Improvement In Tribological And Mechanical Properties Of Al6061-Sic

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In present scenario, there has been heavy surge in the utilization of the aluminium matrix composites. AMCs have gained relative importance in various fields of engineering such as aeronautical, bio-medical, defence system etc. A 6061 Aluminium alloy with Silicon carbide as the reinforcing agent is implemented as composite constituent. The reinforcement content is diversified in terms of weight percentage. Further, the casted specimens are made to experience high strain through means of "Equal channel angular extrusion" wherein grain enhancement takes place leading to improvement in its tribiological and mechanical characteristics with no alteration in the cross section.

***Keywords*:** ECAP, Aluminium, SiC

1. Introduction

Composite material overtakes the homogenous materials because of their enhanced properties specially designed for the suitable purposes. Since conventional metals and their alloys are getting limited/ restricted usage due to the limitations such as achievement of desirable toughness, high temperature performance, combined strength, wear, corrosion inhibition etc. Thus metal scholars have averted their attention from monolithic to amalgamated materials [1]. There are various applications of composites in the field of aerospace, marine, defence, medical purposes, nanotechnology, construction, bio- engineering and the list goes on.

In this research, work has been conducted to create metal matrix composite which is manufactured by a suitable manufacturing technology selected after reviewing from several sources of information. The selection of the matrix and the reinforcement is done considering its suitability for particular application. Later the fabricated materials are made to undergo a severe deformation with a view of enhancing their properties so that its range of applications can be widened.

1.1 Selection of Al6061 And Silicon Carbide

- Selection Criteria for Aluminium 6061

In manufacturing industry, the requirement to produce lightly weighed, strong and most importantly economical material has led to intense research and growth of AMC's. The main objective involved in the production of MMC is to fuse the desirable properties of ceramics and the metals, which will widen its level of applicability. Equally we know aluminium is the third most available in plenty element after silicon and oxygen, making up of 8% of earth's solid surface by weight. Daryoush et al.[1] stated the applicability of aluminium alloys for applications such as diesel engine under high temperature and pressure. Elastic modulus of the pure aluminium was improved through addition of 60% by volume continuous aluminium fibre varying from 70 to 240GPa, but this addition also led to decrement in coefficient of expansion of the alloy.

- Selection of Silicon Carbide

Hard ceramic particulates like Alumina (Al2O3), Silicon carbide, Zirconia, TiC, TiB, ZrB2, AlN, Si3N4 are introduced into the metal matrix to enhance the corrosion and wear resistance, stiffness, strength, fatigue withstand and temperature stability. Amongst these hard ceramics, SiC has a high level of compatibility with aluminium alloys causing enhancement in the wear resistance of alloy, reduction in thermal expansion coefficient, superior modulus of elasticity hence exhibiting remarkable strength to cost and strength- weight ratio in comparison to traditional base alloys. In

addition it is found that composites with SiC as reinforcement and aluminium as matrix exhibited improved wear resistance, light weight and thermal stability.

2. Literature Survey

Claudio et al.[2] fabricated/prepared a metal medium with Al6061 as the matrix with 60% by volume Al2O3 spherical particles as the reinforcement. Gas pressure infiltration process, because of its advantages to produce pore free, high reinforced, defect free and also ease of processing, was adopted for the fabrication of these composites and it was experimentally determined that spherical alumina particles don't react with the molten magnesium containing matrix during the process, making the Al6061 retain its ability of being strengthened by precipitation-heat treatment. Daljeet et al.[3] focused on changing the property of the aluminium by inclusion of reinforcements Al2O3 and SiC in terms of weight percentage and further investigations were carried out concluding that addition of described reinforcements led to enhancement in properties such as ultimate strength, hardness, yield strength but the same time it was found that ductile behaviour had been converted into brittle. Considering the properties of the SiC, the reinforcement of particle type with size of 400microns is used for the addition purpose. The review infers that ECAP can be consecutively implemented for aluminium alloys. The channel angle of 120° is considered for the extrusion purpose with a single passing of the specimen through the ECAP channel via Route A.

3. Methodology

3.1 Material allocations

Table. 1. Aluminium elemental composition

Element	Ti	Zn	Sn	Cr	Cu	Mn	Si	Fe	Mg	AI
Weight %	0.007	0.0889	0.01	0.060	0.197	0.079	0.473	0.5	0.757	Remaining

Table. 2. Properties of Aluminium 6061 & SIC

	Density ρ (gm/cc)	Modulus of elasticity E (GPa)	Poisson's ratio γ	Coeff.of thermal expansion(K^{-1})
Al6061	2.7	68.3	0.345	23.5 x 10^{-6}
SiC	3.2	470	0.17	4.5 x 10^{-6}

Considering the above properties, the reaction during the casting process given as

$$4AI + 3SiC \rightarrow AI_4C_3 + 3Si \qquad (1)$$

The above reaction signifies that reaction yield includes carbide of aluminium. Stir moulding is a type of the liquid metallurgy process which includes integration of liquefied alloy with the reinforcement particulates by constant stirring action.

3.2 The reinforcement addition to the molten matrix

Weight of the 6061 aluminium ingots = 7.633Kg. Since the casting mould die consists of cavity in the form of cylinder-shaped rod of varying diameter and length.

Table. 3. Reinforcement to be added

Percentage of SiC	Weight of 6061Al in Kg	Weight of SiC in gms
0%	7.58	0
2%	7.1	142
4%	6.62	131.4
6%	6.14	120.76
8%	5.665	110.3

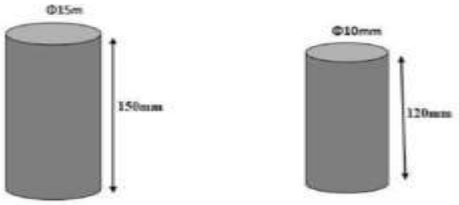

Fig. 1. Aluminium ingots

The reinforcement used was SiC of fine mesh with particle size of 400µ. After weighing of the reinforcements as per the calculation, they were organised systematically as shown in the above figure 3. Split type die configuration was used for casting purpose. The die was made up of tool material.

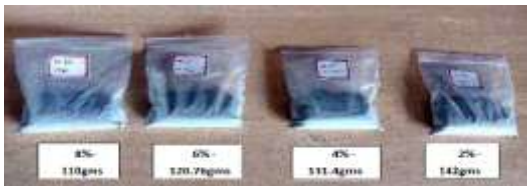

Fig. 2. Weighed and sorted SiC particles

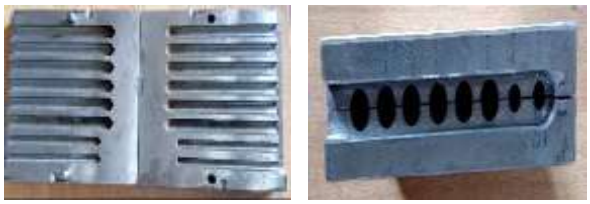

Fig. 3. Manufactured Mould casting die

This graphite crucible was placed within the ceramic muffle with heating coil wounded around it. The chamber is closed to prevent oxidation of the aluminium at liquid stage as it is highly reactive at its molten stage.

Fig. 6. Specimens kept for cooling

Fig. 7. Surface finish achieved between 2% & 6%

It was also observed that the time required to slice the cast specimen increased with a surge in reinforcement percentage, this is due to the restriction to the cutting blade movement offered the SiC particles within the AMC. The latter specimens were needed to be polished by using emery paper which was the requirement for successful and smooth extrusion.

3.3 ECAP working method

The specimen/billet were machined as per the channel specification i.e. Φ10.6mm and length 80mm.

Fig. 8. ECAP die with 120° channel angle

Fig. 9. Extruded sample

Specimen was coated with lubricant and introduced into the die. Pressing was carried on a universal testing machine with pressing speed of the 2~3mm / s. No heat treatment was given to the billet and the die. Route A was implemented during the pressing that is no rotation was given to the billet. Strain imposing was done on the billet by passing it for single time only. The extruded specimens were machined as per the testing requirements.

4. Result and Discussion

4.1 Hardness Test

Hardness is mechanical property of a material by virtue of which it provides resistance to indentation. The specimen's micro hardness were determined through means of Brinell hardness testing machine. Generally in Brinell hardness testing of metallic surface ASTM 10-7a standard is implemented.

Fig. 10. MRB 250 Brinell hardness tester

Fig. 11. Hardness test indentation

$$B = \frac{W}{(\frac{\pi}{2})(D-\sqrt{D^2-d^2})} = \frac{W}{\pi} \qquad (5)$$

Where D – diameter of steel ball. d – Indentation diameter. t - Impression depth, W- Load applied in kilograms

Table 4. Brinell hardness value

% of reinforcement	Non ECAP	ECAP
0	62	68.4
2	64	68.4
4	65.7	84.3
6	67.7	95.4
8	66.2	87.6

4.3 SEM

Scanning electron microscope is a kind of electron microscope which creates images of the specimen by examining it with a concentrated ray of electrons. The electrons intermingle with the atoms in the material hence producing various signals containing data about surface topography. Resolution of 1nano meter can be achieved in SEM. The surface morphology of the specimen can be studied in low and high vacuum condition, elevated temperature and wet conditions. From the images captured, the differentiation of the reinforced particles is scarcely possible. This possibly might be due to smaller particle size of 400 micron mesh. There has been considerable decrease in the porosity level after the ECAP process and clustering of the particles has reduced.

Fig. 12. SEM equipment & Mirror polished specimen ready for SEM analysis

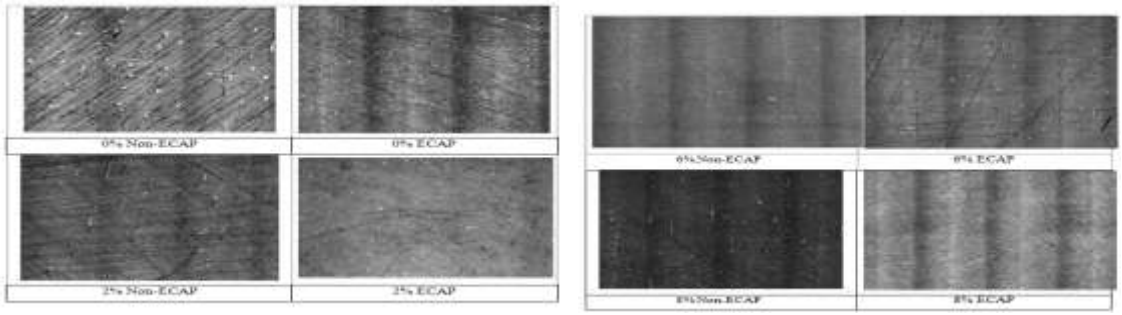

Fig. 13. SEM imaging of the polished surfaces

5. Conclusion

Addition of the SiC particles to the Al6061 alloy leads to enhancement in both tribological and mechanical properties. Since Al6061 belonged to heat treatable series, it could be certainly implemented for stir casting and pressing technique. Thus this casting technique can be successfully adopted for the casting of AMC unless the process parameters are strictly followed. Stir casting technique is reliable and economical in comparison to other processing methods. The Equal channel angular pressing is successfully implemented, i.e. imposing of high strain when passed through the ECAP channel leading to grain refinement which in turn enhances the materials property.

Acknowledgment

Thank our parents and friends who extended their support financially, technically and assisted in this research work.

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