Ultrasonic Investigation

Ultrasonic technique is the potential tool for probing the weld defects through the weld joint. As the inspection area is weld region we cannot directly place probe over it. The buried defect and the defects propagated due to varying load are examined with pulse echo technique and with angle probe of 45º, shear wave development for inspection. Calibration of the ultrasonic flaw detector (Make: Modsonic; Model: Da-Vinci-alpha) is done according to ASTM standards by using V2 blocks for angle probe. Sensitivity Adjustments are carried out using zero key, range, material velocity, angle, measurements, which are set to on and other parameters given to device for inspection conditional sensitive level of ultrasonic flaw detector with angle beam probe 45°, X off is found to be 10 mm as shown in figure 5 and given feed to equipment by considered tolerances as + 1 or -1 on Sound path [9].

3.4.1. Generating Distance Amplitude Curve

The use of electronic methods to compensate for attenuation losses as a function of ultrasonic metal travel distance may be employed by Distance Amplitude Curve (DAC) [10]. Specimen reference DAC block is prepared with aluminum material that is needed to be inspected having dimensions of 50 mm thickness and hole drilled subsequently at t = 10, t = 20, t = 30, t = 40. By considering the thickness of the DAC block sound path and surface distance are calculated. Actual sound path and surface distance are extracted from the device by amplitude response from the DAC block. Capturing the amplitude of first hole by placing the probe at a surface distance of 10 mm and sound path 14 .14 mm is equal to and not greater than 80% sweep-to-peak, adjusting instrument gain to attain 80% echo, entering reading in DAC menu by using "Enter" key as first point, similarly procedure is carried without changing the sensitivity control, obtain maximum amplitudes from second, third, fourth hole without altering gain manually [11]. Due sound attenuation and hole diameter values are varied from actual values to the calculated values and are noted in table 3. Amplitude of first echo is 80% and the second echo is less than the 1st i.e., 71%, the third echo is less than 2nd i.e., 58% but the 4th echo is higher than 3rd i.e., 61% as mentioned in table 3 and at each peak of the indications of echo on the screen feed into DAC menu by entering 2, 3 and 4 points. Connecting the screen marks by pressing DAC ON to provide the distance amplitude curve for the side-drilled hole as in figure 3. The line in DAC curve represent that if echo crosses upper line it implies reject, second one for repair and bottom line for acceptance. Accordingly, all the good and defect tensile samples are examined with ultrasonic investigation for identification and propagation of flaws due to load conditions.

Table 3 Calculated (Calucated) Table of Data to draw DAC Curve.

S. No	Thickness T=50	Actual surface distance	Actual Beam path	Ref DB	Amplitude
1	t = 10	8.86	12.54	48.4	80
2	t = 20	19.14	27.08	48.3	71
3	t = 30	29.56	41.81	49.3	58
4	t = 40	39.42	55.76	52.0	61

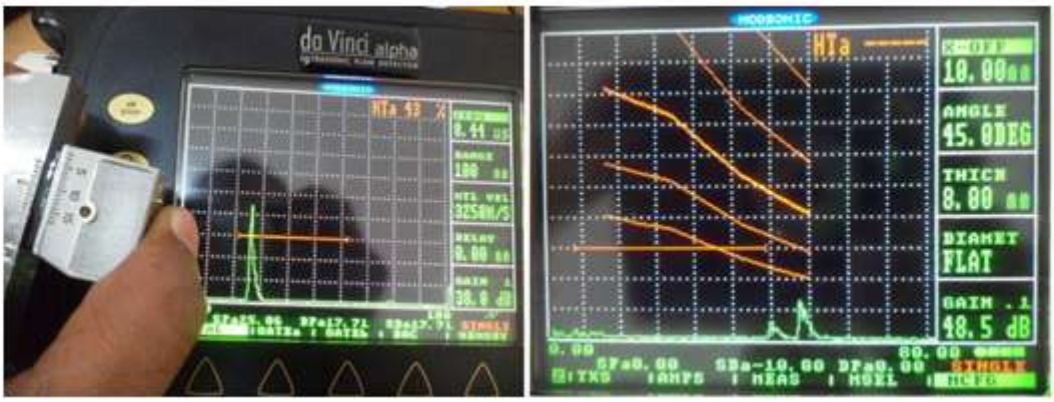

Figure 3 Calibration and DAC curve developed for examination.

3.4.2. Experimental Procedure of Ultrasonic Testing

The experiment is primarily carried over the good weld sample with no load condition. Later on, the samples subjected to loads of 7.5 KN with no elongation and 14 KN with 2 m m elongation with 2T oil as couplet propagation of flaw witth respect to load is clearly examined wiith ultrasonic investigation. Similarly, investigation is carriedd out over "Lack of Penetrant (LOP)" defe ct samples initially at load condition and during loading at 6 KN and 11 KN with no elongation observved considerable increase in defect echo.

IV. Results And Discussions

Good and defective tensile samples, subjected to different intermediate load conditions are considered for ultrasonic examination. Initially clear ultrasonic echo and radiography images are taken from all the weld samples which act as the referen ce samples for further investigation, interpreeted that lack of penetration defect is present in all defect sammples and porosity in good welded sample with in acceptance range as shown in figure [4].

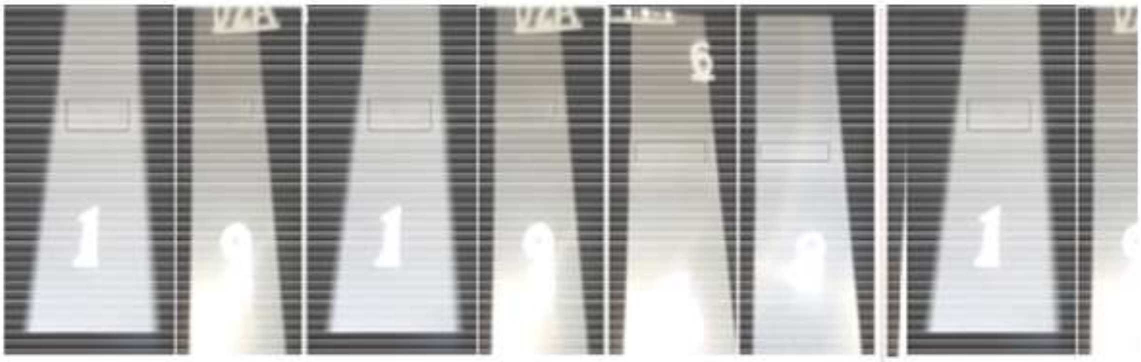

Figure 4 Radioography filim of lack of penetrant and good weld samples.

Good and lack of penetrant deefect samples with variable load are subjected to ultrasonic investigation and a correlation is established with respect to baring load to defect initiation and propagation by ultrasonic attenuation noticed significant changes in ultrasonic echos (Db) due to increa se in load. A visually easer relation between elongation and defect propagation studied using ultrasonic wherein good welding elongation is occurred only at 14 KN and a slight growth in porosity. In lack of penetrant defect sample no significant elongation is occurred only internal crack propagation is observed by ultrasonic test and finally brittle fracture has taken placedd. All the tensile samples one without tensile load, another two at intermediate loads of 6 and 11 K N are subjected to hardness test thoroughly over parent material, Heat Effect Zone and weld region and noticed considerable hardness reduction in weld region due to defect in weld this is due to hardness of the material in weld is reduced with respect to increase in tensile load also, as they are indication of materi al resistance to plastic deformation. Similarly, with good weld too at intermediate load of 7 and 14 KN.
Following are the details of th e various modes in which data was acquired, compiled and analyzed.

V. Observations Made From The Data Analysis

5.1. Loads vs. Defectology

It is observed that, when the load of 7 KN is applied over good weld sample, a minor echo signal with 26 percentage level was noticed at a depth of 0.23 mm under acceptance of DAC curve is identified with the increase of load to 14 KN the d efect propagated further with an echo signal increased amplitude to 53 percentage at the depth of 0.18m m as shown in figure [6] and stress strain cuurve of good weld sample is depicted in figure [5].

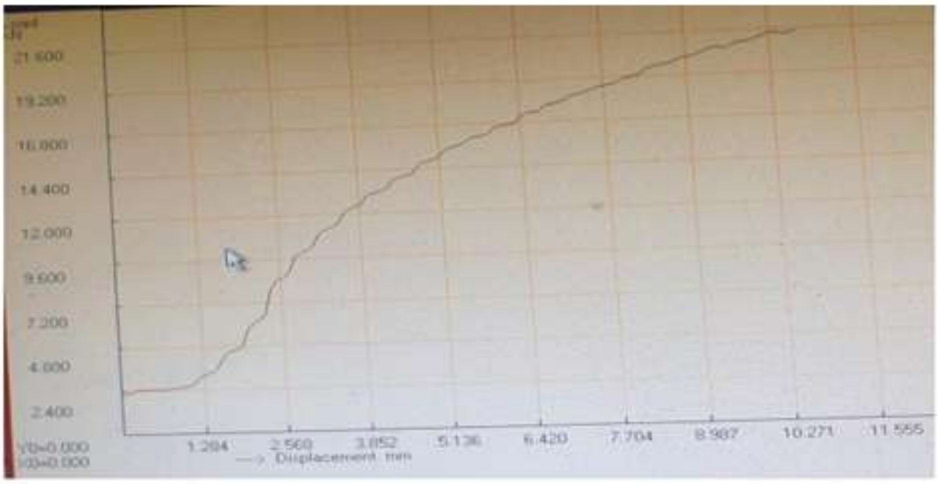

Figure 5 Stress vs. strain graph of good weld sample.

Defect at 7 KN load

Defect Propagation at 14 KN load

Figure 6 Defect propagation in good weld sample due to increase in load.

Whereas for defect sample acoustic impedance mismatch is observed at the depth of 7.09 with applied load of 6 KN with an echo signal 68 percentage crossed reject line of DAC curve, further increase of load to 11 KN crack propagated o.35 mm long into the material at the depth of 7.41 mm as shown in ultrasonic echo figure[8]. Detail stress strain curve of LOP defect sample is shown in figure [7].

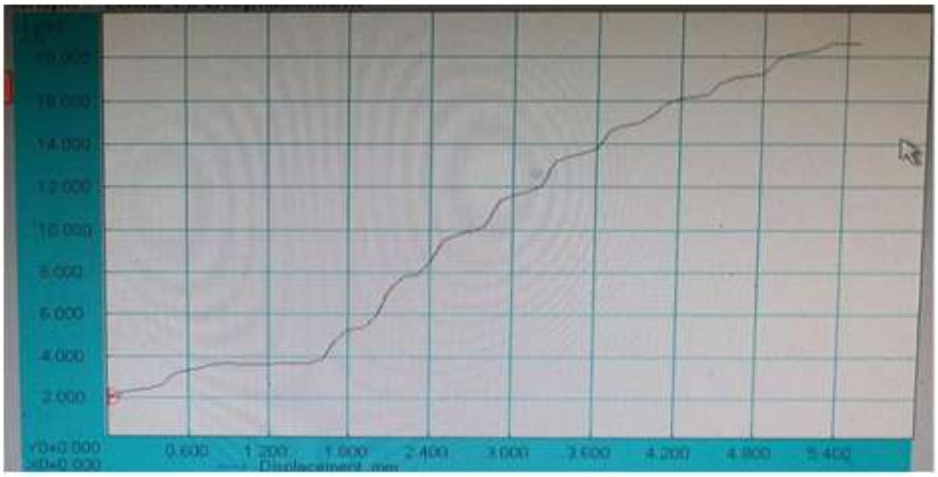

Figure 7 Stress vs. strain graph of Defect good weld sample.

Defect at 6 KN

Defect propagation at 11 KN

Figure 8 Defect propagation in defect weld sample due to increase in load.

5.2. Elongation vs. Defectology

It was found that, with the increase in load over good weld sample small porosity is identi-fied at the depth of 0.23 and it undergo elongation of 2mm at 14 KN further necking taken place till fracture with maximum tensile load of 21.6 KN and with a elongation of 8mm. Figure [9] shows the propagated of defect with respect to elongation.

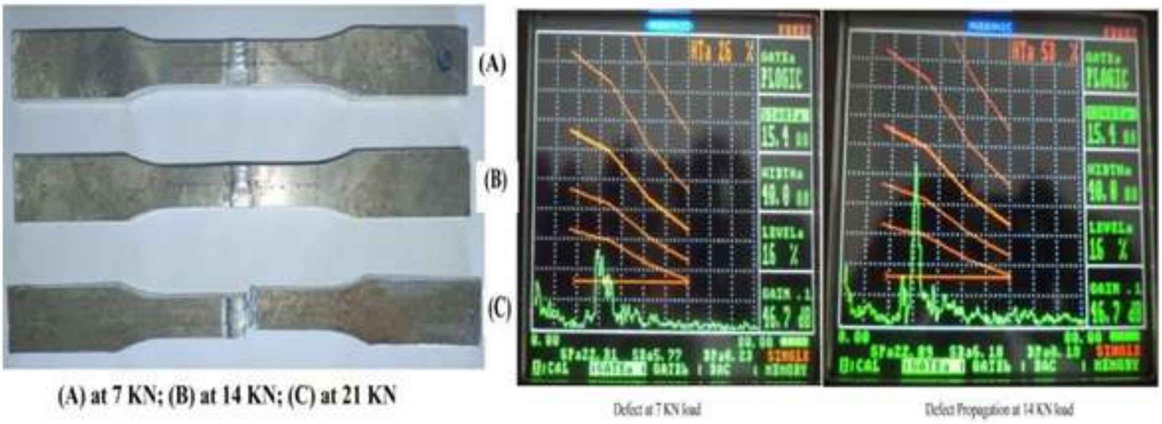

Figure 9 Defect propagation with respect to elongation in good sample.

Defect sample showed no elongation during loading conditions at an interval of 6 KN and 11 KN , it has undergone brittle fracture with very minute 3mm elongation at 18 KN load, the relation between elongation to defect propagation is shown in figure[10].

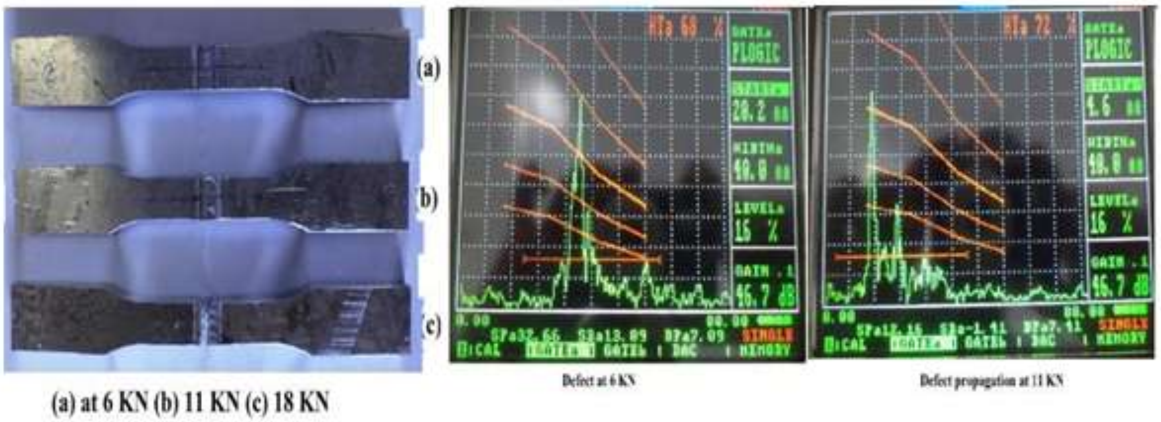

Figure 10 Defect propagation with repect to elongation in LOP defect sample.

5.3. Hardness vs. Load

It is observed that, hardness is proportional to load over weld region, where as it show drastic changes in Heat Effect Zone, which is the effect of micro structural changes occurred due to high temperature during welding process Overall hardness of tensile sample before testing is 54 BHN and for good weld tensile sample under the load of 7 KN and 14 KN it is 53 BHN and 56 BHN respectively as shown in figure [11].

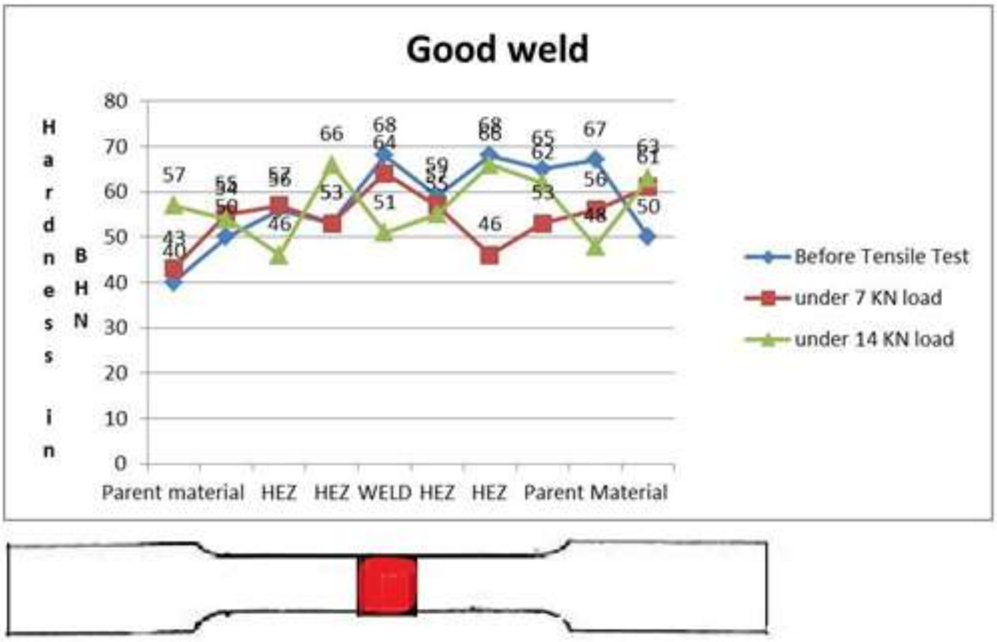

Figure 11 Harness behaviour of good weld sample under load.

Whereas in defect sample also hardness is equally proportional to tensile load as good sample but tensile load over Heat Effect Zone and Parent material is increased with in-crease of load occurred due to residual stress without elongation finally encountered brittle fracture. Hardness profile is vividly shown in figure [12].

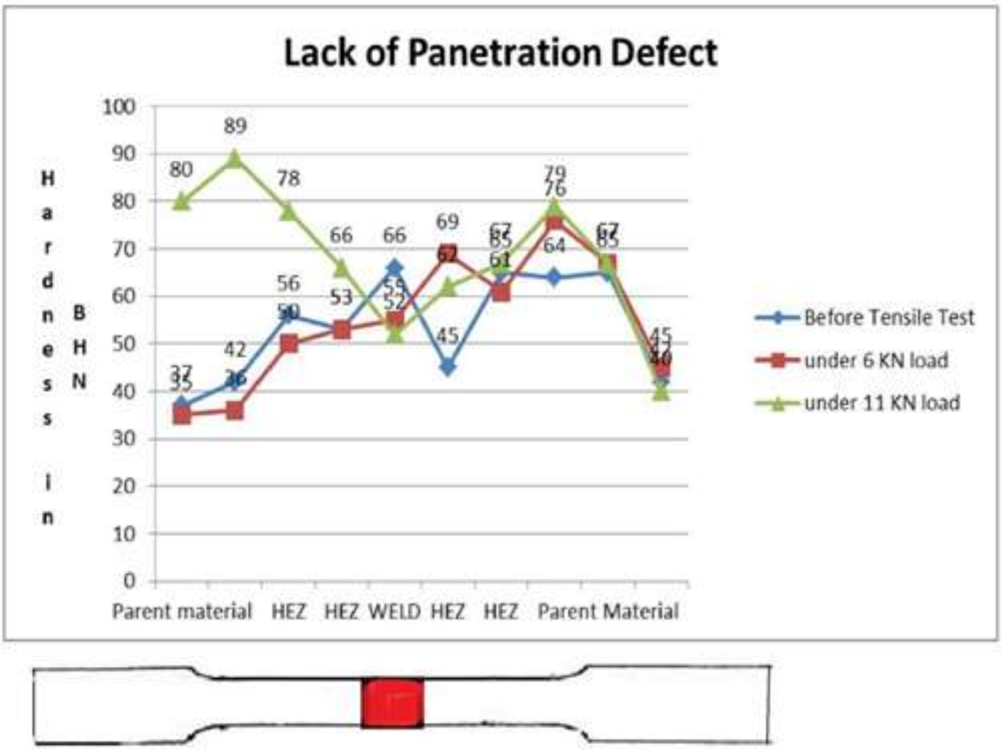

Figure 12 Harness behavior of defect weld sample under load.

VI. Conclusion

The Stages of Damage occurred in aluminum 6082 in specially designed good and defective welded tensile specimens at intermediate and fracture load were studied by the means of ultrasonic examination, X-Radiography, Brinell hardness methods.

X-Radiography method was used to characterize the orientation and magnitude of flaw occurred during welding process. Ultrasonic investigation is carried at various stages of loading conditions. Amplitude of defect location and the propagation due to loading of ultrasonic signals were interpreted. Defect propagation is increased with increase of load in good sample further recorded necking and fracture, whereas in defect sample propagation of flaw is negligible during load condition and final with no elongation was recorded only brittle fracture. Hardness vs. tensile strength is directly proportional in both the cases in weld region but abnormal changes are noticed in Heat Effect Zone Region of defect sample due to residual stresses.

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