Fabrication of red mud particle reinforced AA5083 matrix composite by stir casting and evaluation of mechanical properties of the composite processed by ECAE

A thesis submitted in the partial fulfillment of the
Requirement for the award of the degree of
Bachelor of Technology
In
Mechanical Engineering
Submitted by

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ABSTRACT

Red mud particle reinforced AA5083 matrix composites with 5% weight fraction of red mud were fabricated by the most widely used stir casting technique. The composition of red mud and the aluminum alloy were determined using wet chemical methods. The fabricated composite was kept in a muffle furnace at 100^0C for about 24 hours to relieve the internal stresses and then it was processed by equi-channel angular extrusion through an angular die having a channel angle of 108^0. The billet was given four passes of extrusion and in route 'B'. The mechanical properties of the processed composite were determined after each pass. It has been observed that the yield strength is increased by about 120%, tensile strength by about 85%, hardness by about 50% and the elongation by about 50% after four passes of extrusion. Micro-structural observations were made and significant grain refinement was observed after four passes of ECAE.

Keywords: AA 5083, severe plastic deformation, Equal channel angular extrusion, Hardness, Tensile strength, Yield strength.

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1. INTRODUCTION

Carbon and low-alloy steels are not resistant to corrosion attack in aggressive environments such as seawater. They need a proper surface protection as painting or other type of coatings which should be regularly repeated. On the other hand, aluminum corrodes over 100 times slower than the carbon steels. The excellent corrosion resistance of aluminum originates from the tightly bonded oxide film formed on the surface when it is exposed to air or water. Strength, toughness is one of the most salient attributes of most of the metallic structures. Nano structured aluminum alloys will possess low toughness transition temperatures and hence can be used as a replacement of structural steels. This demand has led to the introduction of various strengthening techniques. Most of these techniques are based on microstructure refinement by plastic deformation. Metal working processes like drawing, rolling and extrusion play a significant role in industry for strengthening of metals and alloys. However, these techniques may not be sufficient for producing materials with preferred properties and/or geometry. Hence, new processing techniques are developed to obviate these problems, called severe plastic deformation (SPD) techniques. Besides high strength, hardness, long fatigue life, good super plastic properties, the ability of producing ultra-fine grained (UFG) microstructures has gained a lot of research interest. One of the popular SPD approaches which can generate UFG microstructure in billet or rod specimens, with no change in the primary geometry, is equal channel angular pressing (ECAP).

1.1. ALUMINIUM:

Aluminium is the most abundant metal in the Earth’s crust (8.1%) but is rarely found uncombined in nature. It is usually found in minerals such as bauxite and cryolite. These minerals are Aluminium Silicates.

Most commercially produced Aluminium is extracted by the Hall–Heroult process. In this process Aluminium oxide is dissolved in molten cryolite and then electrolytically reduced to pure Aluminium. Making Aluminium is very energy intensive. 5% of the electricity generated in the USA is used in Aluminium production. However, once it has been made it does not readily corrode and can be easily recycled.

PROPERTIES:

- It is the 3rd most abundant element in the earth's crust.
- It has low density 2.7 g/c.c.
- It has high thermal and electrical conductivities.
- It is non-magnetic and non-sparking.
- It is non-soluble in alcohol and water.
- It is easy to cast.
- It has corrosion resistance due to the formation of the passive layer on the surface.
- It exhibits ductile nature.

ALUMINIUM ALLOYS:

Aluminium alloys are alloys in which Aluminium (Al) is the predominant metal. The typical alloying elements are copper, magnesium, manganese, silicon, tin and zinc. There are two principal classifications, namely casting alloys and wrought alloys, both of which are further subdivided into the categories heat-treatable and non-heat-treatable. About 85% of Aluminium is used for wrought products, for example rolled plate, foils and extrusions. Cast Aluminium alloys yield cost-effective products due to the low melting point, although they generally have lower tensile strengths than wrought alloys. The most important cast Aluminium alloy system is Al–Si, where the high levels of silicon (4.0–13%) contribute to give good casting characteristics. Aluminium alloys are widely used in engineering structures and components where light weight or corrosion resistance is required.

1.2 CLASSIFICATION:

Aluminium alloys are classified according to their respective composition as shown in the below figure.

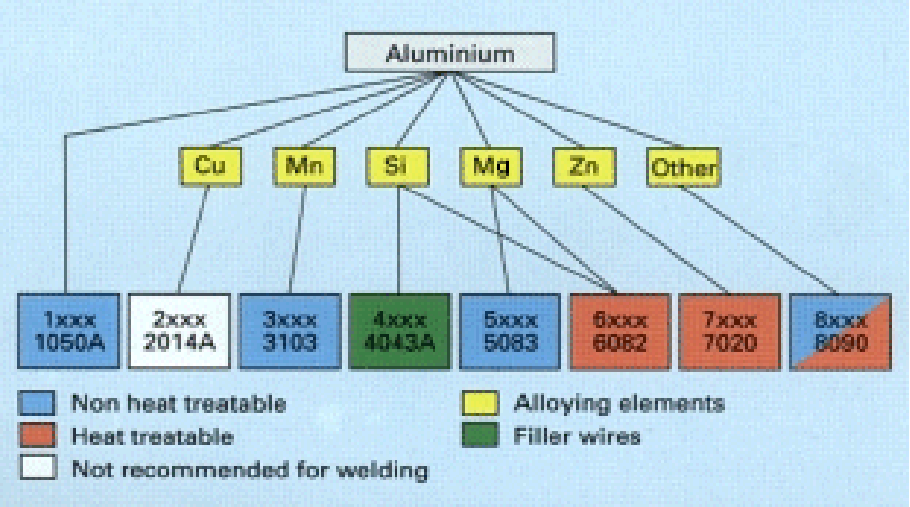


Figure 1.2.1: Classification of Aluminium alloys

Among them 6xxx series occupies a significant role due to their vast applications. The production of the alloys is also cheap. The composition of 6xxx will varies according to the required application.

Aluminium 5xxx series - Aluminum-Magnesium alloy.

Characteristics:

(a) High strength to weight ratio.

(b) Good formability, machinability and weld-ability.

(c) Good corrosion resistance

Applications: 1. Building & Construction,

2. Freight cars,

3. Marine components,
4. TV towers,
5. Drilling rigs,
6. Dump truck bodies.

The major alloying element in 5*xxx* series alloys is magnesium. When it is used as a major alloying element or with manganese, the result is a moderate-to-high-strength work hardenable alloy. Magnesium is considerably more effective than manganese as a hardener, about 0.8% Mg being equal to 1.25% Mn, and it can be added in considerably higher quantities. Alloys in this series possess good welding characteristics and good resistance to corrosion in marine atmospheres. However, certain limitations should be placed on the amount of cold work and the safe operating temperatures permissible for the higher-magnesium alloys (over ~3.5% for operating temperatures above ~65 °C, or 150 °F) to avoid susceptibility to stress-corrosion cracking.

The aluminum-magnesium alloys in the 5*xx.x* group are essentially single-phase binary alloys with moderate-to-high strength and toughness properties. High corrosion resistance, especially to seawater and marine atmospheres, is the primary advantage of castings made of Al-Mg alloys. Best corrosion resistance requires low impurity content (both solid and gaseous), and thus alloys must be prepared from high-quality metals and handled with great care in the foundry. These alloys are suitable for welded assemblies and are often used in architectural and other decorative or building needs. Aluminum-magnesium alloys also have good machinability and an attractive appearance when anodized.

ALUMINIUM 5083:

Aluminium 5083 is known for exceptional performance in extreme environments. 5083 is highly resistant to attack by both seawater and industrial chemical environments. Alloy 5083 also retains exceptional strength after welding. It has the highest strength of the non-heat treatable alloys but is not recommended for use in temperatures in excess of 65°C

.**Applications**: Alloy 5083 is typically used in

1. Shipbuilding Rail cars
2. Vehicle bodies
3. Tip truck bodies
4. Mine skips and cages

Aluminium Alloy 5083 temper types: The most common tempers for 5083 aluminium are:

1. O – Soft
2. H111 - Some work hardening imparted by shaping processes but less than required for H11 temper
3. H32 - Work hardened by rolling then stabilized by low-temperature heat treatment to quarter hard.

1.3. SEVERE PLASTIC DEFORMATION

Since the pioneering work of Hall and Petch, material scientists and engineers have been attracted by materials with small grain sizes. A finer grain size increases the strength and the fracture toughness of the material and provides the potential for super plastic deformation at moderate temperatures and high strain rates. Traditional thermo-mechanical processes and generally leads to a grain size above 10μm or, exceptionally, a few microns in diameter. However, several techniques to obtain submicron or Nano-size grains are now available, e.g. vapor deposition, high-energy ball milling, fast solidification and severe plastic deformation (SPD).

Materials processing by severe plastic deformation (SPD) have received vast focus in the research community the last five to ten years due to the unique physical and mechanical properties obtainable by SPD processing. The process of SPD is based on intense plastic deformation of a work piece, resulting in alteration of the microstructure and texture, in principal reduction of the grain size to the sub-micron or the nanometer scale.

During the last decade of the 20thcentury the expression Severe Plastic Deformation (SPD) came into use to designate a technology able to promote profound changes on the microstructure and properties of metals and alloys. The most important effect of any SPD process is an accentuated grain size reduction that leads to substantial strength increase.

Grain refinement by severe plastic deformation implies the creation of new High Angle Grain Boundaries (HAB). This can be accomplished by three mechanisms. The first is the elongation of existing grains during plastic deformation, causing an increase in high angle grain boundary area. The second is the creation of high angle boundaries by grain subdivision mechanisms. Finally an elongated grain can be split up by a localization phenomenon such as a shear band.

The great majority of articles dealing with SPD are on microstructural evolution and grain size reduction mechanisms, mechanical properties, functional properties, such as superplasticity and hydrogen storage, deformation and annealing textures, and ductilization mechanisms.

Metals and alloys subjected to SPD processing are known as ultrafine – grained materials, and are customarily classified as:

- Nanometric - those having grains size in the range 10-100 nm;
- Sub-micrometric or ultra-fine-grain size below 1000 nm.

1.4. INTRODUCTION TO EQUAL CHANNEL ANGULAR PRESSING

1.4.1. General introduction to Equal Channel Angular Pressing

The most common process of SPD is the equal channel angular pressing (ECAP), which involves pressing a billet through a die consisting of two channels of equal cross sections, intersecting at an angle, typically 90°. The process of ECAP allows us to introduce very large plastic deformations to a work-piece without altering the overall geometry of the work-piece. In the present thesis, the ECAP process has been applied to a commercial 6xxx series Aluminium alloy.

The ECAP process was first developed by V.M. Segal in the former USSR in 1977. This is a process employed to realize a "near ideal" deformation to the material. In 1950 A. Nadai realized that pure shear is the "ideal" deformation for extrusion and drawing. With the ECAP method one can have a "near ideal" deformation by simple shear in the system. The tool is a block with two intersecting channels of identical cross-section. A well lubricated billet of the same cross-section is placed into one of the channels, and a punch then presses it into the second channel. Under these conditions the billet will move as a rigid body, and deformation is achieved ideally by simple shear in a thin layer at the crossing plane of the channels. When the punch is finished it is retreated and the billet has been uniformly deformed, except for a small zone in the lower part of the sample and in the end regions.

Equal Channel Angular Pressing (ECAP) possesses the largest application potential due to the feasibility of scaling the product up to commercial dimensions.

During ECAP - deformation, the sample transverse section is unchanged, thus permitting an infinite number of pressings or passes, N (in practice N is between four and eight). Another advantage is the sheer simplicity of the equipment, composed only of one press and a die, plus load recording and deformation speed control instrumentation.

1.4.2. Equal Channel Angular Pressing as a Technology

Die design

Figure 2 shows the channel geometry and highlights its two most important parameters:

- **Φ angle:** defined at the channels´ intersection; in most cases its value is set at 120° or 90° and is a parameter exerting a very strong influence on the deformation level;
- **Ψ angle:** as shown in Figure 2, it derives from the curvature radii: R (external) and r (internal radius).

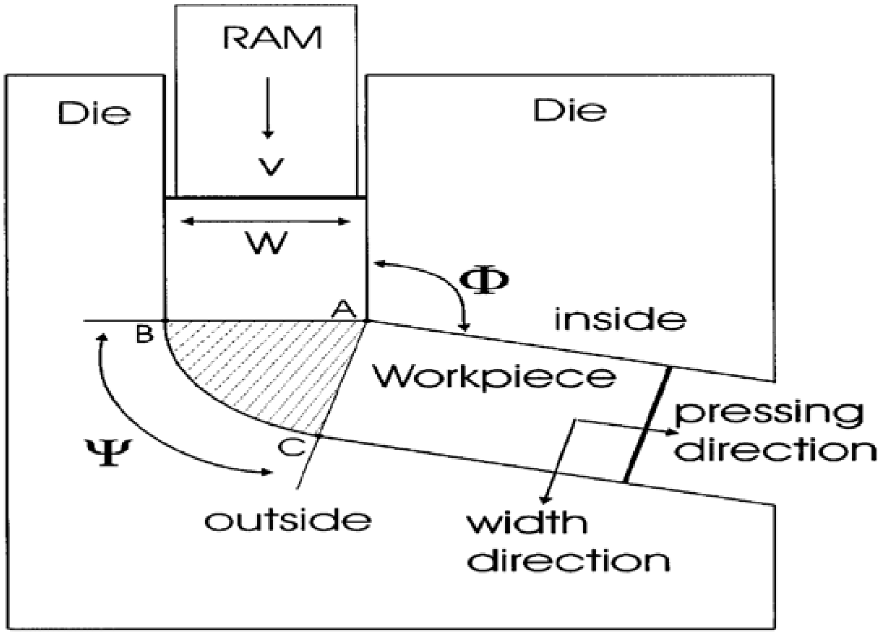


Fig. 1.4.1: Die design and channel angles

A schematic illustration of the equal channel angular pressing set-up showing the die channel angle (Ψ) geometry, the plunger used to press the material (RAM), the pressing direction (V), the width of the material (W) and the pressing and width direction.

The ECAP die is composed of two channels with identical rectangular cross sections connected through the intersection at a specific angle, usually 90°.The cross section can also be circular or square. The work piece is machined to fit within the channel and extruded through two intersecting channels with the same cross section using a plunger (Figure 1). During the ECAP process, adequate lubrication is essential because of frictional influences, tool wear and the loads necessary for plastic deformation. One important advantage of the ECAP process is that it can be repeated several times without changing the dimensions of the work piece, and the applied strain can be increased to any level; these advantages mean that the severe strains that can be applied and a simple shear deformation mode contribute to the strong and unusual properties of the material produced.

1.4.3. Factors that influence grain refinement in ECAP

Channel and curvature angles of the die

The channel angle is the most significant experimental factor that affects grain refinement because it dictates the total strain imposed in each pass. Most of the experimental work reported to date used channel angle values from 90° to 120° and there has been little or no attempt to compare the results obtained when using dies with different channel angles. Despite the efficiency of the ECAP process with dies that have channel angles of 90°, it is experimentally easier to press billets when using dies with angles that are larger than 90° for very hard materials or for materials with low ductility.8 It has been reported that it is difficult to press commercially pure tungsten through a die with a channel angle of 90° at a high temperature of 1273 K because of cracking in the billets. However, excellent results were achieved at the same pressing temperature when the channel angle was increased to 110° to 120°.

The angle of curvature denotes the outer arc where the two parts of the channel intercept within the die. Valiev reported that the most promising approach was to construct a die with a channel angle of 90°, an outer angle of curvature of 20° and no arc of curvature at the inner point of intersection of the two parts of the channel. Figure 1.4.3.1 shows the schematic illustrations of the die used to evaluate the influence of the channel angle.

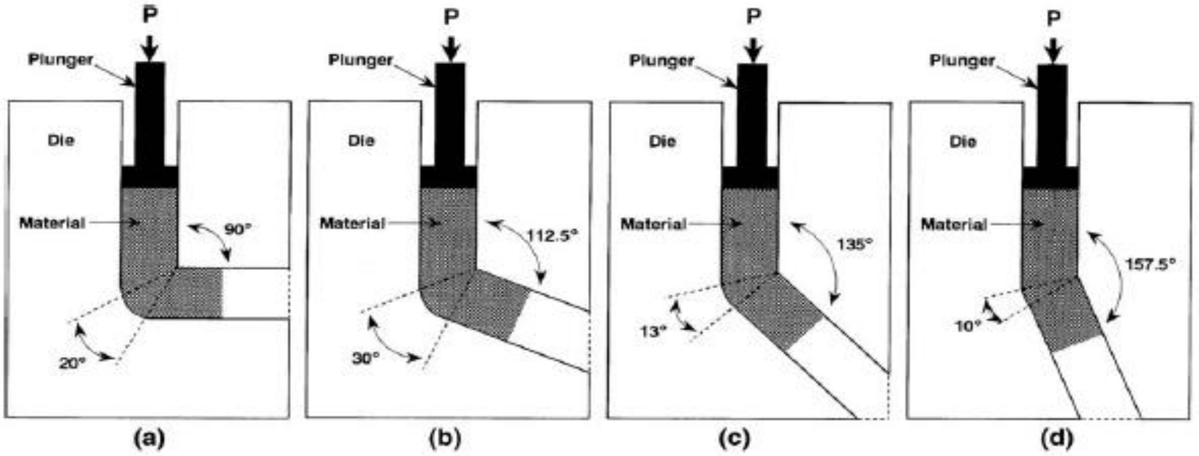


FIGURE 1.4.3.1: Schematic illustrations of the die used to evaluate the influence of the channel angle: (a) 90° (b) 112.5° (c) 135° and (d) 157.5°.

ECAP has become the most frequently used SPD process due to its low force requirement (small press can be used) and the resulting low tool pressure. This together with the simple tool geometry makes laboratory tooling easily attainable. In many laboratories the researchers found ECAP method as convenient tool to investigate the relationship between the strain applied and structure development.

ECAP method does not involve high pressure which is advantageous from the machine and tooling point of view. This may turn into a disadvantage when processing brittle materials. Even ductile materials may require a bit higher pressure to avoid damage accumulation and substantially reduced ductility in further metal forming operations. It is possible to process brittle materials at a smaller pressure provided the temperature is high enough. ECAP is a low-force process by nature. Nevertheless, reducing the amount of deformation in one pass, reducing friction by leaving a clearance between the billet and the die and increasing process temperature may be necessary.

1.5. INTRODUCTION TO HARDNESS

Hardness is a measure of the resistance to localized plastic deformation induced by either mechanical indentation or abrasion. Some materials (e.g. metals) are harder than others (e.g. plastics). Hardness is dependent on ductility, elastic stiffness, plasticity, strain, strength, toughness, viscoelasticity and viscosity.

Macroscopic hardness is generally characterized by strong intermolecular bonds, but the behavior of solid materials under force is complex; therefore, there are different measurements of hardness: scratch hardness, indentation hardness, and rebound hardness. Only indentation hardness is of major engineering interest for metals.

Indentation hardness measures the resistance of a sample to material deformation due to a constant compression load from a sharp object; they are primarily used in engineering and metallurgy fields. The tests work on the basic premise of measuring the critical dimensions of an indentation left by a specifically dimensioned and loaded indenter. Common indentation hardness scales are Rockwell, Vickers, Shore, and Brinell.

Vickers Hardness:

Vickers Hardness is a very popular test, which is characterized by a square based diamond pyramid indenter, exactly ground to a standard form with **136^0** between opposite faces and used to leave a mark in metal under a precisely applied force by taking care to avoid impact. The diagonals of the impression have to be measured using a suitable microscope and the results are calculated using a given formula. The 136^0 angle is chosen because it corresponds to the most desirable ratio of the indentation diameter to the ball diameter of 0.375 mm in the Brinell hardness test.

The values found are designated by HV for Hardness Vickers, followed by the force (load) in kg, or by DPH which means Diamond Pyramid Hardness and sometimes with the number of seconds when the load was applied. Commonly used loads are **5, 10, 30 and 50 kg**, but the range can be enlarged if necessary. The load selected for a given test piece should be as large as possible, with due consideration for the dimensions of the test piece, the relative hardness of the material and the purpose of the test. For case hardened components loads ranging between 1 and 2.5 kg are suitable whereas for most of the other materials loads from 10 to 40 kg are suitable. For cast irons and cast components higher loads are desirable, if an overall average hardness of a heterogeneous structure is to be measured. In theory the hardness number should be independent of the force used, but in practice, as differences can be found, one must always report the load used.

The hardness tester is semi-automatic in operation in which after the specimen surface is brought close to the indenter the pre-set load is applied for some definite tie and the load is removed automatically. The loads are slowly applied to avoid errors due to inertia effects. The time of load application and load duration can be controlled and is between 10 and 30 seconds after an impression has been made on the test surface, the diagonals of square impression by special microscope. Alternatively, the impression can be projected at a magnified scale on a focusing screen and the diagonals can be measured. From the measured diagonal, area of indentation can be calculated.

The formula used for calculating the Vickers Hardness Number (or Diamond Pyramid Hardness) is as follows:

Vickers Hardness Number (VHN) = (1.8544 * P)/ d^2,

where **P** = force (load) in kilograms, **d** = diagonal length of the impression in mm (millimetres) (or, better, average of two readings).

This hardness number is called Vickers Pyramid Number (VPN) or Diamond Pyramid Hardness (DPH).

For Vickers hardness testing the surface should be smooth and free from oxide, dirt and defects because the impressions are very small. High level polish is recommended. If the test surface is not parallel to the bottom surface, the impressions will not be perfectly square and under this situation both the diagonals should be measured and hardness should be found out the average diagonal length.

The minimum thickness of the test piece will depend on the hardness of the metal and the magnitude of the load applied. It is recommended that the thickness of the piece should be at least 1.5 times the diagonal of the impression. Maximum three readings should be taken and the average value should be reported.

It is therefore similar to the Brinell test, but although overlapping, the typical applications are different: therefore Vickers should not be used for cast iron which has a non uniform structure, because the impression tends to be small, and unable to give a true average. The smaller impression requires a smoother surface, to be read accurately.

Vickers hardness is applicable to soft and hard materials, to thick and thin specimens. There is no danger to deform the indenter during normal operation, but sharp blows must be avoided because diamond tip could break and then give erroneous results. Minimum thickness of at least ten times the depth of the indentation is to be observed, but it is easier to reduce it, simply by selecting a lighter load. As usual no marks should be seen on the opposite surface.

Many different types of Vickers hardness testers exist, from different manufacturers. As with any precision instrument, the equipment should be regularly maintained following the instructions, and the tip of the pyramid should be examined under a microscope at regular time intervals.

ADVANTAGES OF THE TEST:

- The impressions are small because of the small size of the indenter. This does not damage or reduce the life of the component. Hence this test is suitable for finished components.
- Since the indenter is made of the diamond, it does not deform during testing of hard materials.
- For any load of testing, the contact angle remains the same 136^0 because of pyramidal geometry of indenter (and no deformation of indenter).

For completeness we shall note that for testing very thin specimens or layers, (or even single crystals or phases in a microstructure). A similar method has been standardized which employs very light forces (loads) (from 1 g to 1 kg).

It should be understood that these microhardness values cannot be interchanged with regular Vickers Hardness values and that they do not represent bulk hardness of sizeable chunks of materials.

1.6. INTRODUCTION TO COMPRESSION TESTING MACHINE

Theoretically, compression test is merely the opposite of the tension test with respect to the direction of applied stress. The compression test can be done on the same machine on which the tension test is done like universal testing machine or some other machine which is designed specifically for the purpose. In general, brittle materials are good in compression than in tension and therefore, they are used for compressive loads. Due to this, compression test is mainly used to test brittle materials such as cast irons, concrete, stones, bricks and ceramic products. During testing, fracture occurs in brittle materials and therefore, the ultimate strength id found out for some arbitrary amount of deformation. It has been observed that some errors are always bond to come in the compression test due to the following practical difficulties.

- Since the top and bottom faces of the specimen are seldom perfectly parallel to each other and there is always a tendency for bending of the specimen during testing, it is very difficult to apply truly axial loads.
- The friction between the ends of the specimen and heads of the testing machine prevent the deformation of the specimen uniformly throughout the length. This results in more lateral expansion in the central region than the other regions giving barrel like shape to the specimen.
- Since the length is kept short enough (not more than twice its diameter) to avoid its buckling, it is difficult to obtain strain measurements accurately.
- For a constant length to diameter (L/D) ratio, length can be increased with proportionate increase in diameter. However, for testing large diameter specimens, high capacity testing machines are required.

The test specimens can be square, rectangular or circular in cross section: but circular section is preferred for uniform application load. The length to diameter (L/D) ratio is between 1.5 and 1.0 for different materials but a ratio of 2 is commonly employed. For longer (i.e. L/D > 10) beading is more which reduces the compressive strength and for shorter specimens (i.e. L/D < 10) frictional effects at the ends become more important which increases the compressive strength.

1.7. MICROSTRUCTURAL ANALYSIS

Microstructures of the composite samples were observed under computerized optical microscope. Success in microscopic study depends largely upon the care taken in the preparation of the specimen.

2. LITERATURE REVIEW

Metal matrix composites are advanced materials resulting from a combination of two or more materials in which tailored properties are realized. However the ductility of the MMCs deteriorates with high ceramic particle concentration (Akio et al., 1999). The particulate reinforced aluminium matrix composite are gaining importance because of their low cost with advantages like isotropic properties and the possibility of secondary processing facilitating fabrication of secondary components. The particulate composite can be prepared by injecting the reinforcing particles into liquid matrix through liquid metallurgy route by casting. Casting route is preferred as it is less expensive and amenable to mass production. Among the entire liquid state production routes, stir casting is the simplest and cheapest one.

Red mud is a residue or solid waste of bauxite processing for the production of alumina and it mainly consists of alumina, iron oxide, silica, calcium oxide, titania and trace components of gallium and scandium. Generally 1-1.5 tons of red mud is generated for every ton of alumina and due to its caustic nature, it poses a major environmental problem such as unsightly, undesirable and a non-productive use of land resources, as well as posing a non-going financial burden through their long-term maintenance. Therefore, utilization of red mud will produce significant benefits in terms of environmentally and economically by reducing landfill volume, contamination of soil and ground water, and release of land for alternative uses. Hence, an attempt is made to explore the use of red mud as a reinforcement phase in MMNCs.

Aluminium composites have emerged as advanced materials for applications like aerospace, automobile, defence and other engineering fields. Wear behaviour of aluminium matrix composite was studied by Rosenberger et al. in which the matrix alloy AA6061, was reinforced with Al2O3, B4C, Ti3Al and B2Ti in volume fraction ranging from 5% to 15%. Sudarshan and Surappa studied the wear behaviour of Al-fly ash composite and have reported that the composite has shown better wear resistance compared to unreinforced alloy upto a load of 80N and fly ash particle size and its volume fraction significantly effect the wear and friction properties of composites.

M.H. Shaeria, M.Shaerib, M.T.Salehic, S.H.Seyyedeinc, M.R.Abutalebic have studied the effect of aging treatment on microstructure and mechanical properties of equal channel angular pressed Al-7075 alloy was examined. Commercial Al-7075 alloy in the solid solution heat-treated condition was processed by Equal Channel Angular Pressing (ECAP) through route BC at both the room temperature and 1200C. Only three passes of ECAP was possible due to the low ductility of the alloy at both temperatures. Followed by ECAP, the specimens have been aged at1200C for different aging times. Mechanical properties were measured by Vickers microhardness and tensile tests and microstructural observations were undertaken using transmission electron microscopy, X-ray diffractometer as well as optical microscopy. Microstructural investigations showed that ultrafine-grained materials with grain size in the range of 200–350 nm and 300–500 nm could be obtained after three passes of ECAP at room temperature and1200C, respectively. ECAP of solid solution heat-treated Al-7075 alloy accelerates precipitation rate and subsequently leads to a significant decrease in aging time to attain maximum mechanical properties.

Bert Verlinden et al., studied and discussed all the main methods to produce Severe Plastic Deformation (SPD) materials. The mechanisms leading to the formation of fine grains are reviewed and the influence of changes in strain path is highlighted. During post-SPD thermal annealing, some typical microstructural changes take place. The influence of SPD and subsequent annealing on strength, ductility and superplastic properties are reviewed. Finally a short overview of fatigue resistance and corrosion properties of those materials is carried out.

J. Zrnik, S. V. Dobatkin, I. Mamuzi,Reviewed historical development of SPD processes and their effect at obtaining fine crystalline structure, and on the other side also partially focused on development of UFG structure and its stability in commercial pure aluminium as a function of strain and post-deformation annealing applied. Go Horikiria, Tsubasa Kitazumia, Keiko Natorib, Tatsuya Tanakac have worked with the formability of high strength aluminum alloys (extra super duralumin 7075), by focusing on two methods, semi-solid casting and Equal-Channel Angular Pressing processing. Reported observations of effect of subsequent aging treatment to Equal-Channel Angular Pressed semi-solid cast AA7075. As a result, tensile strength and total elongation of semi-solid AA7075 was improved with increasing number of pressed processing pass and subsequent T6 heat treatment contributed to further improvement. T6 heat treated 4pass pressed modified AA7075 had lower tensile strength, higher total elongation, and higher toughness than wrought AA7075-T6.

G.I.P. De Silva1, W.C. Perera1 haveInvestigated the improvement of the mechanical properties of the Aluminium 6063 T5 extrudates by varying the aging condition. Aluminum 6063 T5 is artificially age hardened alloy contains magnesium (0.45-0.9%) and silicon (0.2-0.6%) as the main alloying elements. Age hardening process is used to harden this alloy by forming second phase particles of Mg2Si. Focused mainly on the enhancement of properties like hardness and strength of Aluminum 6063 T5 extrudates and increase in the production rate while keeping the cost effectiveness. Two step age hardening treatment is going to be developed as a substitution for existing single step age hardening treatment applied in local industry to reduce the total time period and temperatures while improving the mechanical properties.

3. EXPERIMENTAL WORK:

3.1 Chemical composition:

Commercially available AA 5083 alloy is procured from Hyderabad and its chemical composition is determined by wet chemical analysis. Its composition is furnished in Table3.1

S. No.	Element	Weight percent
1	Si	0.4
2	Fe	0.4
3	Cu	0.1
4	Mn	0.4-1.0
5	Mg	4.0-4.9
6	Zn	0.25
7	Ti	0.15
8	Cr	0.05-0.25
9	Al	Balance

Table 3.1: Chemical composition of AA 5083 alloy

Redmud is a solid waste occurs in tonnes from alumina manufacturing industries and the redmud used in the present investigations is obtained from NALCO Bhubaneswar. Its chemical composition is determined and the same are reported in table 3.2.

SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	SO_3
44.8	22.2	24	0.8	1.8	0.9	0.9	2.4	1.4

Table 3.2: Chemical composition of Red Mud

3.2 Fabrication of the composite:

AA 5083-5 wt% red mud composites were synthesized by stir casting technique. AA5083 was taken into a graphite crucible and melted in an electric furnace. After maintaining the temperature at 760°C, a vortex was created using mechanical stirrer made of graphite. While stirring was in progress, the preheated red mud particulates were introduced. Care was taken to ensure continuous and smooth flow of the particles addition in the vortex. The molten metal was stirred at 400 rpm under argon gas cover; stirring was continued for about five minutes after addition of red mud particles to get the uniform distribution in the melt. During stirring small pieces of magnesium (0.5 wt. %) were added to the molten metal to enhance the wettability of red mud particles with melt. The melt with the reinforced particulates were bottom poured into preheated metal mould while stirring was in progress. The stir casting furnace used in the present research and the composites fabricated are shown in figures 3.1 and 3.2 respectively.

Fig 3.1 Stir casting furnace

3.3 **Equi-channel angular extrusion**:

AA 5083 matrix composite reinforced with 5 wt% redmud is considered as the work material in this study. Square rods obtained from stir casting are sectioned and were polished to improve the surface finish so as to reduce the coefficient of friction during ECAE. The ECAE die used in this study had a channel angle of 108° as shown in Figure 3.3. Molybdenum disulfide (MoS_2) lubricant, in grease form, was applied to the billets. The composites were extruded in route B for four cycles at room temperature as illustrated in Figure 3.4. All ECAE passes were conducted at a pressing velocity of 2 mm/s. The extruded billets after the fourth pass are shown in Figure 3.2.

Fig.3.2: Composite

3.4 Micro-structural studies:

Micro-structural evolution was performed on the sectioned surfaces of as-received and extruded billets using a Carl Zeiss Neon 40 cross-beam field emission scanning electron microscope (FE-SEM) with 1·1nm resolution. The micro-hardness measurements were also measured on the same surfaces at a load of 200 g for a dwell period of 15s.To fully understand how the SEM can be used for micro-structural analysis, a brief discussion of the principles of the SEM appears required. It has been shown in the past that a transmission electron microscope is quite similar to a biological-type light microscope in that they both contain a light source, an objective lens, a projector lens system, and an image recording system (a fluorescent screen or the retina of one's eye). Also, the illuminating system (light or electrons) passes through the sample being studied, and the contrast of the image occurs by absorption or diffraction of the photons or electrons in the sample. The SEM functions quite differently. In the SEM there is really only one lens system (corresponding to a condenser lens) which focuses electrons emitted from the electron gun to a fine spot on the surface of the sample being examined. As the name implies, in the SEM the primary electron beam is scanned, or deflected, in a raster on the sample. This is accomplished by "X" and "Y" deflection plates which are placed on opposite sides of the beam. When the primary electron beam strikes the surface of the sample, its energy is converted into many different forms. It is these energies which can be used in various ways to obtain information about microstructures. A certain amount of the energy of the primary beam is converted into secondary electrons, i.e., electrons which are excited within the specimen by the higher energy primary electron. Although many of us consider the SEM as a metallographic tool, its use for examining and interpreting microstructures has really been quite limited. This is rather strange, since much of its use has been for topographic studies and, p.ven in light microscopy, microstructures are usually revealed, after polishing and etching, because of topographic differences between the various phases or features.

3.5 Determination of mechanical properties:

The hardness of the composites processed by ECAE are determined using vickers hardness tester. After each ECAE process four hardness measurements were taken and their average is considered. The hardness tester used in the present work is depicted in figure 3.3

Fig 3.3: Vickers Hardness Tester

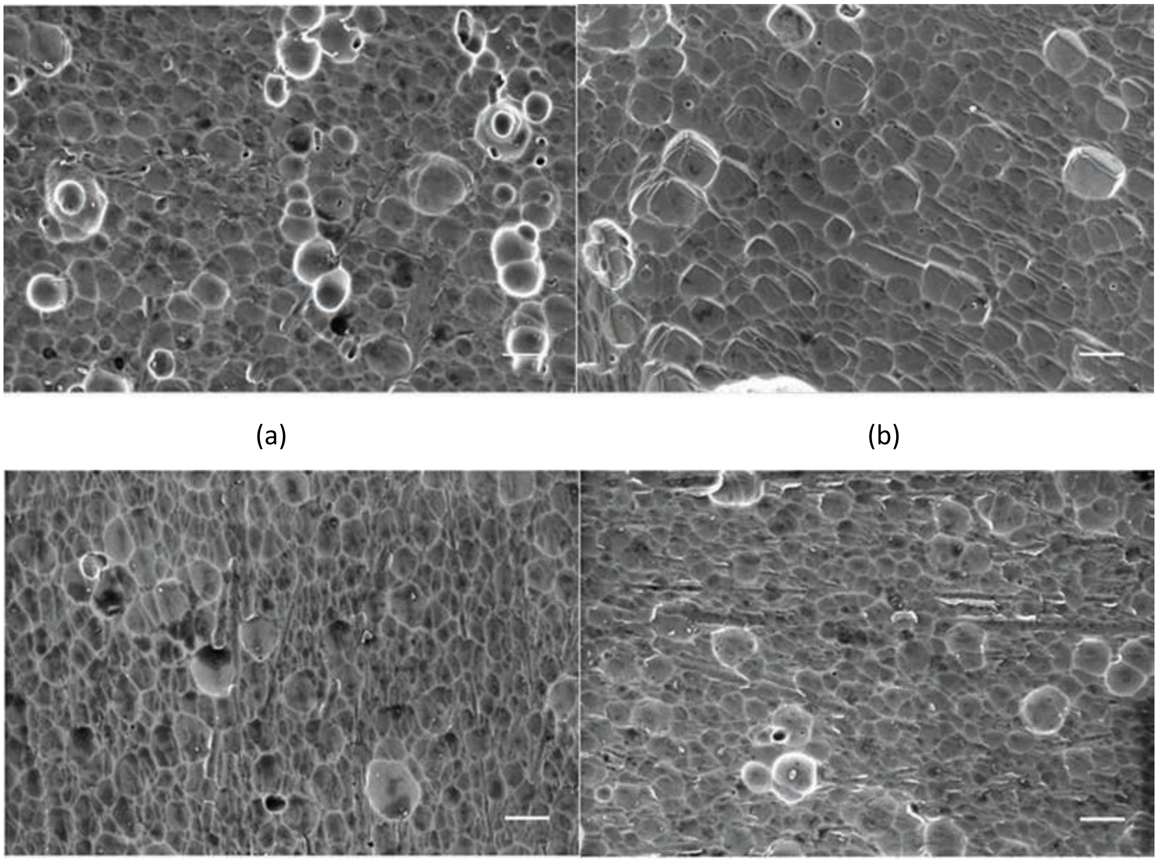
The yield strength, tensile strength and percentage elongation were determined using UTM. The specimen is placed in the machine between the grips and an extensometer if required can automatically record the change in gauge length during the test. If an extensometer is not fitted, the machine itself can record the displacement between its cross heads on which the specimen is held. However, this method not only records the change in length of the specimen but also all other extending / elastic components of the testing machine and its drive systems including any slipping of the specimen in the grips. Once the machine is started it begins to apply an increasing load on specimen. Throughout the tests the control system and its associated software record the load and extension or compression of the specimen. The equipment used is shown in figure 3.4.

Fig 3.4: Universal Testing Machine

4.0 RESULTS AND DISCUSSIONS:

4.1 **Micro-structural studies:**

An increase in extrusion load is observed with increase in number of passes. Figure 5 shows the FE-SEM photograph of AA 5083 in the as- received condition. The severe plastic strain, induced in the composite, at the intersection of die channels results in the refinement of coarse grains to a few hundreds of nanometres. A greater reduction in grain size is observed after the very first pass of ECAE, and it is considerably less in further passes. Inhomogeneity in the material is observed due to the dead metal zone. ECAE resulted in elongated grains. The micro structureare observed under SEM are shown in figure 4.1



(a) (b)

(c) (d)

Fig 4.1 Microstructure analysis for each pass

4.2 **Mechanical properties**:

The mean microhardness measurements on the sectioned surface normal to flow direction of the extruded billet types are determined. The structural homogeneity and formation of submicron grains in the billet are high. The hardness measurements of the various billet types in every pass are presented in Table 4.1.The hardness is increased from 69 Vickers hardness number (VHN) to 134 after fourth pass of ECAE.

Number of passes	VHN
Casted composite	69
1st pass	97
2nd pass	113
3rd pass	127
4th pass	134

Table 4.1: Vickers Hardness Number

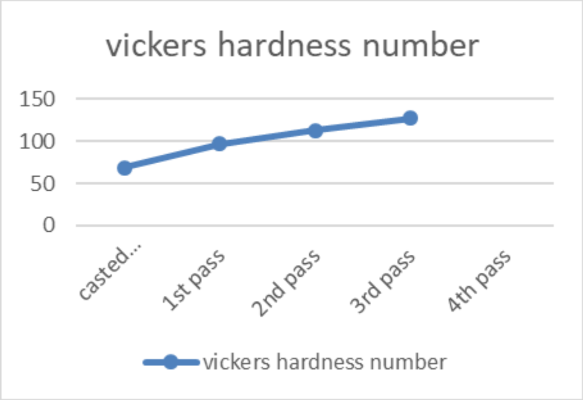


Fig. 4.2: Graph for Vickers Hardness Number

The measurements of the tensile test for the initial and ECAE'd material are presented in Table Figure 11 presents the tensile strength of the extruded alloy, which follows the same trend as micro hardness. The tensile strength is increased for billet after each pass. The yield strength is increased from 210 MPa to 460 MPa after four passes of ECAE. The tensile strength of the composite is also increased after each pass and the measurements are shown in table. The successive passes of extrusion have resulted in a moderate increase in yield strength.

Number of passes	Yield Strength
Casted composite	210 MPa
1st pass	320 MPa
2nd pass	380 MPa
3rd pass	430MPa
4th pass	460MPa

Table 4.2: Yield Strength

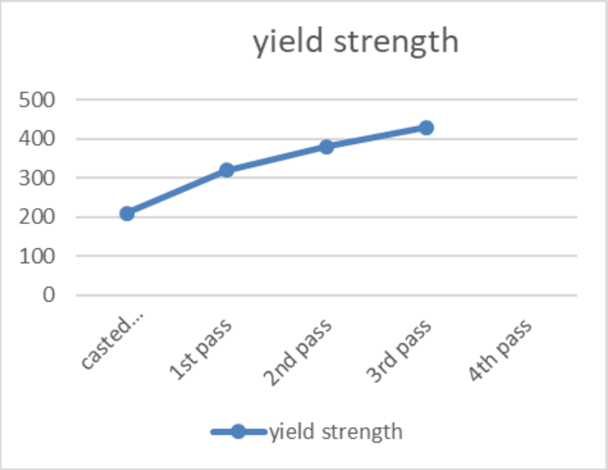


Fig. 4.3: Graph for Yield Strength

Number of passes	Ultimate tensile strength
Casted composite	320 MPa
1st pass	460 MPa
2nd pass	520 MPa
3rd pass	560 MPa
4th pass	595 MPa

Table 4.3: Ultimate tensile strength

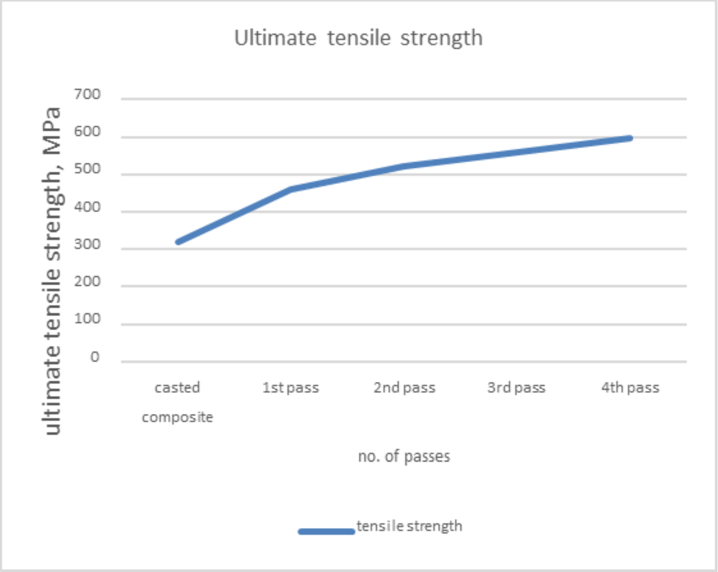


Fig. 4.4: Graph for Tensile strength

The % elongation of the ECAE'd composite is depicted in Figure 12. It is noticed that the the ductility of the extruded composite has been reduced after each pass.

Casted composite	12%
1st pass	6.5%
2nd pass	6.0%
3rd pass	4.5%
4th pass	4.5%

Table 4.4: % Elongation Length

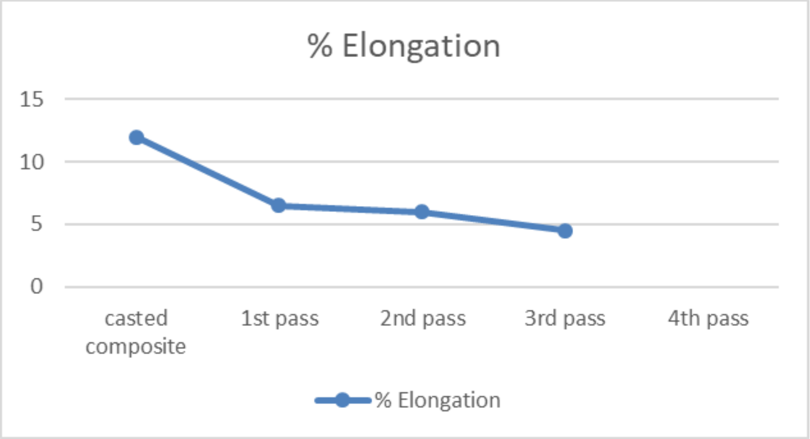


Fig. 4.5: Graph for % elongation Length

4. CONCLUSION

The following conclusions can be drawn from the present investigations

1. AA5083 matrix composites with 5wt% red mud are successfully fabricated by stir casting.

2. Significant grain refinement has been observed and the same is reflected by SEM structures

3. The hardness of the composite is increased after each pass of ECAE and it was increased from 69 to 134 after four passes of ECAE.

4. The yield strength and tensile strength are also increased after each pass of ECAE. The yield strength has been increased from 210 MPa to 460 MPa after four passes and the tensile strength is increased from 320 MPa to 595 MPa.

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