Modern day researchers are interested in Metal matrix composites; as the conventional materials have the limitation in achieving better strength, toughness and density. In advanced materials, there is scope for improvement in Metal matrix composites. Metal matrix composites contain a matrix alloy and reinforcement such as Particulates; Whiskers and short or continuous fibers. Uniform mixing of both matrix alloy and reinforcements provide tailor-made properties of composites which is not possible with individual components (Ibrahim et al., 1991; and Clyne and Withers, 1993). In present day applications, extruded aluminum composites are extensively used in transport for airframes, road-rail vehicles and in marine applications which help in minimizing the secondary machining and make the process cost effective. This study reports on processing the MMC’s and characterization to evaluate the mechanical properties of uncoated and Ni-P coated SiC reinforced Al6061 composites produced by stir casting method and further by extrusion of the casted billets. Electroless plating technique was used to nickel coat SiC particles (Ramesh et al., 2007). The reinforcement incorporated varied from 2 to 10wt% in steps of 2wt%. Developed hot extruded composites were subjected to microstructure, hardness and tensile tests. The developed composites exhibited improved mechanical properties when compared with the base alloy.

**Keywords:** Extrusion, Coatings, Metal matrix composites, Microstructure

**INTRODUCTION**

Composite materials are designed and engineered to exhibit properties that are most desirable for unique application such as low density, high specific strength and stiffness, good fatigue strength and high thermal conductivity (Stefanos Skolianos, 1996). Of all the aluminum alloys, Al6061 is the one carrying better formability characteristics in addition to high strength making it a popular choice for matrix material to prepare aluminum based metal matrix composite (Kaczmar et al., 2000). Reinforcement of aluminum alloys with ceramics leads to a new generation of tailor made engineering materials.
with superior properties to weight ratio (Suresh et al., 2003). Many researchers have reported that the addition of ceramic particle to the aluminum matrix leads to enhance the mechanical properties (Seah Kar Hang et al., 2003). It has been reported that the interface between matrix and reinforcement plays a significant role on mechanical properties of composites (Urena et al., 2005). Absence of sound interface between matrix and reinforcement/ formation of interfacial products, can lead to deterioration of properties of composites (Asthana, 1998; and Ren et al., 2008). Aluminum matrix composites are candidate materials for several engineering applications especially for aerospace and automotive industry because they can be readily shaped with conventional secondary metal working techniques such as extrusion, forging, rolling, etc. (Kim et al., 2008). Since, these processes can alter the microstructural parameters of the composites; they do influence the microstructure and various properties of the composite materials (Liu et al., 2007). In the light of the above, the present investigation focuses on mechanical properties of Ni-P coated SiC reinforced Al6061 composites.

MATERIALS AND METHODS
Al6061 alloy with the chemical composition given in Table 1 was used as the matrix material. Silicon Carbide (SiC) 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 as shown in Figure 1.

Machined billets were then subjected to hot extrusion in a 200 T hydraulic extrusion press, at a billet temperature of 500 °C. Extrusion billets were heated in a muffle furnace for 2 hrs. 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 (both uncoated and Ni-P coated) were subjected metallographic studies, micro hardness and tensile test.

RESULTS AND DISCUSSION
Microstructure
Figures 2a, 2b and 2c shows the optical photographs of Al6061 matrix alloy, Al6061-10wt% Ni-P coated and Al6061-10wt% Ni-P coated SiC composites.
SiC (Uncoated) and Al6061-10wt% SiC (Ni-P coated) reinforced with Silicon Carbide particles respectively. From the microphotographs it is observed that silicon carbide particles are fairly homogeneously distributed. Agglomeration of reinforced phase is also noticed in some composites with higher weight percentage of silicon carbide particles. 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.

**SEM (Scanning Electron Microscopy) Studies**

Figures 3a, 3b and 3c shows the SEM photographs of Al 6061 matrix alloy, Al6061-10wt% SiC (Uncoated) and Al6061-10wt% SiC (Ni-P coated) reinforced with Silicon Carbide particles respectively. It is observed that SiC particles of range 5-30 microns are found distributed in a homogenous manner within the matrix alloy and also no such agglomerations/clusters are noticed in coated composites. Further, there exists strong interfacial bond between matrix alloy and reinforcement as a beneficial result of metallic coating. Uniform distribution of Ni-P coated SiC particles 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, Al6061-10wt% SiC (Uncoated) and Al6061-10wt% SiC (Ni-P coated) reinforced with Silicon Carbide particles predominantly.

**Hardness**

Micro hardness tests were performed on both Al6061 alloy and Al6061-SiC composites (both
Tensile

Tensile tests were performed on both Al6061 and Al6061-SiC composites using INSTRON universal testing machine. The samples were machined as per the machine requirement specified by M/s. Sri Ram Institute of Industrial Research, Bangalore. The specimens were machined to dimensions as per ASTM A370 standards. Tests reveal the following results tabulated in the table below.

Table 2 shows the variation of ultimate tensile strength of Al6061 matrix alloy and its composites. It is observed that all the developed composites have higher ultimate tensile strength when compared with the cast Al6061 matrix alloy. A maximum improvement of 53% is observed for Al6061-10Wt% SiC where as in case of Ni-P coated SiC reinforced composites it is found to be 60%. Basically tensile properties of composite material are a strong function of nature and properties of reinforcing elements and matrix material. The compatibility between matrix and reinforcement plays a pivotal role in enhancing the mechanical properties; in particular, ultimate tensile strength of composites. The size and shape of the reinforcement also dictates the UTS of composites. The improvement in UTS of developed composites is attributed to the fine size of the particles.

Figure 5 shows SEM photographs of fractured surfaces of the developed alloy and composites. The fractography shows few shallow dimples and micro cracks. A large number of relatively flat and

<table>
<thead>
<tr>
<th>Material</th>
<th>Microhardness (VHN)</th>
<th>Yield Strength (MPa)</th>
<th>Ultimate Tensile Strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al6061 Alloy</td>
<td>66</td>
<td>80</td>
<td>126</td>
</tr>
<tr>
<td>Al6061-10wt% SiC (Uncoated)</td>
<td>84</td>
<td>125</td>
<td>272</td>
</tr>
<tr>
<td>Al6061-10wt% SiC (Coated)</td>
<td>92</td>
<td>148</td>
<td>314</td>
</tr>
</tbody>
</table>

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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 during extrusion. Elimination of defects such as porosity, cracking is a virtue of the secondary process.

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CONCLUSION

Microhardness and ultimate tensile strength increases with increase in SiC content and is 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 reveals fine shallow dimples as well as ductile shear bands indicating the amount of ductility retained by the composite, despite the incorporation of reinforcement. Further, there is no evidence for the presence of features such as particle debonding and fracture. 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.
REFERENCES


