# Microstructure and mechanical properties comparison of Cast and Extruded Al6061-SiCp composites

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***Abstract*** **-** Casting and Extrusion are typical mechanical processes classified as primary and secondary process respectively. Casting as a primary process is prominently used in making intricate shapes and is considerably economical. Secondary process such as extrusion is metal working technique used to produce components and objects having cross sectional profile. The present paper reports on the comparison between uncoated and Ni-P coated SiC reinforced Al6061composites produced by stir casting and hot extrusion method. Electroless plating technique was used to nickel coat SiC particles. The extent of incorporation of reinforcements was varied from 2 to 10 wt% in steps of 2wt%.SEM examinations were also carried out to observe the possible mechanisms in the matrix alloy and developed composites.

***Keywords****- Coating,Microstructure,Casting,Extrusion,Metal Matrix Composites.*

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## I. INTRODUCTION

Over the past two decades metal matrix composites (MMCs) have been transformed from a topic of scientific and intellectual interest to a material of broad technological and commercial significance. Today MMCs are widely used in a variety of applications and the worldwide MMC markets in 1999 accounted for 2500 metric tons valued at over $100 million in the ground transportation (auto and rail), thermal management, aerospace and recreational industries [1].Metal Matrix composites are a class of materials with at least two constituent parts, one being a metal and the other material being a different metal or another material (it can be a ceramic or an organic compound).Aluminium based composites are mainly fabricated by liquid metallurgy route. It involves addition of externally synthesized reinforcement into the molten matrix. This conventional technique poses various problems like poor bonding, uneven distribution, poor isometric properties, formation of interfacial reaction products, inherent casting defects due to incomplete adhesion of reinforcement to matrix and thermo dynamic instability of dispersoids with matrix [2-6].These problems can be successfully addressed by providing metallic coating on the surface of ceramic particles before addition in to the molten metal as reported by many researchers [7-10].Cast aluminum has the potential to experience deformities due to its elasticity. Metal extrusion tends to produce an elongated grain structure, usually considered favorable with improvised properties.

## II. MATERIALS AND METHODS

Al6061 alloy with the chemical composition given below in Table 1 was used as the matrix material. Silicon Carbide in powder form having particle size of range 5-40μm was used as reinforcement. Silicon carbide particles were subjected to electroless nickel coating. The composites were developed using stir cast method. Both Ni-P coated and uncoated silicon carbide was varied in proportions of 2 to 10wt%. Dispersion was achieved by use of ceramic coated impeller. The composite melt was poured into preheated metallic moulds maintaining a pouring temperature of 720 °C. The cast matrix alloy and the developed Al6061-SiC composites (Both uncoated and Ni-P coated) were machined to the size of 70 mm diameter and 200 mm length respectively. Machined billets were then subjected to hot extrusion in a 200 T hydraulic press, at a billet temperature of 500°C. Extrusion billets were heated in a muffle furnace for 2hrs.The temperature of the die inserts within the container was maintained at 300°C. A graphite based lubricant was applied on the billet, container and die. Extruded Al6061 alloy and Al6061-SiC composites were processed. Micro hardness tests were performed by applying 100 grams of load for a period of 10 secs. The hardness was noted by taking the diagonal length of indentation produced. The test was carried out at five different locations in order to contradict the possible effect of indenter resting on the harder particles. The average of all the five readings was taken as hardness of sample. Tensile tests were performed on both Al 6061 and Al6061-SiC composites using INSTRON universal testing machine. The specimens were machined to dimensions as per ASTM A370 standards. Cast and extruded composites were subjected to SEM studies and properties were assessed.

| Elements | Si | Fe | Cu | Mn | Ni | Zn | Ti | Mg | Al |
|---|---|---|---|---|---|---|---|---|---|
| Percentage | 0.43 | 0.43 | 0.24 | 0.139 | <0.05 | 0.006 | 0.022 | 0.802 | Bal |

**Table 1: Chemical Composition of Al6061 Alloy**

## III. RESULTS AND DISCUSSION

### Microstructure

Figure 1(a) and 1(c) shows the SEM photographs of Al 6061 casted alloy and Al 6061 reinforced with uncoated Silicon Carbide casted composite respectively. From the microphotographs it is observed that silicon carbide particles are fairly homogeneously distributed. Agglomeration of reinforced

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phase is also noticed.Further, detachment/decohesion of reinforced phase is also observed in the composites which is a clear evidence of poor bond between matrix alloy and reinforcement. Figure 1(e) shows the SEM photograph of Al 6061 matrix alloy reinforced with Ni-P coated SiC particle casted composite. It is observed that SiC particles of range 5-30 microns are found distributed in a fairly homogenous manner within the matrix alloy and also no such agglomerations/clusters are noticed. Further, there exists strong interfacial bond between matrix alloy and reinforcement as a beneficial result of metallic coating.

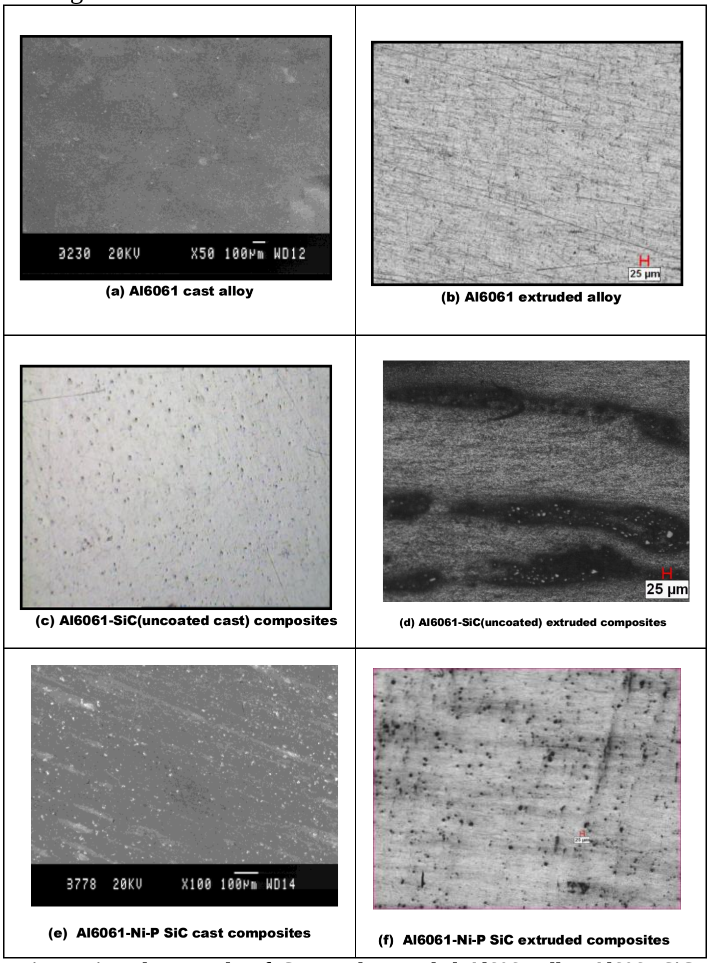



**Fig 1 Microphotographs of Cast and Extruded Al6061 alloy Al6061-SiC composites (both coated and uncoated)**

Pores and vacancies spread all over throughout the material in casting. Metal working helps to push and redistribute material; by overcoming the vacancies. Impurities in molten metal usually combine together in masses upon hardening, forming solid inclusions within the metal. Generally, inclusions cause weakness in the surrounding material. Hot working causes these inclusions to break up and distributes them throughout the mass of metal. Cast parts have large, irregular, columnar grain structures. Hot working a metal will break up irregular structures and recrystallize the mass of material into a finer grain structure. Figure 1(f) shows uniform distribution of Ni-P coated SiC particles which may be attributed to favorable effect of metallic coating which has improved the wetting kinetics in the liquid aluminum. Grain refinement is evident after extrusion of the Al6061 matrix alloy, Al6061- SiC uncoated and Al6061-NiP-SiC composites. Mechanical properties such as, ductility and strength characteristics; are improved significantly.

Hardness

Figure 2 shows the variation of micro hardness of Al 6061 matrix alloy and its composites (cast and extruded – both coated and uncoated).Micro hardness tests were performed on both Al 6061 alloy and Al6061 – SiC composites. The micro hardness test was conducted on the polished samples using Vickers Microhardness tester.

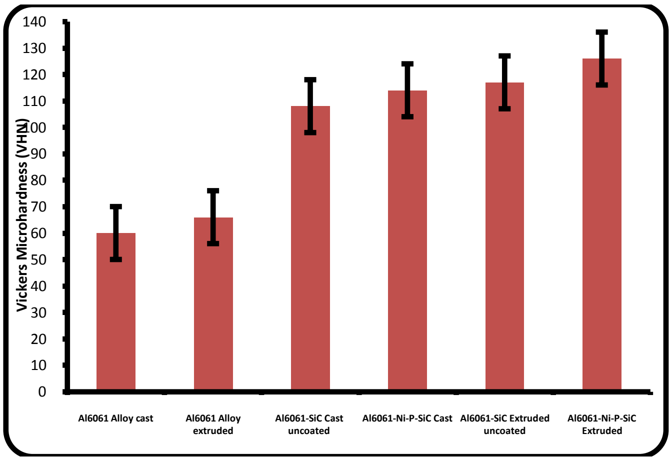


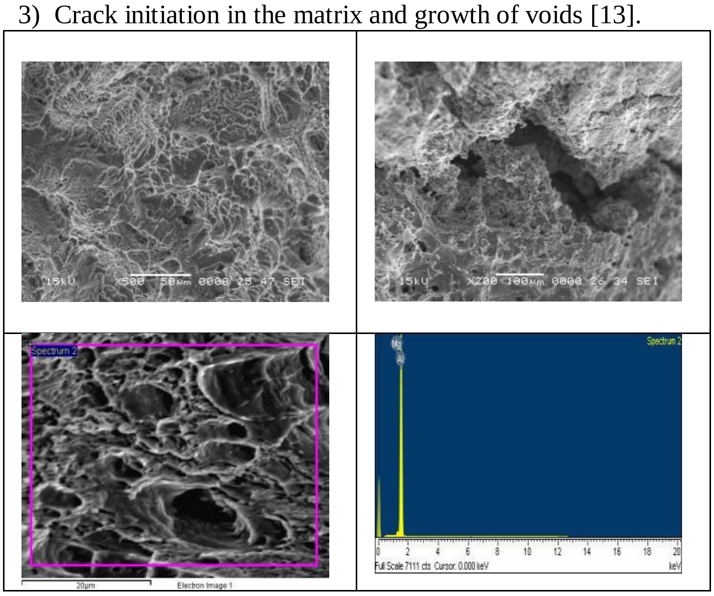

**Fig 2 Variation of Micro hardness of Al6061matrix alloy and its composites (cast and extruded – both coated and uncoated)**

An improvement in extruded composites (coated) of 9-18% is observed significantly when compared with cast composites (both uncoated and uncoated) respectively. Higher hardness values of Ni-P coated silicon carbide composites when compared with uncoated ones can be attributed to reduced casting defects and improved bond strength/load transfer efficiency between matrix alloy and reinforcement.

Fractography

Fracture may be due to the result of one or a combination of the following mechanisms.

1) Reinforcing particle Fracture [11];
2) Partial debonding of particle-matrix interface and nucleation of voids [12];
3) Crack initiation in the matrix and growth of voids [13].



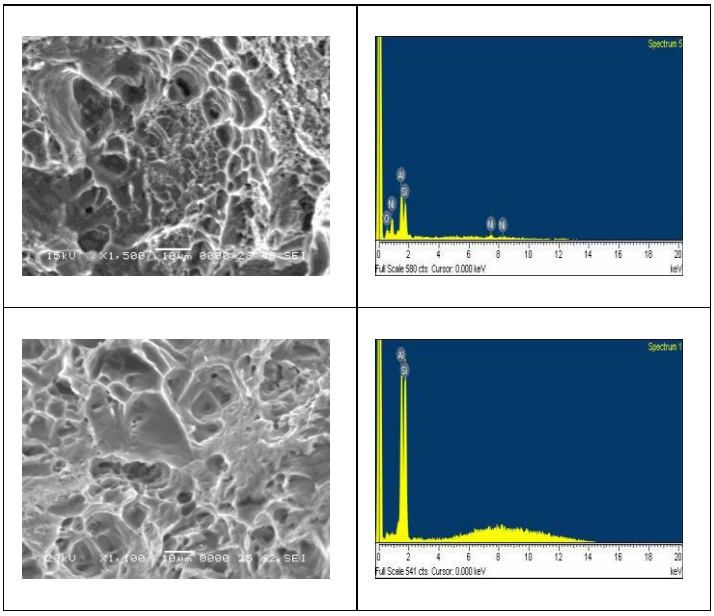


**Fig 3 Fractured surfaces of composites and EDAX analysis**

Figure 3 shows SEM photographs of fractured surfaces of the developed alloy and composites cast, extruded (both coated and uncoated). The fractography shows few shallow dimples and micro cracks. A large number of relatively flat and smooth areas, called mirror regions have been observed. The occurrence of mirror regions reflects sudden rupture of the matrix. This type of fracture is more consistent in materials with relatively low ductility. The fracture surfaces also reveal the coexistence of ductile and dimple fractures. Fractography displays fine shallow dimples as well as ductile shear bands indicating the amount of ductility retained by the composite, despite the incorporation of reinforcement.EDAX pattern shows the composition present and coated; uncoated composites can be easily differentiated via this technique. The growth of fracture is manifested via interfaces and brittle intermetallic particles. Large flat mirror surfaces with huge interfacial cracks have been noticed, indicating the dominance of brittle fracture.

## IV. CONCLUSION

Microhardness increases with increase in SiC content and is prominent in Ni-P coated SiC extruded composites. The developed composites revealed commendable improvement in mechanical properties when compared with base alloy. This may be attributed to the grain refinement, rearrangement and recrystallization during extrusion. Elimination of defects such as porosity, cracking is a virtue of the secondary process.SEM studies and failure of the material was studied thoroughly. Homogenous dispersion was achieved successfully. Hot extrusion resulted in uniform distribution of SiC particles and its orientation.

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