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Microstructural Evolution in AA7055 Aluminium Alloy Under Dynamic Shock Loading

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Abstract

The material investigated in this project is AA7055 Aluminium alloy at T7751 tempered condition. It was solution heat treated to obtain two additional temper conditions; T6 and T4. To produce the T4 temper, the as-received aluminium alloy was subjected to single-step heat treatment at 450ºC for 1.5h and quenched in water. Other sets of as-received samples were subjected to two-step heat treatment which involves heat treating at 450ºC allowed to homogenize for 1.5hrs and quenched in water. The as-quenched specimens were age-hardened for 8hours at 100ºC and for 24hrs at 120ºC. Upon impacting these alloys, maximum strength obtained for the T7751, T6, T4 tempered alloy are 822MPa, 748MPa and 640MPa respectively. Similarly, Compressive tests were carried out at a slow strain rate and the maximum strength obtained for T7751, T6, T4 are 1392MPa, 957MPa and 525MPa respectively.

As a result of the dynamic impact test and slow strain rate deformation carried out on the aluminium alloys, adiabatic shear bands are seen mostly along the circumference of these alloys as detailed in the results section. This can be due to the high deformation resistance of these alloys, heat generated at the point of impact as well as dislocation of second phase particles distributed within the crystal structure are observed with the Scanning Electron Microscope.

Keywords: Impact loading; Adiabatic; Shear band; Stress; Strain; Aluminium Alloy; Heat treatment

1. Introduction

The AA7055 Aluminium alloy was developed by ALCOA in the early 1990s and produced in the form of both extruded plates. It is an alloy of Al-Zn-Mg-Cu and finds application as the upper wing structural material in aircraft, especially the Boeing 777 airplane [1]. The AA7055 aluminium alloy has low density, high strength, and good fracture toughness and good stress corrosion cracking resistance. This kind of alloy is an aging-hardenable alloy and heat thermal processing which has a great effect on its microstructure and properties. In order to obtain the combination of high strength, ductility and corrosion resistance, different temper conditions have been developed [2]. This type of alloy is an aging-hardenable Al-Zn-Mg-Cu alloy and heat treatment processing can effectively be used to modify its microstructure and properties [3]. In order to obtain the combination of high strength, good fracture toughness and stress corrosion resistance, AA7055-T77 temper was developed [4]. T77 temper is a kind of triple-stage aging. The first stage is peak aging, the second-stage is regression treatment, and the third stage is re-aging following regression treatment. Alloy 7055 in the T77 temper is best suited for applications where compressive strength is the critical design criteria such as upper wing structures, horizontal stabilizer, keel beams, seat and cargo tracks in aircraft [5].

Homogenization treatments could be most effective while using the alloy AA7055 with copper and magnesium at its lower limits of the composition range. For the AA7055 alloy, Zinc is kept on the higher side of the alloy composition range, because it is understood to be the major alloying element influencing the strength properties of the alloy [6].

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Many impacts are completely inelastic – the impacting object is simply swept along by a moving target without rebounding, with the impacting object or possibly the target being totally or partly crushed. An insect striking an automobile windshield is a common example of this phenomenon, but a more important case is a bird strike on an aircraft. In such a case where the impacting object is easily deformable, the forces of deformation will be small with respect to the inertia and the impacting object simply gets 'squashed'. The impact duration is defined as the time taken between first contact and the time required for the remainder of the body (also known as 'bird wedge' in the analyses of bird-strike), assumed to continue travelling at the speed of impact, to make contact [7]. Hence, the need to study the behaviour of AA7055 aluminium alloy to understand the dynamic impact shock loading in comparison to quasi-static shock loading (i.e. the slow strain-rate deformation) so as to predict its behaviour under dynamic impacts loading.

2. Experimental Procedure

The AA7055 Aluminium Alloy investigated in this study has a chemical composition as shown in Table 1

Table 1 Chemical Composition range of AA7055 Alloy

Element	Al	Zn	Cu	Mg	Zr	Fe	Mn	Cr
% Range Composition	85.9 -88.5	7.6 – 8.4	2.0 – 2.6	1.8 – 2.3	0.08 – 0.25	<0.15	<0.05	<0.04

The alloy was machined to cylindrical specimens of 10.55mm in length and 9.55mm in diameter for the impact compressive tests. The AA7055 Aluminium alloy were solution heat treated at 450^{0}C for 1.5hours to T4 temper condition, and also quenched in water at ambient temperature and peak-aged to T6 temper using a two-step aging treatment involving soaking for 8hrs at 100^{0}C and 24hrs at 120^{0}C. This heat treatment was done using the Thermo Scientific Lindberg Blue M Heat treatment furnace at the Materials Laboratory, University of Saskatchewan.Also, another set of samples were solution heat treated at 450^{0}C for 1.5hrs, quenched in water and cooled in air in order to attain the naturally aged T4 Temper condition.

High strain rate deformation was carried out on the heat treated aluminium alloy specimen using the split Hopkinson pressure bar located in the materials science laboratory, University of Saskatchewan. The cylindrical test specimen is placed in between an incident bar and a transmitted bar. A metal gun which is fired from the application of pressure in a pressure chamber through the incident bar strikes the specimen. An elastic wave is generated when the specimen is impacted which travels through the input bar, the specimen and the output bar. The waves were captured by the strain gauge attached to the bars. These provide the strain signals that become amplified and captured by the amplifier and digital oscilloscope. Stress-strain curves were generated from the captured strain signals.

Slow strain rate deformation of the aluminium alloys were performed using the Instron Testing machine in materials testing lab, University of Saskatchewan. The test were carried out using, a strain rate of $3.2*10^{-3}$/s and cross head speed of 2mm/min up to a maximum load of 100KN at room temperature.

The etching of the aluminium alloys was carried out using a solution consisting of 25ml HNO_3, 25ml HCl, 25ml methanol and 1 drop of HF. The process involved dipping of aluminium alloys in the acid, holding for a particular period of time and soaking in water rinsing with methanol and drying. The optimum etching time for the as-received T7751 alloy was 30s. The etching time for T4 and T6 alloys were 10s.

The microstructural examination of the Aluminium Alloy samples were observed using the Nikon 100MA Eclipse Inverted Optical Microscope at the University of Saskatchewan. Magnifications of X50, X100 and X500 were used for the different temper conditions of the alloy.

The JEOL JSM-6010LV Scanning Electron Microscope is used to capture the fractured specimens of the AA7055 aluminium alloy. The fractured images were taken at magnifications of X4000, X500, and X50.

3. Results and Discussion

The elastic wave data obtained from impact tests using the split Hopkinson pressure bar were used in an excel spreadsheet to obtain the dynamic impact stress – strain curves. The applied pressure ranged from 100 – 200KPa at an interval of 20KPa to determine the impact load at which the specimens will fracture. For the AA7055-T7751 alloy, failure occurred at an applied pressure of 200KPa with a velocity of 17.43m/s. The Stress-Strain curves are shown below:

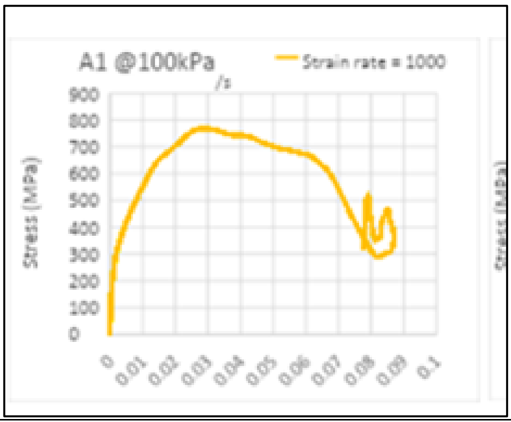


Figure 1 AA7055-T7751 Aluminium Alloy at 100kPa

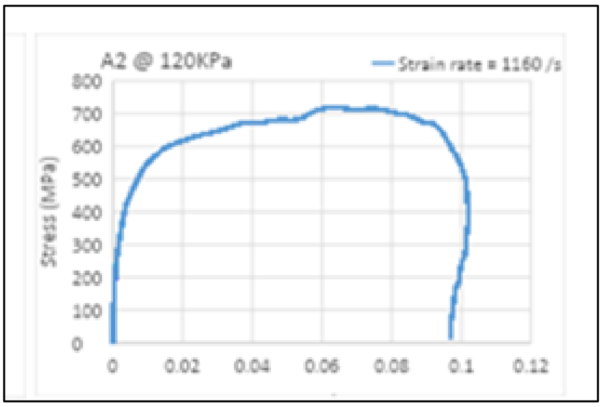
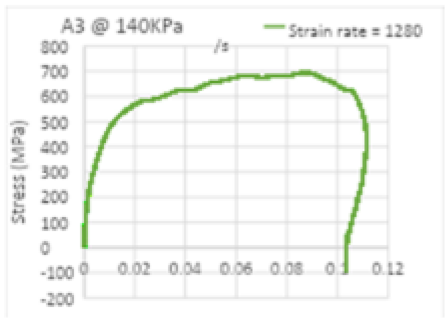


Figure 2 AA7055-T7751 Aluminium Alloy at 120kPa

From the Engineering Stress strain curve above, at impact pressure of 100kPa, the maximum Stress obtained is 768.20MPa and maximum strain is 0.077 with a strain rate of 1000/s (Figure 1). At an impact pressure of 120kPa, maximum stress is 718.05MPa and maximum strain is 0.096 with a strain rate of 1160/s (Figure 2). For 140kPa pressure, maximum stress is 692.31MPa and maximum strain is 0.103 with a strain rate of 1280/s (Figure 3). At impact pressure of 160kPa, maximum stress is 822.19MPa at maximum strain of 0.115 with a strain rate of 1400/s. (Figure 4)



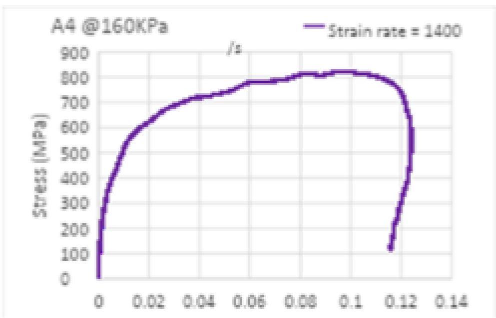


Figure 3 AA7055-T7751 Aluminium Alloy at 140kPa Figure 4 AA7055-T7751 Aluminium Alloy at 160kPa

For an impact pressure of 180kPa, maximum stress is 735.86MPa and maximum strain is 0.128 with a strain rate of 1540/s (Figure 5). At an impact pressure of 200kPa, maximum stress is 768.59MPa and maximum strain is 0.14 at a strain rate of 1640/s. (Figure 6)

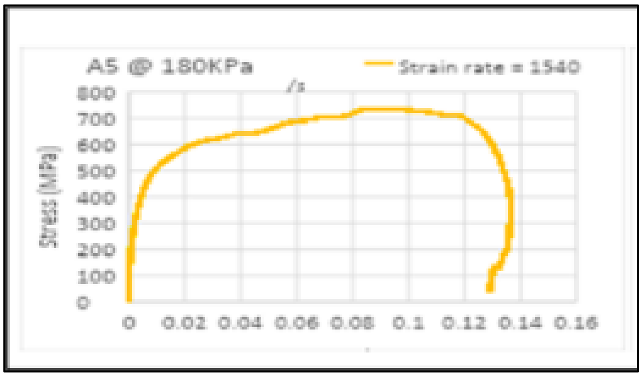


Figure 5 AA7055-T7751 Aluminium Alloy at 180kPa

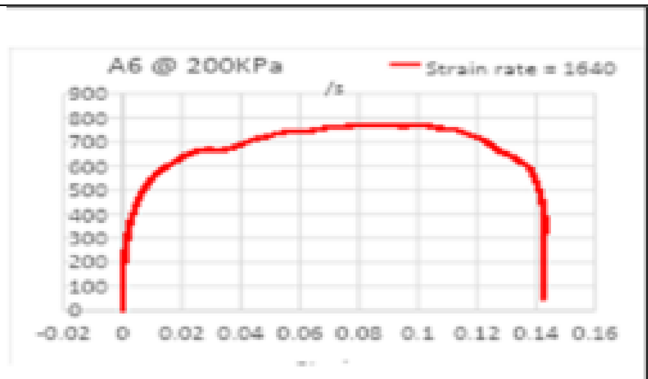


Figure 6 AA7055-T7751 Aluminium Alloy at 200kPa

From the Engineering Stress strain curve above, we can deduce as follows:

Table 2 Impact test result on AA7055-T7751 temper alloy

Impact Pressure (kPa)	Max Stress (MPa)	Strain @ max stress	Strain rate (/s)
100	768	0.0280	1000
120	718	0.0625	1160
140	692	0.0871	1280
160	822	0.0962	1400
180	736	0.0950	1540
200	768	0.1007	1640

Based on Table 2 above, we can make a co-plot of the Stress - Strain curve of all six impact pressures

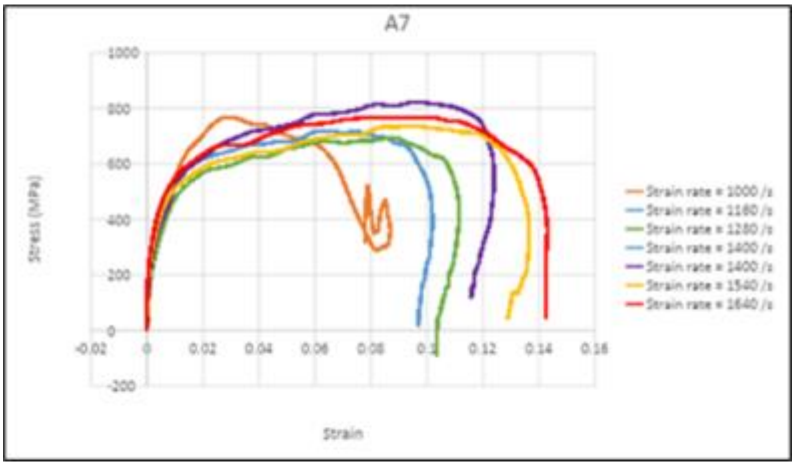


Figure 7 A co-plot of AA7055-T7751 of varying pressure of 100-200kPa.

3.1. Stress –Strain curves were also obtained for AA7055 in the T4 Temper condition

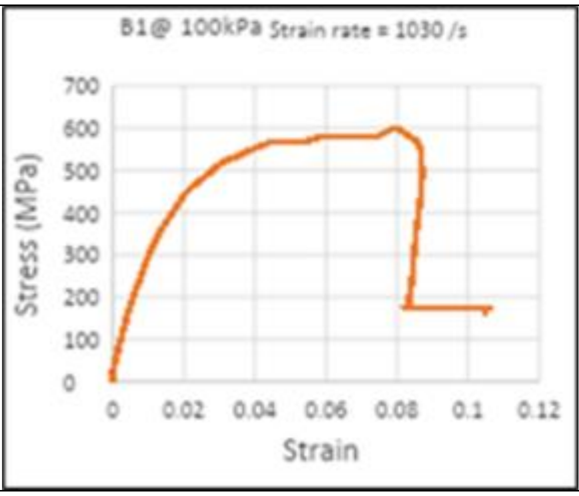


Figure 8 AA7055-T4 Aluminium alloy at 100kPa

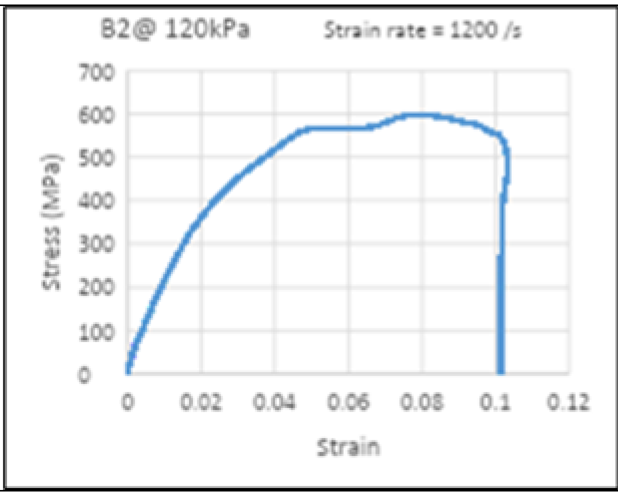


Figure 9 AA7055-T4 Aluminium alloy at 120kPa

At an impact pressure of 100kPa, maximum stress is obtained as 598.64MPa and maximum strain is 0.104 with a strain rate of 1030/s (Figure 8). Also, for 120kPa, maximum stress is 597.72MPa and a maximum strain rate of 0.101 with a strain rate of 1200/s (Figure 9). At an impact pressure of 140kPa (Figure 10), maximum stress is 577.49MPa and maximum strain is 0.101 with a stain rate of 1400/s. For an impact pressure of 160kPa, maximum stress is 639.79MPa and maximum strain is 0.125 with a strain rate of 1500/s (Figure 11). At pressure of 180kPa, maximum stress is 625.56MPa and maximum strain is 0.162. (Figure 12)

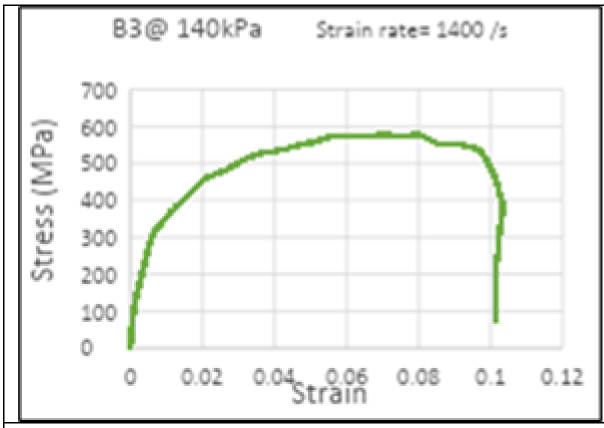


Figure 10 AA7055-T4 Aluminium alloy at 140kPa

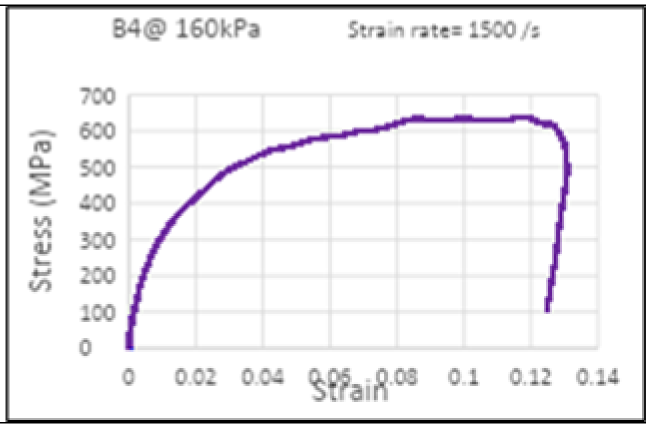


Figure 11 AA7055-T4 Aluminium alloy at 160kPa

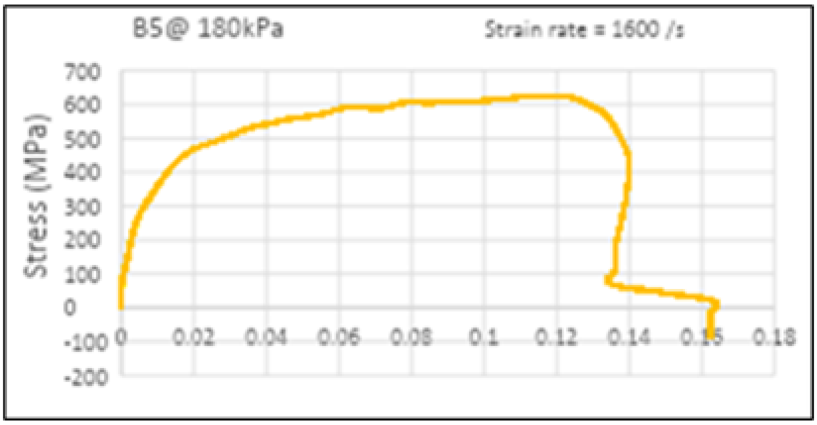


Figure 12 AA7055-T4 Aluminium alloy at 180kPa

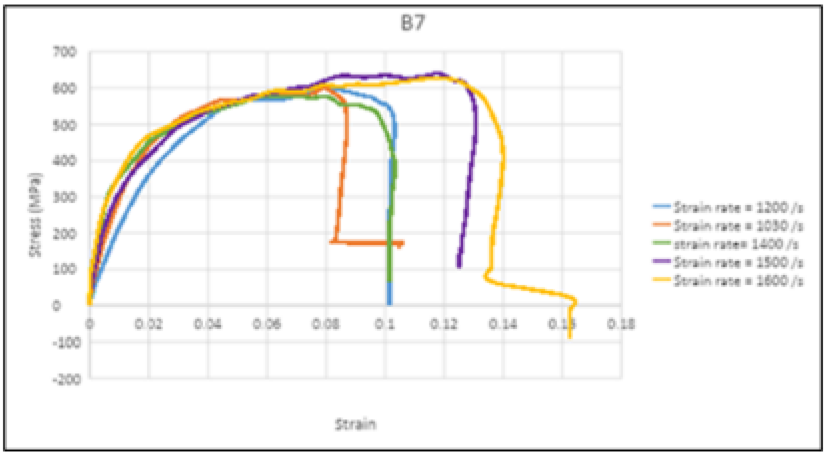


Figure 13 A co-plot of AA7055-T4 Aluminium alloy

3.2. Stress-strain curves were obtained for AA7055 Aluminium alloy in the T6 Temper condition

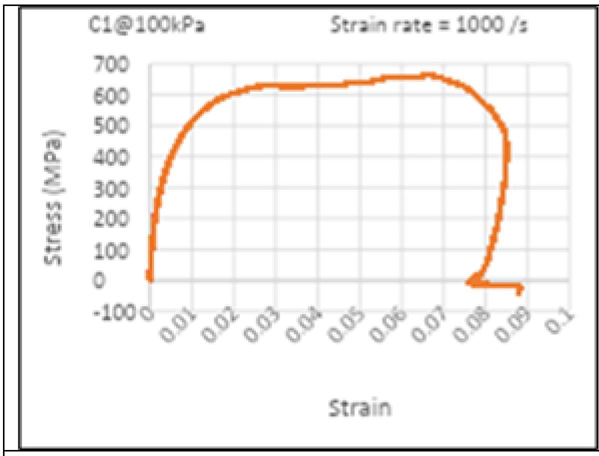


Figure 14 AA7055-T6 Aluminium alloy at 100kPa

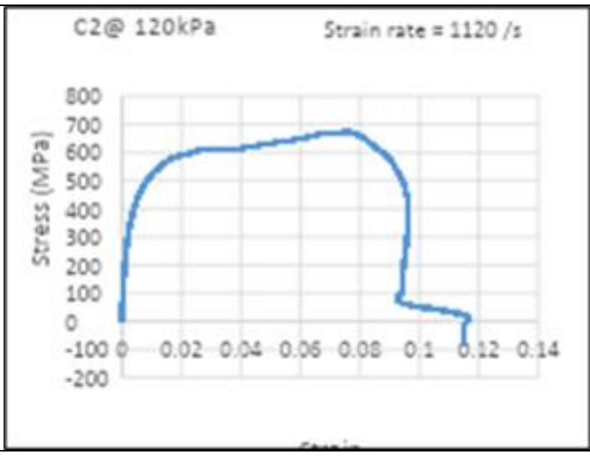


Figure 15 AA7055-T6 Aluminium alloy at 120kPa

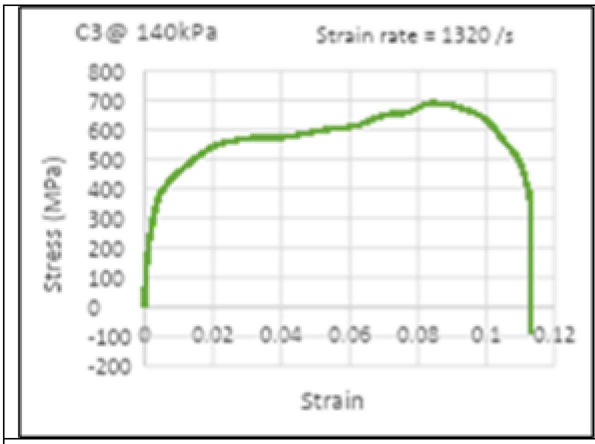


Figure 16 AA7055-T6 Aluminium alloy at 140kPa

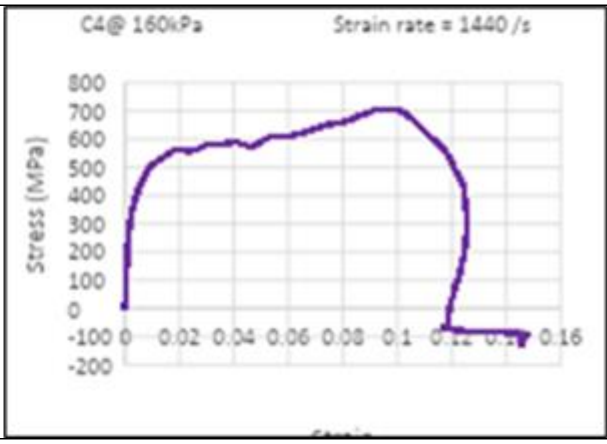


Figure 17 AA7055-T6 Aluminium alloy at 160kPa

In Figure 14; at an impact pressure of 100kPa, the maximum strength obtained is 662.11MPa and maximum strain is 0.076 with a strain rate of 1000/s. At an impact pressure of 120kPa, maximum strength obtained is 671.87MPa and maximum strain is 0.115 with a strain rate of 1120/s (Figure 15) At an impact pressure of 140kPa, the maximum stress obtained is 690.36MPa and maximum strain is 0.112 with a strain rate of 1320/s (Figure 16). At impact pressure of 160kPa, maximum strength is 707.48MPa and a maximum strain of 0.118 with a strain rate of 1440/s (Figure 17).

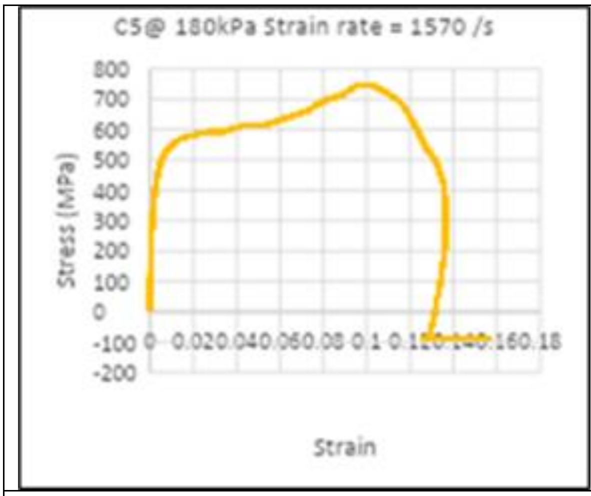


Figure 18 AA7055-T6 Aluminium alloy at 180kPa

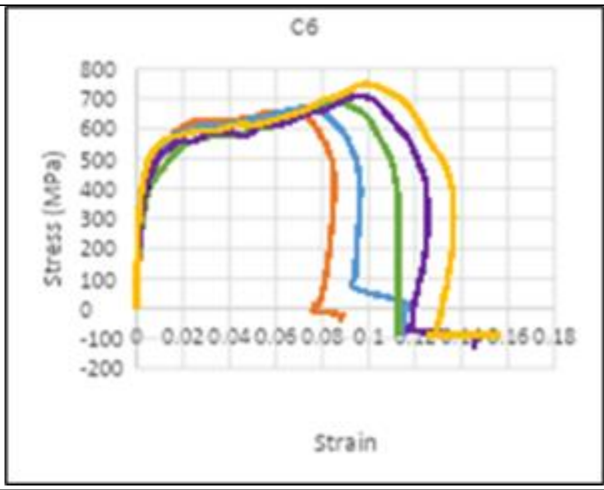


Figure 19 A co-plot of AA7055-T6 Aluminium alloy

At an impact pressure of 180kPa, maximum strength obtained is 748.46MPa and a maximum strain rate of 0.131 with a strain rate of 1570/s (Figure 18). A co-plot generated in Figure 19 above.

3.3. Engineering Stress-Strain Curves for Compression Tests experiment made

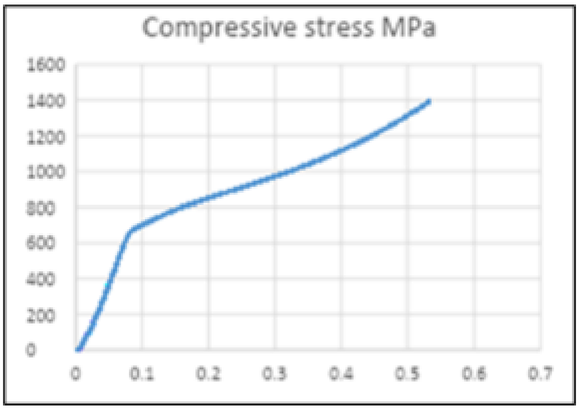


Figure 20 As received AA7055-T7751 (01)

From Figure 20 the ultimate tensile strength is obtained as 1391.86MPa and strain at failure is 0.532

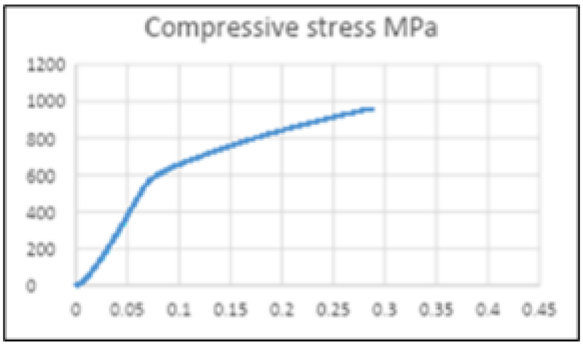


Figure 21 AA7055-T6 Temper Aluminium alloy (01)

For the T6 temper alloy, UTS obtained was 957.06MPa and strain at failure is 0.287 as shown in Figure 21

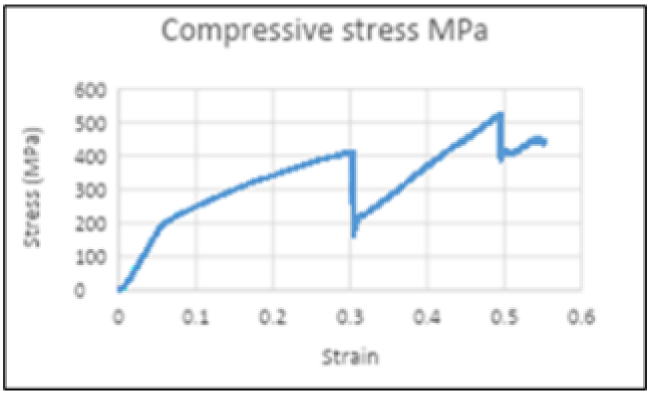


Figure 22 AA7055-T4 temper aluminium alloy (01)

In Figure above (Figure 22), the applied load for compression used is 100KN at a strain rate of $3.2*10^{-3}$/s. The stress-strain curve obtained has an ultimate tensile strength of 410.92MPa with a necking region and on further application of the load the UTS obtained was 524.89MPa with strain at failure obtained as 0.494.

3.4. Geometry Change Of Impacted Surfaces

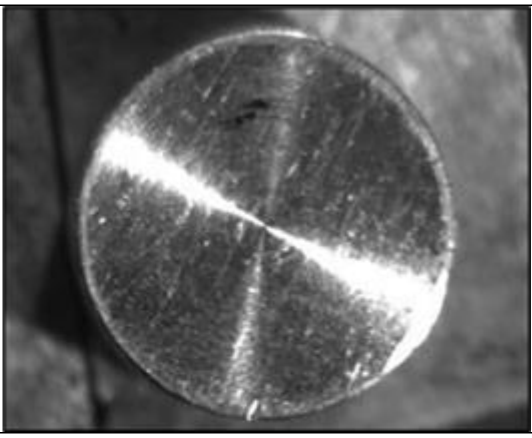


Figure 23 Incident impact showing formation of failure at 100KPa

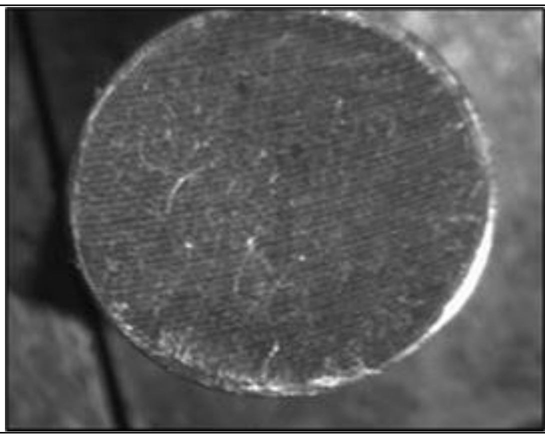


Figure 24 Reflected fracture surface showing striations at 100KPa

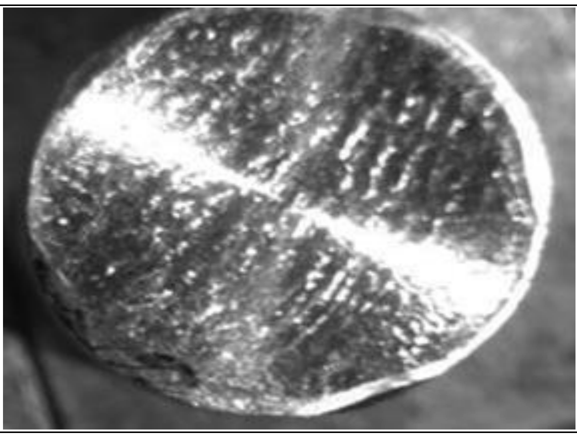


Figure 25 Incident impact showing formation of fracture at 120KPa

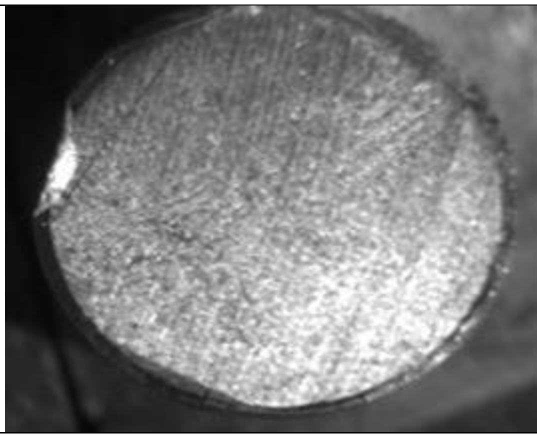


Figure 26 Reflected fracture surface showing striations at 120KPa

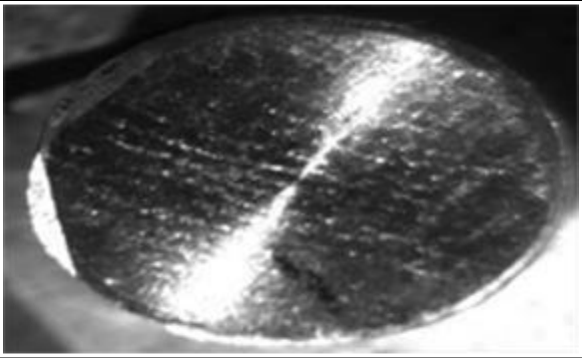
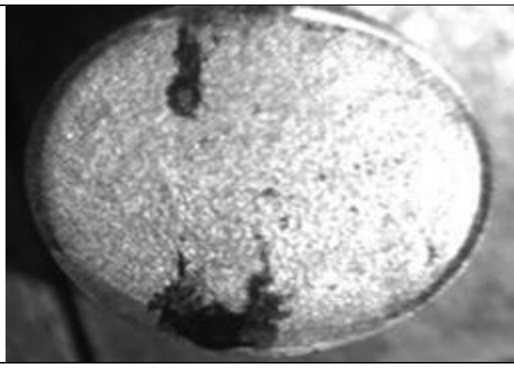
	

Figure 27 Incident impact showing formation of fracture at 140KPa	**Figure 28** Reflected fracture surface showing inclusions and striations

In Figure 23 - Figure 28, there is an impact showing formation of fracture at 100KPa as well as striations in the reflected fracture surface. At 120KPa, incident impact showing formation of fracture becomes more visible and reflected fracture surface showing striations. With impact pressure of 140KPa, the formation of fracture is shown while reflected fracture surface indicates inclusions and striations.

In Figure 29 - Figure 32, at impact pressure of 160KPa, there is formation of cracks and the reflected surface shows cracks and inclusions as in Figure 30. At an impact pressure of 200KPa, there is a cup and cone fracture showing failure of the alloy as seen in Figure 31 and in Figure 32 there is also a cup and cone fracture showing failure of the alloy AA7055.

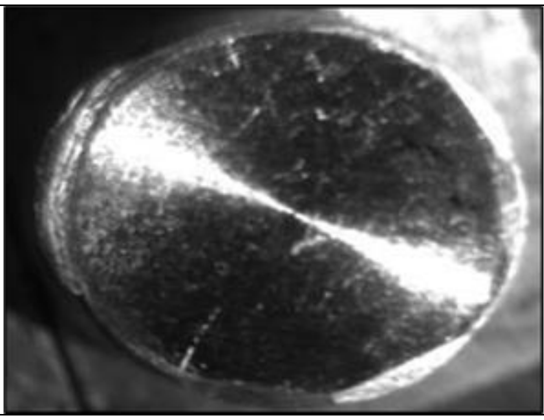
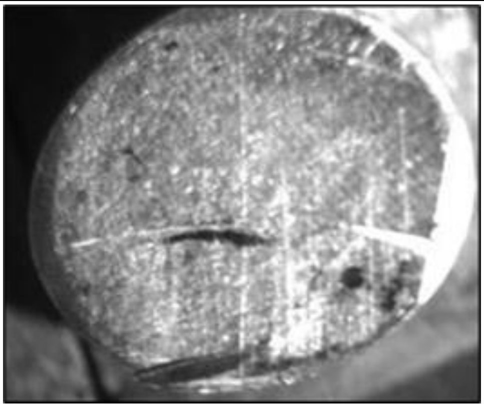
	

Figure 29 Incident impact showing formation of cracks at 160Kpa	**Figure 30** Reflected surface showing cracks and inclusions at 160KPa

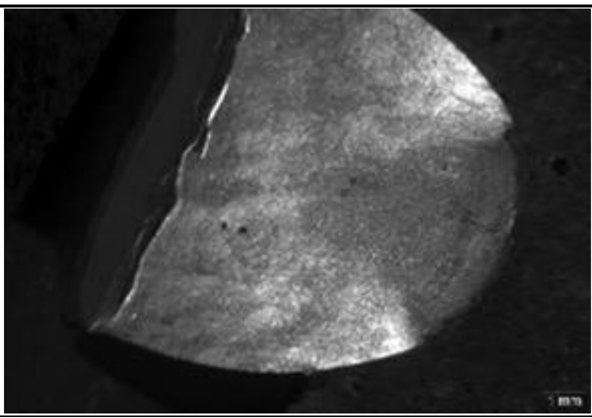
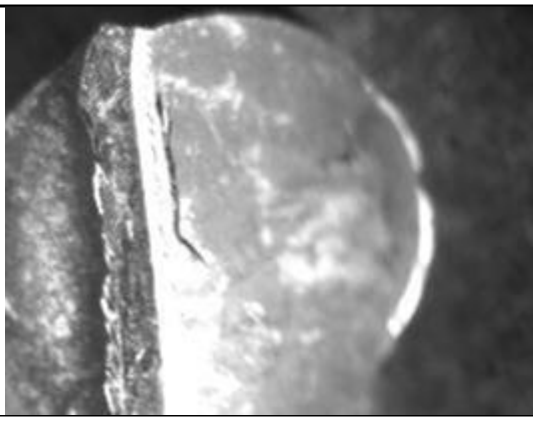

	

Figure 31 Cup and Cone fracture showing failure of the alloy at 200KPa	**Figure 32** Cup and cone failure of AA7055 alloy at 200KPa

3.5. Compression Tests

Figure 33 Reduction in height of AA7055-T7751 Aluminium alloy

Figure 34 Failure of AA7055-T4 Aluminium alloy (side view)

Figure 35 Crack failure of AA7055-T6 Aluminium alloy

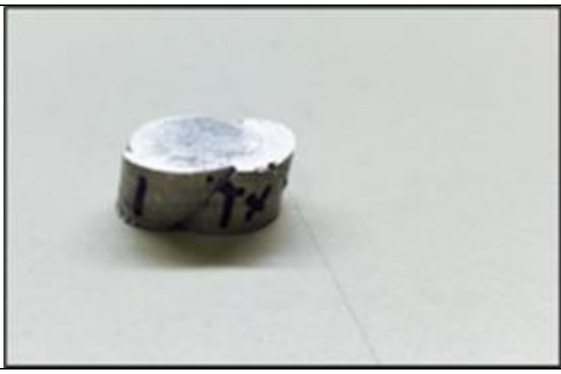


Figure 36 Failure of AA7055-T4 Aluminium alloy (Front view)

In Figure 33 – 36 above, pictorial view of AA7055 aluminium alloy at temper conditions of T7751, T6, and T4 shows reduction in height from the original dimensions as well as failure of the alloy (cracks) when subjected to a load of 100KN at a cross head speed of 2mm/min and strain rate of $3.2*10^{-3}$. Table 1.3 gives the reduction in height obtained.

Table 3 Compression results acquired from Instron Testing machine

Aluminium Alloy Temper	Initial diameter (D_0) (mm)	Initial height (H_0) (mm)	Final diameter (D_f) (mm)	Final height (H_f) (mm)	Longitudinal Strain	Lateral Strain
T4	9.55	10.50	14.12	5.88	1.478	0.560
T4	9.55	10.53	12.00	5.22	1.256	0.495
T6	9.55	10.50	11.17	7.86	1.169	0.748
T6	9.55	10.48	11.46	7.58	1.200	0.723
T7751	9.55	10.53	13.15	6.31	1.376	0.599
T7751	9.55	10.48	13.11	6.33	1.372	0.604

3.6. Examination of Microscopic Evolution

The AA7055-T7751 Aluminium alloy was impacted showing the adiabatic shear band below at a Magnification of X50. The deformed band can be seen to progress across the circumference of the alloy as shown in Figure 37.

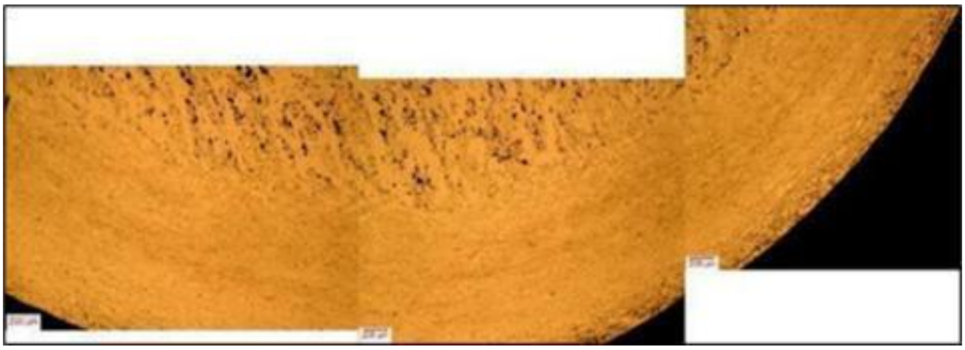


Figure 37 Shear band formed in the as-received AA7055-T7751 alloy after impact with a magnification of X50

In Figure 37(a) there are elements of trace particles that can be considered as second phase particles with a magnification of X50; with clearly visible grain boundaries shown inside the deformed band of the adiabatic shear band formed by the impact of AA7055-T7751 alloy at a higher magnification of X500. (Figure 37b)

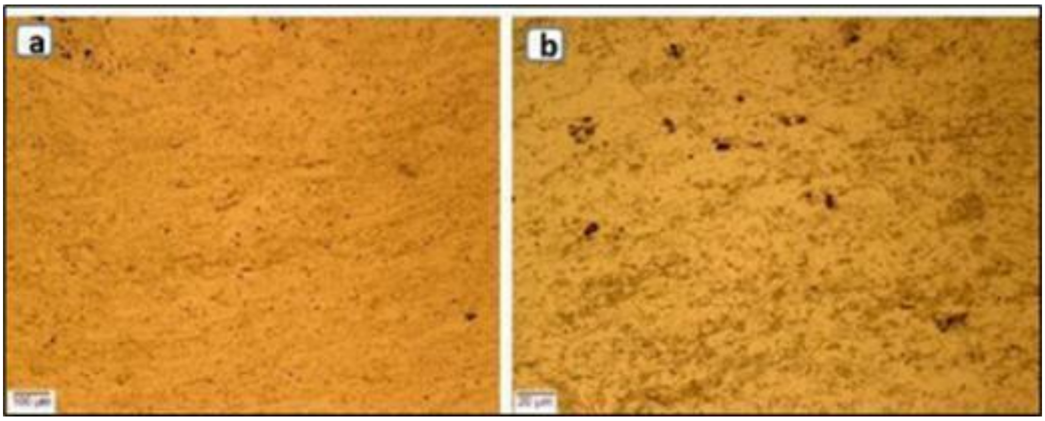


Figure 37 (a) Inside band of shear band formed at a magnification of X100 (b) Inside band of shear band at magnification of X500

In Figure 38a the microstructure can be viewed to occur outside the deformed shear band at a magnification of X100. At a higher magnification of X500, (Figure 38b) the second phase particles are seen as well as the grain boundaries.

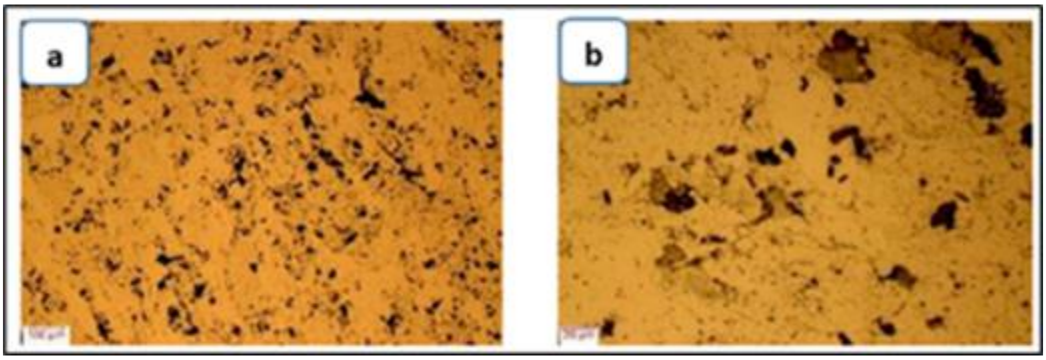


Figure 38 (a) outside band of AA7055-T7751 at magnification of X100; (b) a higher magnification at X500

3.7. The AA7055-T7751 Quasi static Compressed

In Figure 39 Adiabatic shear band formed at the circumference of the alloy indicating deformation of the alloy. Irregular coarse grains are formed outside the band in Figure 40a and a higher magnification reveals the grains in Figure 40b.

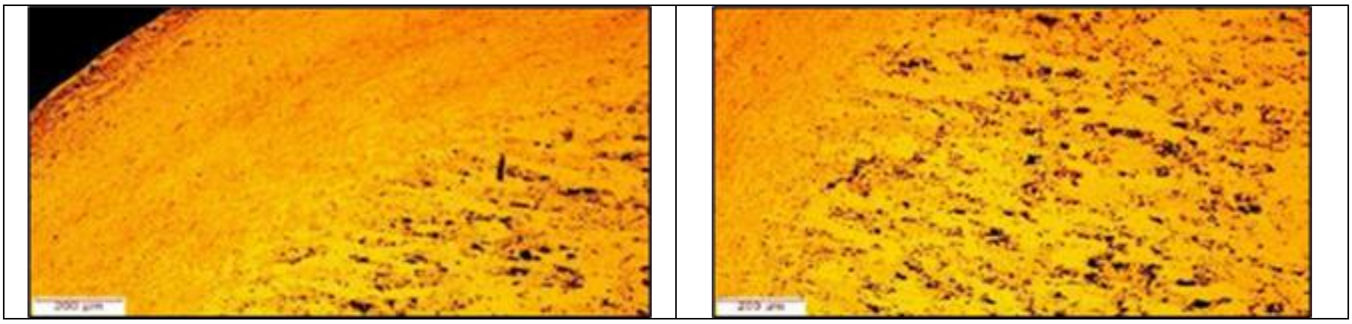


Figure 39 Adiabatic shear band formed along the circumference of the alloy at X50

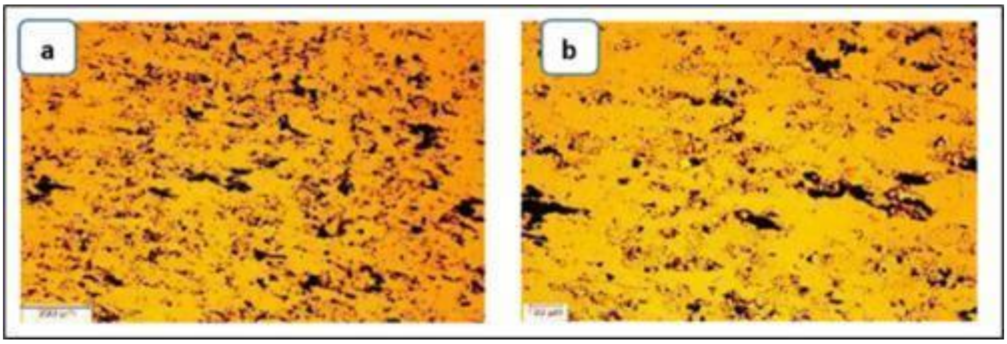


Figure 40 (a) Images at X50 of compressed AA7055-T7751 (b) Outside band of AA7055-T7751 at magnification of X100

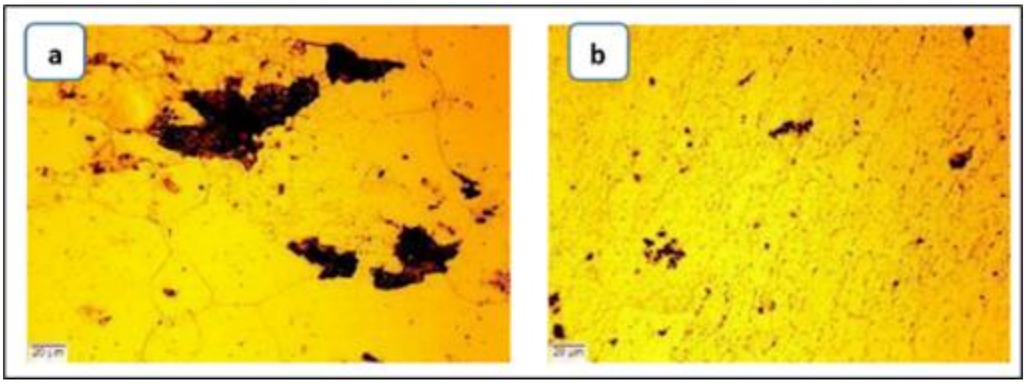


Figure 41 (a) outside band of AA7055-T7751 at X500 (b) Inside band of AA7055-T7751 at magnification of X500

In Figure 41(a) at a higher magnification, we can clearly see large grain boundaries and presence of second phase particles. In Figure 41(b) a fine uniformly dispersed and elongated grain of alloy is seen as well as traces of second phase particles.

3.8. Microstructure Of AA7055-T6 Temper Aluminium Alloy

Figure 42 Microstructure of AA7055-T6 aluminium alloy at Magnification of X50, X100, X500 when impacted at 100kPa (C1)

In Figure 42 above, no presence of adiabatic shear band formed in the microstructure. However,

The alloy was subjected to an impact pressure of 100kPa with a momentum of 33kg.m/s. The alloy can be said to be finely dispersed with uniform distribution of second phase particles. At higher magnification of X500, the grain boundaries are clearly visible and the fine structure shown.

In Figure 43, a closely packed microstructure is shown below with no presence of adiabatic shear band formed at the centre. This alloy was subjected to impact pressure of 120kPa and momentum of 39.02kg.m/s. However, along the circumference of this particular alloy, Figure 44, there are visible traces of adiabatic shear band formed as a result of the alloy.

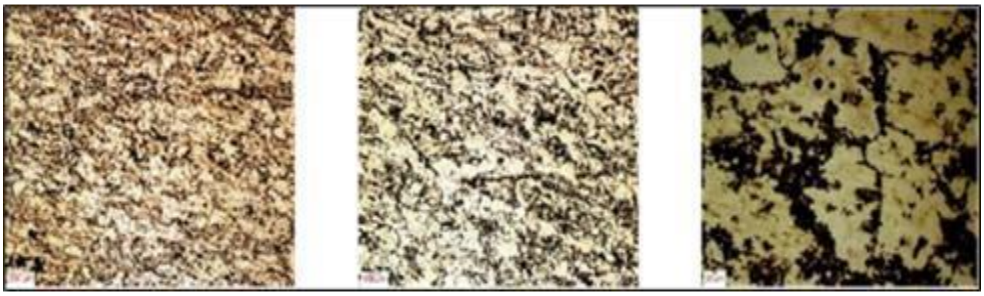


Figure 43 Microstructure of AA7055-T6 aluminium alloy at Magnification of X50, X100, X500 when impacted at 120kPa (C2)

Deformation of T6 tempered alloy is noticeable along the circumference of the alloy as shown in Figure 43 at a magnification of X50. The failure of this material is due to the presence of cracks formed at the tip.

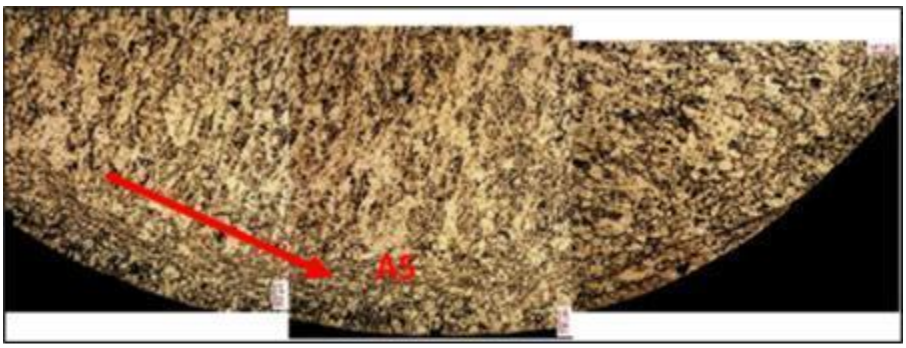


Figure 44 Deformation of AA7055-T6 alloy along the circumference at impact pressure of 120kPa (C2) at magnification of X50

Also, at an impact pressure of 140kPa with momentum of 45.01kg.m/s, slight deformation can be found at the circumference of the alloy. Hence, the higher the impact pressure applied the more the material deforms. As can be seen at the third section of Figure 45.

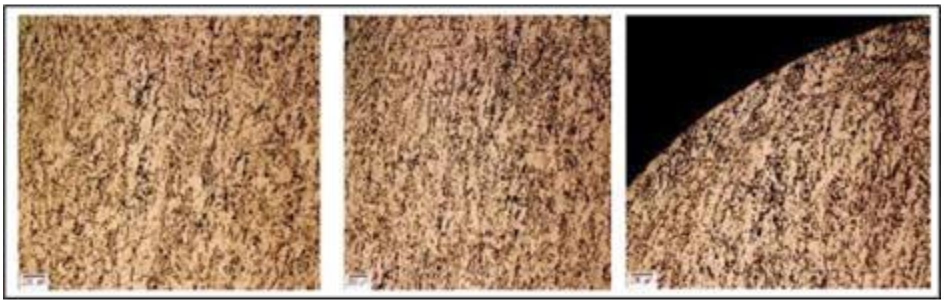


Figure 45 Microstructure of AA7055-T6 alloy at impact pressure of 140kPa (C3) at a magnification of X50

Figure 46 Microstructure of AA7055-T6 alloy at impact pressure of 160kPa (C4) at magnifications of X50, X100, X500

In Figure 46, the microstructure above shows closely packed grain structure at magnification of X50, X100 and X500. However, in Figure 47 an adiabatic shear band is formed along the circumference of the alloy showing deformed band from a pressure of 160kPa and momentum of 50.51kg.m/s.

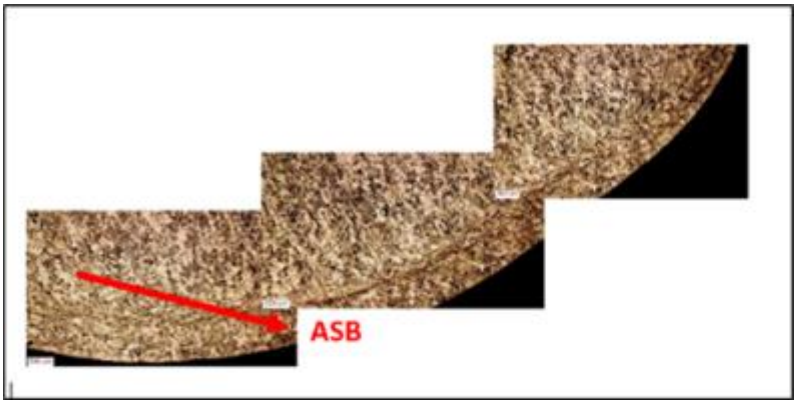


Figure 47 Deformed shear band formed along the circumference at an impact pressure of 160kPa (C4) at magnification of X50

In Figure 487.12, the microstructure shows densely populated second phase particles and this region is outside the deformation area. In Figure 497.13, the region of deformation is clearly seen along the circumference of the alloy showing adiabatic shear band formed and presence of cracks along the edges caused by an impact pressure of 180kPa and momentum of 55.85kg.m/s.

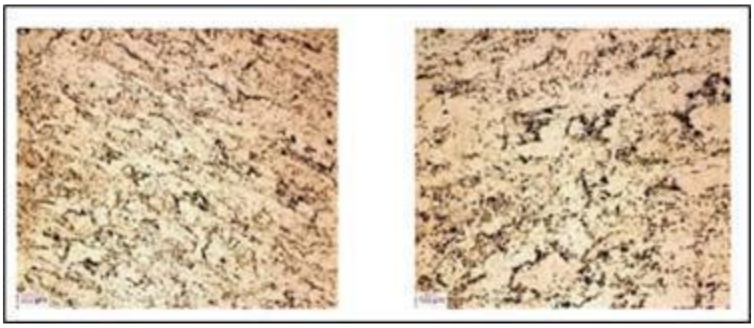


Figure 48 Microstructure of AA7055-T6 alloy at impact pressure of 180kPa (C5) at magnification of X50 and X100

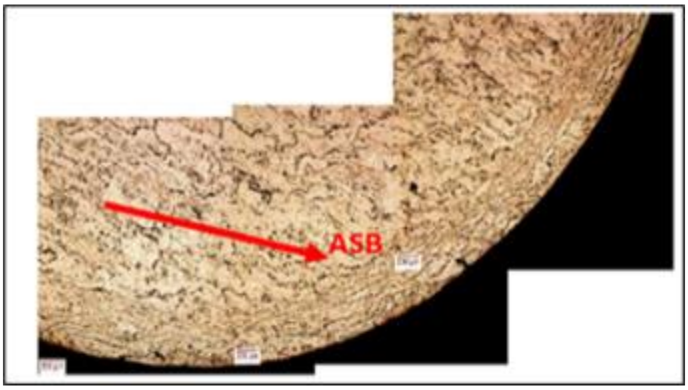


Figure 49 Adiabatic shear band formed at the circumference of the alloy at an impact pressure of 180kPa (C5) and magnification of X50

3.9. Microstructure of Compressed AA7055-T6 Temper Aluminium Alloy

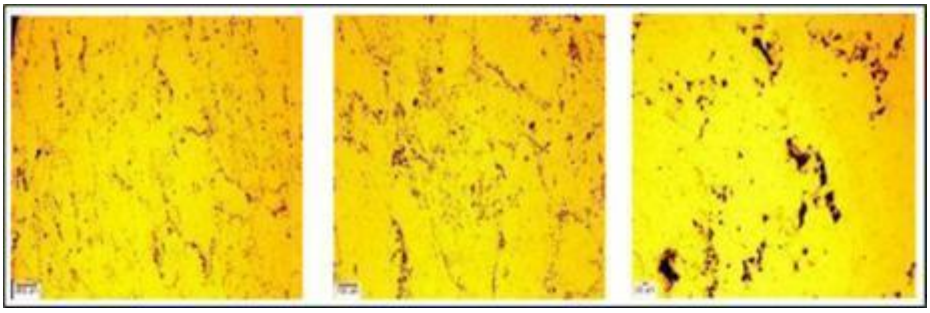


Figure 50 As received AA7055-T6 alloy at a magnification of X50, X100 and X500

The microstructure above Figure 50, shows fine grains with scarcely displaced microstructure at magnifications of X50, X100 and X500. The presence of large cracks can be seen in Figure 51. This is due to the applied load of 100kN. Also the deformed bands are seen at the circumference of the alloy and along the cracks.

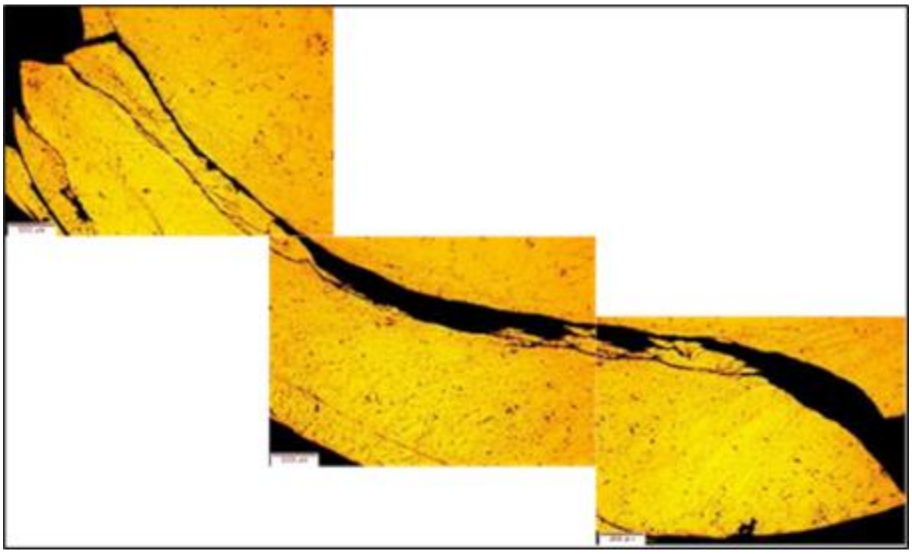


Figure 51 Compressed AA7055-T6 alloy at magnification of X50

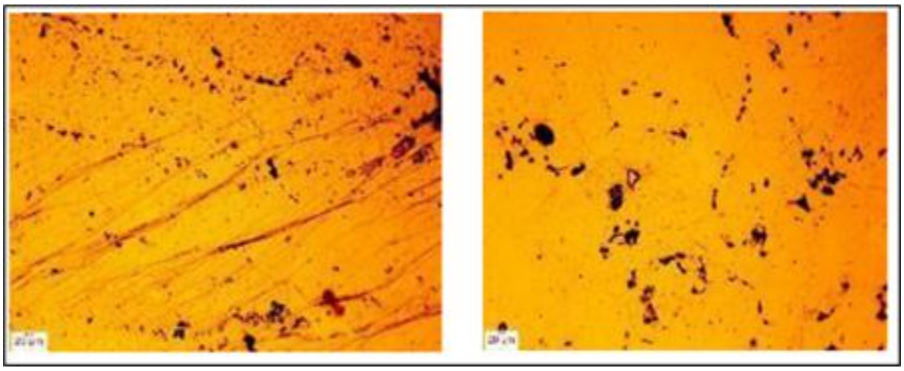


Figure 52 Microstructure of AA7055-T6 alloy at magnification of X500

In Figure 52 above, presence of metal flow can be seen in the microstructure in the first region and presence of scarcely populated second phase particles are shown in the second region.

3.10. The Microstructure Of Aa7055-T4 Temper Aluminium Alloy

In the microstructure below (Figure 53), the presence of second phase particles are non-uniformly dispersed and account for a large fraction of the microstructure. There are no signs of adiabatic shear band formed at an impact pressure of 100kPa and momentum of 32.0kg.m/s.

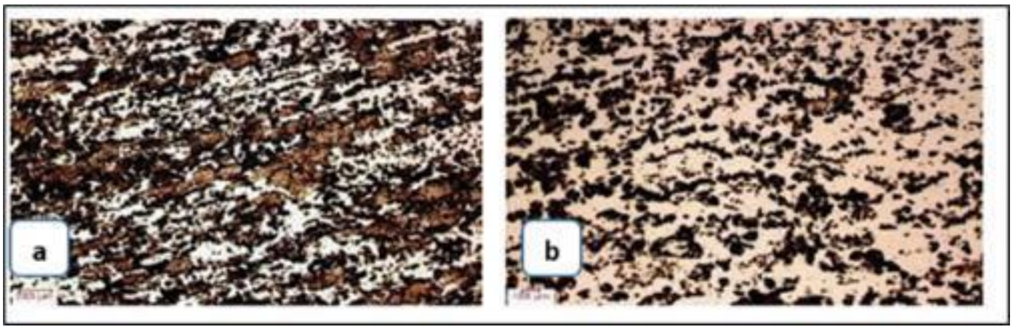


Figure 53 Microstructure at impact pressure of 100kPa X50 (B1) (b) at an impact pressure of 100kPa and magnification of X100 (B1)

In Figure 54, no formation of shear band is noticeable but significant second phase particles are shown as well as in the higher magnification.

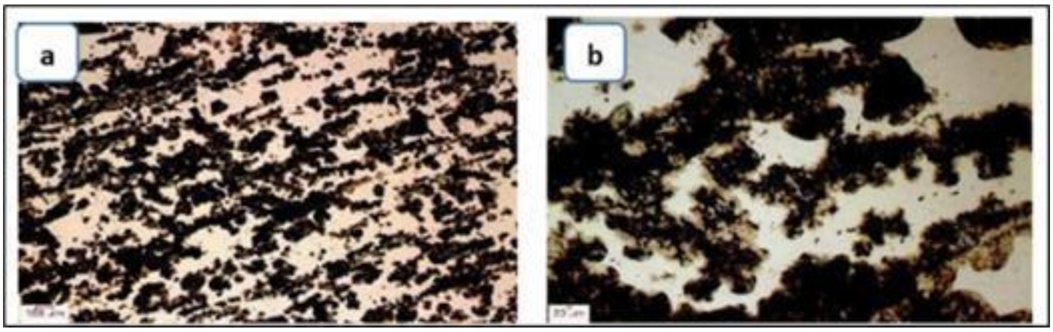


Figure 54 Microstructure at impact pressure of 120kPa at X100 (B2) (b) Impact pressure of 120kPa and magnification of X500 (B2)

In Figure 55, at an impact pressure of 140kPa and momentum of 38.20kg.m/s, microstructure is seen to have a higher concentration of particles that are closely packed at a magnification of X50 and X100.

Figure 55 Microstructure of AA7055-T4 alloy impacted pressure at 140kPa at a magnification of X50, X100 and X500 (B3)

Deformation occurs at an impacted pressure of 160kPa and momentum of 49.53kg.m/s, Figure 56 shows the section of the area outside the deformed band while the adiabatic shear band can be viewed from Figure 57.

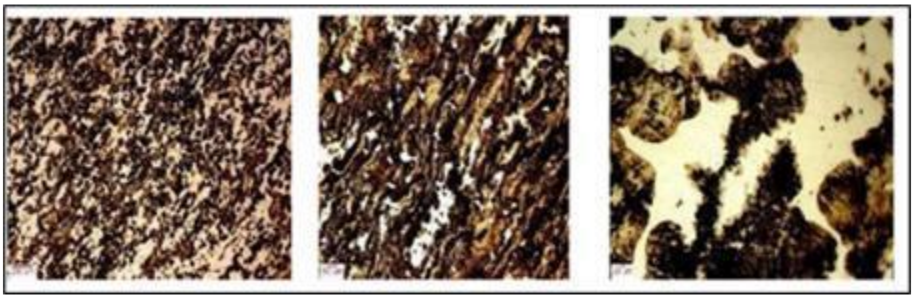


Figure 56 Microstructure of AA7055-T4 alloy impacted pressure at 160kPa at a magnification of X50, X100 and X500 (B4)

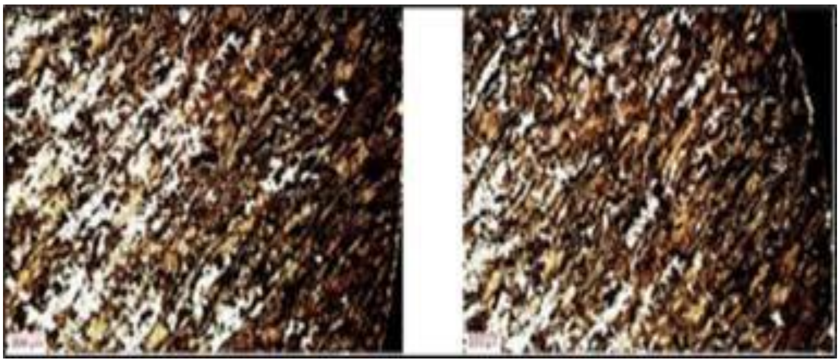


Figure 57 Shear band formed around the circumference of the AA7055-T4 alloy impacted at 160kPa at a magnification of X50 (B4)

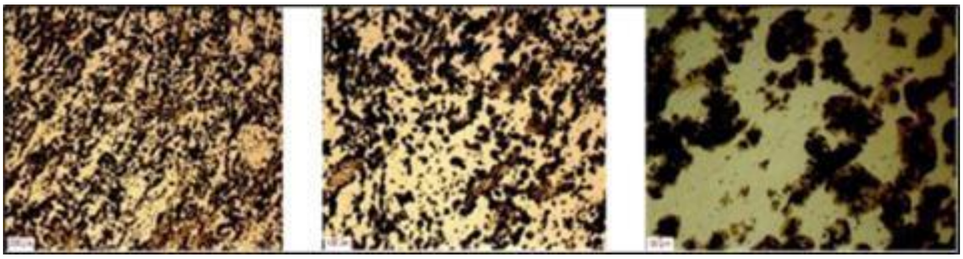


Figure 58 Microstructure of AA7055-T4 alloy at impacted pressure of 180kPa at a magnification of X50, X100, and X500 (B5)

In Figure 58, the alloy had an impact pressure of 180kPa and a momentum of 55.0kg.m/s

3.11. Microstructure of Compressed AA7055-T4 Temper Aluminium Alloy

In Figure 59, crack initiation can be seen to occur at the crack tip which propagates across the material. Also, deformation of the alloy is seen with a clear adiabatic shear band shown along the crack.

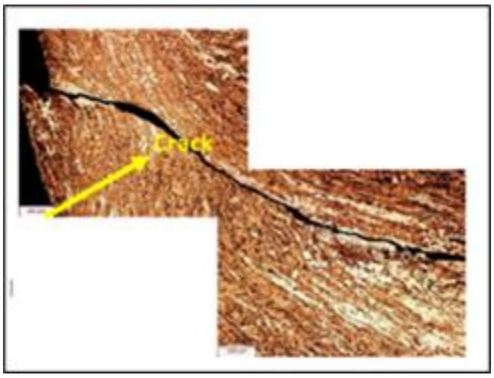


Figure 59 Crack formed at the tip and across the surface specimen at a magnification of X50

Figure 60 Microstructure of AA7055-T4 alloy showing deformed band at Magnification of X50, X100, X500

In Figure 60, deformation of the alloy can be seen in the microstructure as the concentration of the particles are closely packed.

3.12. Fractographic Images

It is known that the superior combination of properties of AA7055 aluminium alloy is largely determined by the stability, morphology as well as the chemistry of the strengthening precipitates. Mondal and Mukhopadhyay studied the phases in the as-cast and homogenized AA7055 alloy and revealed that the major residual phases were h($MgZn_2$), T($Al_2Mg_3Zn_3$), S(Al2CuMg) and θ(Al2Cu) [8]. These can be termed as the second phase particles present in the microstructure as stated in section 4.5, which enhances dislocation movement thereby strengthening the alloy. The following images of AA7055-T7751 alloy were observed with the JEOL JSM 6010LV Scanning Electron Microscope. The tempered alloy had an impact pressure of 200kPa and momentum of 36.23kg.m/s and strain rate of 1640/s at magnifications X4000, X500, and X50 as shown in Figure 61.

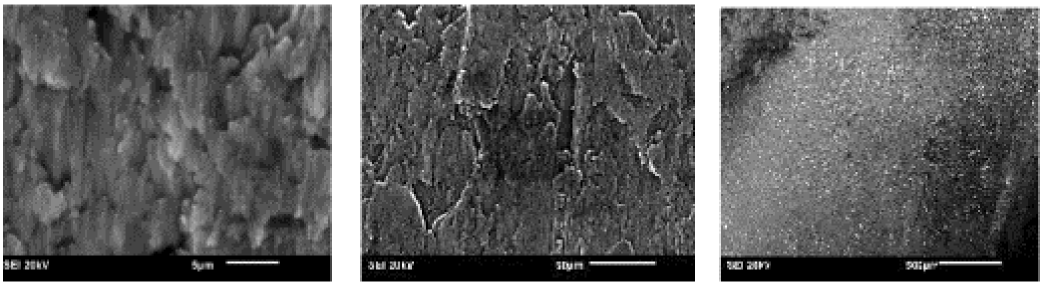


Figure 61 SEM images of AA7055-T7751 (AA6) inside cone at magnification of X4000, X500 and X50 respectively

The captured images for shear band formed inside the cone of the as received AA7055-T7751 alloy is shown in the magnifications of X4000, X500 and X50 below, Figure 62.

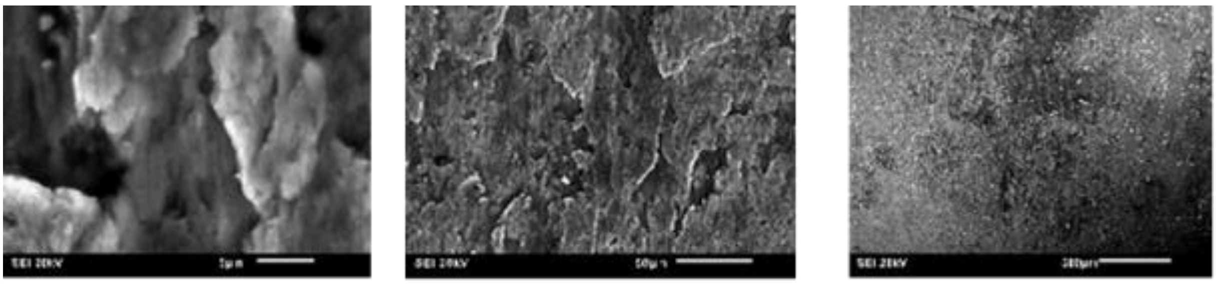


Figure 62 SEM images of AA7055-T7751 (AA6) outside cone at magnification of X4000, X500 and X50

The next specimen captured is the AA7055-T6 tempered alloy impacted at a pressure of 180kPa with a momentum of 54.7kg.m/s. The captured images are shown below for both inside cones (Figure 63) and outside cone structure (Figure 64).

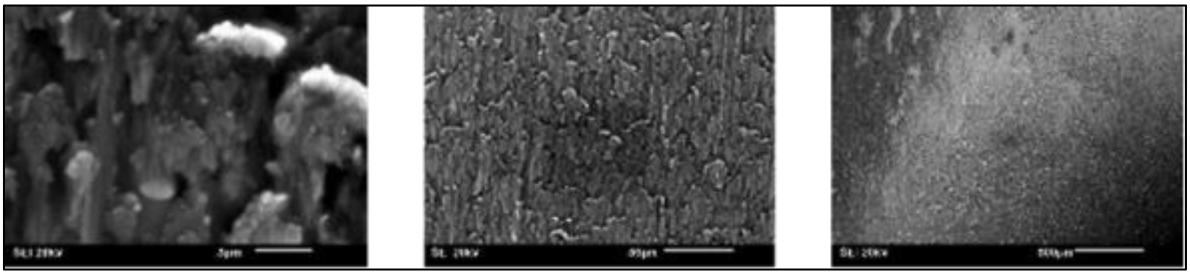


Figure 63 SEM images of AA7055-T6 alloy (CC5) inside cone at magnification of X4000, X500, X50 respectively

Images of the deformed T6 tempered alloy are observed outside the cone as shown below

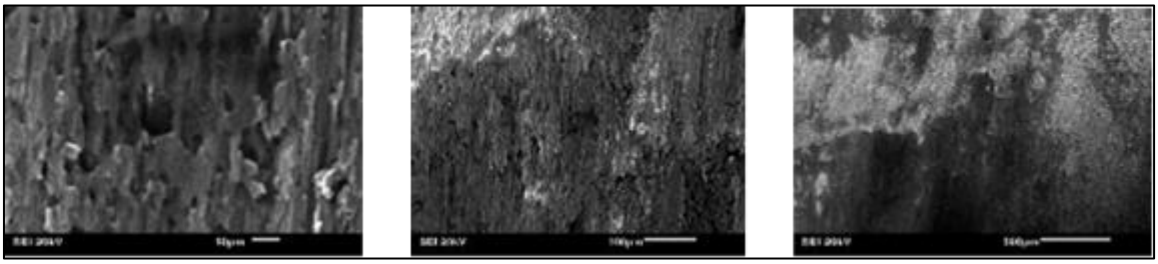


Figure 64 SEM images of AA7055-T6 alloy (CC5) outside cone at magnification of X4000, X500, X50 respectively

The other tempered alloy which is the AA7055-T4 was also captured. The alloy was impacted at a pressure of 180KPa and momentum of 55kg.m/s. Fracture images of the deformed band showing the inside of the cone fracture are shown for the AA7055-T4 tempered alloy below (Figure 65)

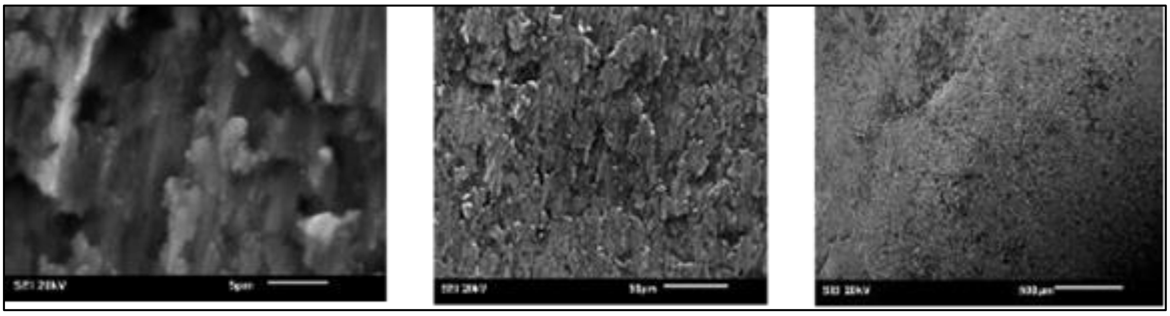


Figure 65 SEM images of AA7055-T4 alloy (B5) inside cone at magnification of X4000, X500 and X50 respectively

Images of the deformed T4 tempered alloy are observed outside the cone as shown below (Figure 66).

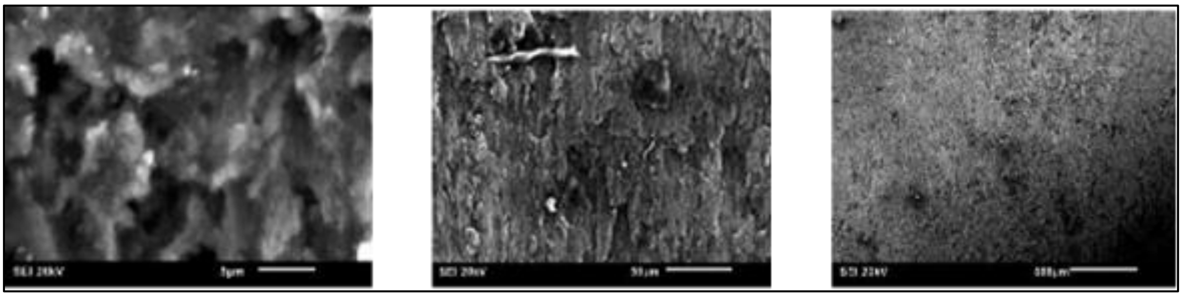


Figure 66 SEM images of AA7055-T4 alloy (B5) outside cone at magnification of X4000, X500, X50 respectively

4. Conclusion

Based on the results obtained from the Dynamic impact tests, using the Split Hopkinson's impact pressure bar, we can conclude as follows:

For as received AA7055-T7751 alloy, the maximum strength from the Engineering stress- strain graph is 822MPa with a maximum strain at 0.115 at a strain rate of 1400/s.

For AA7055-T6 Temper alloy, the maximum strength obtained from the stress-strain curve is 748.46MPa with a maximum strain at 0.131 at a strain rate of 1570/s.

For AA7055-T4 Temper alloy, the maximum strength obtained from the stress-strain curve is 640MPa with a maximum strain at 0.125 at a strain rate of 1500/s.

For the Compression test using the Instron testing machine, we have as follows:

- For as received AA7055-T7751 alloy, the maximum compressive strength is 1392MPa with a strain of 0.532
- For AA7055-T6 Temper alloy, the maximum compressive strength is 957MPa with a strain of 0.287
- For AA7055-T4 Temper alloy, the maximum compressive strength is 525MPa with a strain of 0.494

From the values above we could say that the two-step heat treatment resulted in an increase in the Strength of the T6 temper alloy in both the compressive strength test and the dynamic impact test than the T4 temper alloy that had a single step natural aging heat treatment.

Also the T6 temper alloy has a greater surface area in the Engineering Stress-strain curve as well as the compressive Stress-strain curve than the T4 temper alloy, indicating the ability to undergo large amounts of deformation. Hence, the toughness of the T6 alloy.

The T6 temper alloy also possesses the greater amount of strain in the Compressive test as well as the Dynamic impact test than the T4 temper alloy.

The AA7055-T7751 Aluminium alloy once impacted shows adiabatic shear bands formed around the circumference of the alloy with fine grain structure formed and few second phase particles present.

The T6 temper alloy possesses fine, uniformly dispersed grains and second phase particles at 100kPa. Deformed adiabatic shear bands occur from 120kPa through to impact pressure of 180kPa. Cracks are visible during the compression tests and as well as deformed shear bands acting along these cracks.

For the T4 Temper alloy, deformation occurred at impact pressure of 160kPa, presence of deformed shear band can be seen along the cracks formed during compression tests.

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