CHAPTER-2

LITERATURE REVIEW

This chapter deals with literature review related to stir casting process, material characterizations, mechanical properties, machining responses (surface roughness, cutting forces, tool wear, tool life, and power consumption), modeling and optimizations of machining parameters, and multi characteristic optimization. Gaps in the literature review have been identified.

2.1 STIR CASTING PROCESS STUDIES

Fabrication techniques affect the microstructure, the distribution of the reinforcing materials and interfacial bond condition between reinforcing phase and matrix. These techniques have to ensure uniform distribution of the reinforcing material in the matrix and formation of good bond between matrix and reinforcing material, to obtain MMCs with optimum properties [Hashim et al., 1999].

There are several fabrication techniques available to manufacture different MMC. Depending on the choice of matrix and reinforcement material, the fabrication techniques can vary considerably. According to Naher et al., [2004], fabrication methods can be divided into three types. These are solid phase process, liquid phase process and semi solid fabrication process. Among the variety of manufacturing processes available for discontinuous metal matrix composite, stir casting is generally accepted as a particularly promising route, because of low cost. According to Seo and Kang, [1999] its advantages
lie in its simplicity, flexibility and applicability to the large quantity production. This semi solid metallurgy technique is the most economical of all available routes for MMC production. It allows very large sized components to be fabricated, and is able to sustain high productivity rates. Naher et al., [2004] has shown that the cost of preparing composite materials using a casting method is about one third to one half that of competing methods. A comparative study of different techniques for MMC is given in Table 2.1 [Hashim et al., 1999].

Table 2.1: Comparative evaluation of different processing techniques:

<table>
<thead>
<tr>
<th>Method</th>
<th>Range of shape &amp; size</th>
<th>Metal Yield</th>
<th>Range of volume fraction</th>
<th>Damage to reinforcement</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powder metallurgy</td>
<td>Wide range, restricted size</td>
<td>high</td>
<td>-</td>
<td>Reinforcement fracture</td>
<td>expensive</td>
</tr>
<tr>
<td>Squeeze casting</td>
<td>Limited by preform shape Upto 2cm height</td>
<td>low</td>
<td>Upto 0.45</td>
<td>Severe damage</td>
<td>Moderately expensive</td>
</tr>
<tr>
<td>Spray casting</td>
<td>Limited shape, large size</td>
<td>medium</td>
<td>0.3 to 0.7</td>
<td>-</td>
<td>expensive</td>
</tr>
<tr>
<td>Mechanical stirring</td>
<td>Not limited by size</td>
<td>medium</td>
<td>0.4 to 0.7</td>
<td>Little damage</td>
<td>moderate</td>
</tr>
<tr>
<td>Electro magnetic stirring</td>
<td>Not limited by size</td>
<td>high</td>
<td>0.5 to 0.8</td>
<td>No damage</td>
<td>Moderately expensive</td>
</tr>
</tbody>
</table>

One significant requirement when using a stir casting technique is the continuous stirring of the melt with a motor driven agitator to prevent settling of particles. The vortex method for particulate entrapment was the one most frequently used in previous studies since any stirring of a melt naturally results in a formation of a vortex. During these
works, stirrer speeds ranging from 100 to 1500 rpm were investigated by Yilmaz and Altintas [1994]. The reinforcement particles can also be pre-treated by heating. For SiC oxidation, different researchers have used varying temperature and times: 1000°C for 1.5 h in air [Yilmaz and Altintas, 1994], 1100°C for 1-3 h [Zhou and Xu, 1997], 850°C for 8 h [Kevorkijan and Sustarsic, 1997]. Doel and Bowen, [1996] has chosen stainless steel as the main crucible and stirrer material. The machine consisted of a four 45° flat bladed stirrer and a crucible in a resistance heated furnace chamber. Stirring speed was varied from 200 to 500 rpm.

Microstructure of 7075 aluminium alloy reinforced with 15% SiC particulates of size 5, 13 and 60 µm, fabricated by co-spray deposition process were investigated. In optical micrographs the distribution of SiC particles was reasonably homogeneous. Although particles were seen to have aligned some what in the longitudinal direction [ Doel and Bowen,1996]. Microstructures of spray formed 13 vol % SiC reinforced 7075 aluminum metal matrix composite (MMCs) were studied. Nearly, all of the SiC particles locate at the grain boundaries, which suggest that the solidification rate at the deposit surface was not high enough to allow the solid liquid front to entrap the particles within the grains [Su Frank et al., 2004]. The microstructures of spray–deposited 7075 alloy with TiC particles were studied using scanning electron microscopy and X-ray diffraction. X-ray diffraction analysis indicated that the main second phase, TiC is contained in the microstructure of the composite [Wang et al., 2005].

The composites investigated were made by powder metallurgy. Four different gas atomized Al–6Cu–0.4Mn (wt. %) alloy powders were used as the initial matrix materials.
Composites were fabricated by extrusion of billets that were previously formed using cold pressing blend of matrix alloy powders and ceramic particles. More aggregated microstructures were generated with an increase in ceramic volume fraction (upto 20%) and the matrix alloy powder mean particle size from 40 to 180 μm as well as with a decrease in the reinforcement particle size (3–14μm). An attempt was made to correlate the Young’s modulus of SiC particle reinforced aluminum alloy composites, measured by resonant ultrasound method, to reinforcement spatial distribution. Ultrasonic wave velocity as well as Young’s modulus diminishes with a decrease in SiC content and its particle size, and with increase in matrix alloy particle size [Vdovychenko et al.,2006].

Composites were formed by adding 15 wt% of SiC dispersoid in the size range of 20-40 μm to Al-Zn-Mg-Cu alloy (corresponding to 7075 series) by stir casting process. The composite exhibits a uniform distribution of SiC particulates as well as good bonding between the matrix and particulates. Grain boundaries are clearly defined with some precipitates in the grains [Dasgupta and Meenai, 2005]. Kalkan and Yilmaz [2008] investigated the squeeze casting of aluminium alloy 7075 reinforced with 10%, 15% and 20% SiC particles. Homogeneous distribution of the SiC particulates was obtained using vertical pressure/squeeze casting of the SiC composites. Some agglomeration was observed but there was no evidence of porosity among the SiC particles when they were close to each other.

2.2 MATERIAL CHARACTERIZATIONS

Microyield phenomena during thermocycling of Al 7075 alloy/15 vol % SiC metal matrix composite due to mismatch of the thermal expansion coefficients of the matrix and the
SiC particles are studied over the temperature range from 50 to 300 °K by means of internal friction techniques [Kustov et al., 2001]. Macrostructure of spary-formed 13 vol.% SiC reinforced 7075 aluminium metal matrix composites were studied. The workability of spary-formed MMCs was studied, which was compared with that of conventional continuously-cast 7075 aluminium alloy. Upset forming was employed to study the workability, for which the strain, strain rate, and temperature were varied. Macrostructural evolution during upset forming was characterized [Su Frank et al., 2004].

The microstructures of spary –deposited 7075 alloy with TiC particles were studied using scanning electron microscopy and X ray diffraction. The dry sliding wear behaviour of the alloys was investigated using a pin-on-disc machine under different loads [Feng Wang et al., 2005]. Composites have been formed by adding 15%SiC dispersoids in the size range of 20-40 µm to 7075 Al alloy. The 7075 Al alloy and composites have been subjected to heat treatment in an attempt to optimize their properties [Dasgupta and Meenai, 2005].

The composites were fabricated by pressure infiltration of commercial purity Al and Al/1–8 wt.% Si alloy melts into abrasive grade green-SiC particle performs. SiC particles having mean diameter of 23µm were compacted into a cylindrical shape. Uniform distribution of the SiC particles in the matrix was observed in microscopic examination. However, porosity mainly located near the tips of the SiC particles was found. Results indicated that the amount of porosity present in the microstructure of Al/60 vol % SiC composites decreased with increasing Si content of the matrix. In the pure Al matrix composite, eutectic Si and Al₄C₃ intermetallics were evident, while further Si addition suppressed the precipitation of Al₄C₃ and in turn encouraged the precipitation of eutectic
Si. Quantitative metallographic analyses revealed that the volume fraction of the reinforced SiC particles was about 60% and that amount of porosity decreased with increasing Si content of the matrix. High magnification examination did not show any evidence of dendritic growth but the presence of rectangular shaped black colored and needle shaped gray colored constituents in the matrix. In X ray diffraction (XRD) patterns presence of eutectic Si is evident in the pure Al and Al–8% Si alloy matrix composites. Additionally, peaks of Al₄C₃ phase were noticed in the case of the pure Al matrix composite. When the surface of the SiC particles contacts with liquid Al, it dissolves producing Si and C ions. These then react with Al to produce Al₄C₃ and free Si [Hayrettin et al., 2004].

The composites were processed by vacuum hot pressing of the intimate mixtures of inert gas atomized powders of Al–Cu–Mg alloy and SiC particles, followed by extrusion at the ratio of 25:1 after soaking at 450 °C for 0.5 hour. The average size of SiC particles was 5 µm in the composite reinforced with 5 vol.% SiC, and 50 µm in case of those with 15 and 25 vol.% SiC. The as-extruded Al–Cu–Mg alloy–SiC composites were solution treated either at 495 °C for 30 min, or at 504 °C for 4 hour and quenched in ice-cold water. The microstructures and particle–matrix interfaces of the as-extruded and heat-treated samples were studied using secondary (SE) and back-scattered electron (BSE) imaging modes on a scanning electron microscope (SEM). The chemical compositions of the different phases were investigated through spot and line-scan analyses on Energy Dispersive X-Ray (EDX) detector, attached to the SEM. The particle sizes were measured on an optical microscope, and from SEM micrographs using image analysis software along longitudinal and transverse directions. To identify the phases formed
during the aging heat treatments, X-ray diffraction (XRD) studies were conducted on a using CuK$_\alpha$ radiation. TEM observations in bright and dark field imaging modes accompanied by energy dispersive X-ray analyses were carried out. Precipitates of CuAl$_2$, CuMgAl$_2$ and those enriched in Fe have been observed in the alloy matrix as well as at SiC–matrix interfaces in the composites in as-extruded and aged conditions. The CuMgAl$_2$ precipitates appear rod shaped, and aligned along the orthogonal {1 0 0} directions. The composite samples solution treated at 495 ºC for 0.5 hour have a larger fraction of the Al–SiC interfaces with undissolved precipitates and enrichment of alloying elements, than those solutionized at 504 ºC for 4 hours [Sharmilee Pal et al., 2008].

The effect of alloying and age hardening for AlCu$_3$ and AlZn$_6$Mg$_1$ as well as the specific role of Mg additions to Al/SiC MMCs on interface microstructure formation, mechanical properties and fracture mode were analysed. When using squeeze casting assisted pressurization for the infiltration of SiC particle preforms with high purity Al, the formation of Al$_4$C$_3$ is widely prevented. This is due to the peculiarities of the squeeze casting process which does not provide favourable thermodynamic and kinetic conditions for the associated reaction to proceed. However, under identical process conditions, additions of Mg lead to the formation of both Al$_4$C$_3$ and Mg$_2$Si. Si which is released from the direct reaction between Al and SiC reacts with Mg to form Mg$_2$Si. This reaction, in turn, decreases the Si activity and, thus favours the formation of Al$_4$C$_3$ in squeeze cast AlMg/SiCp composites. Any potential positive effect of enhanced interfacial bonding strength due to the Mg addition on mechanical properties is counterbalanced by the embrittling effect of the interfacial reaction products [Olivier Beffort et al., 2007].
The average size of Al, Mg and SiC particles used in this study was about 50, 13, and 22 μm, respectively. After these powders (Al-1.2wt.%Mg-0.8wt%Si-20vol.%SiC) were blended by roll mixing in an alumina jar, the powder mixture was put into a crucible. A 6061 Al ingot was placed on this powder bed. This assembly was heated to 700 and 800 °C, and held for 1 hour under a flowing nitrogen atmosphere in the retort furnace (5000 cc/min). Then the assembly was cooled to about 600 °C under the nitrogen atmosphere, in order to inhibit oxidation during solidification, and was removed from the furnace. For comparison, the control AA6061 was made through the same route, using a powder bed without the SiCp. The resulting microstructures and reaction products were investigated using scanning electron microscopy (SEM), and transmission electron microscopy (TEM). Reaction product (Al₄C₃) was formed at the interface between SiCp and Al alloy matrix. In addition, the amount and size of the Al₄C₃ is increased significantly by increasing the infiltration temperature. Results of investigation indicated that the reaction product (AlN) was formed as a result of the in situ reaction in both the control alloy and the composite. A significant strengthening even in the control alloy occurred due to the formation of in situ AlN particle even without an addition of SiCp. Variation of tensile strength with aging time at 177 °C in commercial AA6061, control AA6061 and composites which were solution treated for 2 hours at 529 °C, was analysed. The tensile strength in the control AA6061 was 55–70 MPa greater than the commercial AA6061. These values were an additional 84–99 MPa higher in the composite reinforced with SiC compared to the control alloy. A large increase in strength in the case of the control AA6061 is related to the in situ formation of AlN particles [Lee.et.al. 2001].
The effect of SiO$_2$ in SiCp and effect of the processing parameters i.e. Mg content in the aluminum alloy, SiC particle size, and holding time on the microstructure and impact strength of Al/SiCp composites fabricated by pressureless infiltration was investigated. Preforms of SiCp in the form of rectangular bars (10×1×1cm) were infiltrated at 1150°C in an argon/nitrogen atmosphere for 45 and 60 min by utilizing two aluminum alloys (Al–6 Mg–11 Si and Al–9 Mg–11 Si, wt.%). The results obtained show that the presence of SiO$_2$ in SiC affects the microstructure and impact strength of the composites significantly. When Al$_4$C$_3$ is formed, the impact strength decreases. However, a high proportion of SiC to SiO$_2$ limits the formation of the unwanted Al$_4$C$_3$ phase in the composites. Also, a higher content of Mg in the Al alloy lowers the residual porosity and, consequently, increases the composite strength. The impact strength grows with decrease in SiC particle size and increases considerably when the residual porosity is less than 1%. The ratio between the types of SiC green silicon carbide (GC)/black silicon carbide (C) affects the microstructure of Al/SiC composites significantly. A higher amount of SiCp with SiO$_2$ limits the formation of the unwanted Al$_4$C$_3$ even for long processing times. It is also found that the magnesium content in the aluminum alloy does not affect the formation of Al$_4$C$_3$. However, it does influence the residual porosity and, consequently, the impact strength of the composites. Moreover, the impact strength grows when the size of SiC particles decreases and when the Mg content in the alloy varies from 6 to 9 wt.%. By contrast, the presence of the Al$_4$C$_3$ phase decreases the strength. Interestingly, even a minor decrease in the residual porosity produces a considerable increase in the impact strength [Pech-Canul.et.al., 2000].
Methodologies both to avoid the formation of $\text{Al}_4\text{C}_3$ and to tailor the interfacial structures in a SiC/2014 Al composite were demonstrated. Modification of the interfacial structures in the SiC/2014 Al composite was made by forming $\text{SiO}_2$ layers on the surfaces of SiC via passive oxidation at elevated temperatures. In the 2014 Al composite reinforced with the oxidized SiC, MgAl$_2$O$_4$ and Si crystals were observed to be present at the interfacial region as a result of the reaction between the $\text{SiO}_2$ layer and the matrix. On the other hand, in the case of the 2014 Al composite reinforced with unoxidized SiC, SiC was found to react with the Al matrix to form both $\text{Al}_4\text{C}_3$ and Si. Qualitative measurements of the interfacial bonding strength were carried out on composites having various types of interfaces and thicknesses. Detailed interfacial structures and phase identifications, which were examined using scanning electron microscopy (SEM) and transmission electron microscopy (TEM), were presented. Based on X-ray diffractometry (XRD), a-$\text{SiC}$ with a hexagonal crystallographic structure was observed to be a dominant phase, although the exact volume fraction of this phase was not determined. Based on the calculated equilibrium Si contents and the experimental ones obtained from the passive oxidation of SiC, the oxidation fraction of SiC and the oxidation conditions required to prohibit the formation of $\text{Al}_4\text{C}_3$ within the SiC/2014 Al composite could be determined. According to the qualitative measurements of the interfacial bonding strength, the strength of the MgAl$_2$O$_4$ interface was observed to be significantly higher than that exhibited by the $\text{Al}_4\text{C}_3$ interface. In addition, the interfacial bonding strengths were measured to be higher, with thinner interfaces. Such a result indicates that the undesirable interfacial characteristics shown by the SiC$\text{as}/$Al composite could be modified if the composites
were made by using oxidized SiC particles which had an adequate thickness of the SiO$_2$ layer [Jae Chul Lee et al., 2000].

2.3 MECHANICAL PROPERTIES

The 7075 aluminum alloy is widely used in the aerospace applications for its light weight and high stiffness. To further improve the mechanical properties, particle or whisker-reinforced 7075 MMCs can be developed. The mechanical properties and deformation behavior of these MMCs are quite different from their base alloys.

Aluminium – based, particulate-reinforced Metal Matrix Composites (MMC’s) were of interest for structural applications where weight saving was of primary concern. Ceramic particles in the ductile matrix lead to the desirable properties. These properties include increased strength, higher elastic modulus, higher service temperature, improved wear resistance, decreased part weight, low thermal shock, high electrical and thermal conductivity [Altinkok and Koker, 2005]. A study has been made of 7075 Al alloy particulate-reinforced metal matrix composites in underaged, peak aged and overaged condition. The silicon carbide was used as reinforcement. All the composites were produced by the co-spray deposition process. The tensile properties and fracture toughness of material were investigated at room temperature. The material reinforced with coarse particulate was observed to have poor yield strength, and poor fracture stress compared with fine particulate [Doel et al., 1993]. Tensile tests at room temperature have been carried out on 7075 Al alloy and monolithic material. The particulate reinforcements used were SiC in three nominal sizes, 5, 13 and 60 µm. Three matrix ageing conditions were studied, peak aged and equivalent underaged and overaged matrix
condition based on microhardness measurement [Doel and Bowen, 1996]. The fracture behaviour of a composite based on 7075 aluminium alloy was studied under uniaxial tensile loading in the temperature range 25-400°C at a strain rate of 10^{-3} s^{-1}. The ductility of the composite was found to be much lower than that of the monolithic alloy at all temperatures, but both materials exhibited similar strength levels above 300°C [Razaghian, et al., 1997]. The composites investigated were made by powder metallurgy. Four different gases atomized Al–6Cu–0.4Mn (wt. %) alloy powders were used as the initial matrix materials.

The hardness as well as toughness of a composite material depends significantly on the matrix microstructure, size and distribution of the dispersoid and the interfacial bonding characteristics [Liang et al., 2000]. The 7075 aluminum alloy and 15 wt% of SiC dispersoid (size 20-40 µm) composites fabricated by stir casting process were subjected to heat treatment in an attempt to optimize their properties. Result was that heat treatment definitely improves the properties of the 7075 aluminum alloy and SiC composite [Dasgupta and Meenai, 2005]. Kalkani and Sencer Yilmaz [2008] investigated the squeeze casting of aluminium alloy 7075 reinforced with 10%, 15% and 20% SiC particles. In tensile tests, the composite containing 10 wt % SiC particles showed maximum strength in both the as cast and heat treated states as compared to the composites containing 15 wt % and 20 wt % SiC particles.

There are technical challenges associated with producing homogeneous high density composite. In order to achieve optimum MMC properties, the distribution of the reinforcement material in the matrix alloy must be uniform and the bonding between
these two substances should be optimized [Oh et al., 1989]. The mechanical properties of MMCs are controlled to a large extent by the structure and properties of the reinforcement metal interface. A stronger interface permits transfer and distribution of load from the matrix to the reinforcement, resulting in an increased elastic modulus and strength.

This work addresses the effect of alloying and age hardening for AlCu$_3$ and AlZn$_6$Mg$_1$ as well as the specific role of Mg additions to Al/SiC MMCs on interface microstructure formation, mechanical properties and fracture mode. In contrast to the composite flow stress, the elastic modulus of AlXX/SiCp composites is not significantly influenced by matrix alloying and heat treatment; instead, it is dictated by the SiC volume fraction and its values is 200–210 GPa. An AlCu4Mg1Ag/SiC/60p-T6 composite made by squeeze casting infiltration has been shown to yield a bending strength of 700 MPa, along with an elastic modulus of 200 GPa, a fracture toughness of 9.5 MPa. Hence, the tensile strength of Al-based metal matrix composites with high volume fractions of SiC particles can be enhanced by specific matrix alloying and heat treatment without deterioration of the composite’s fracture toughness [Olivier Beffort et al., 2007].

The nominal composition of alloy is Al–8.5Fe–1.3V–1.7 Si. SiC particles with a volume fraction of 15% and mean size of about 10 µm were selected as the reinforcement phase. The composite preforms were firstly fabricated by self-developed spray deposition equipment. Hot pressing and hot extruding were used for densification of the composite performs. The addition of SiC particulates has improved the mechanical properties at ambient temperature of the alloy for its particle reinforcement and texture reinforcement
at a certain extent (after rolling). The optimum Ultimate tensile strength (UTS), Yield strength (YS) and Young's modulus (E) of the composite sheet prepared by rolling after hot pressing are 620 MPa, 555 MPa and 9.5%, respectively. Ambient temperature properties of composite samples fabricated in route of multi-layer spray deposition → hot pressing → rolling was better than that of composite samples fabricated in route of multi-layer spray deposition → extrusion → rolling [Chen et.al. 2007].

SiC powders with an average granularity of 70 µm and Al powders with an average granularity of 40 µm were used to fabricate the composites. A commercial pure aluminum with purity of 99.5% was used to prepare aluminum powders by powder metallurgy method. The volume fractions of the SiC particles in the composites are 0, 4%, 8%, 12%, 16% and 20%. SiC particle reinforced pure aluminum composites were fabricated using a powder metallurgy method. The effect of the volume fraction of the SiC particles on the mechanical properties of the composites was studied by both model simulation and experiment. The results indicate that the yield strength and tensile strength increase, but the elongation decreases with the increase in the volume fraction of the SiC particles [Song Min, 2004].

The effect of the type of SiCp (green or black), Mg content in the aluminum alloy and holding time on the microstructure and impact strength of Al/SiCp composites fabricated by pressureless infiltration was investigated. Preforms of SiCp in the form of rectangular bars (10 cm×1 cm×1 cm) were infiltrated at 1150 °C in argon→nitrogen atmosphere for 45 and 60 min utilizing two aluminum alloys (Al–6Mg–11Si and Al–9Mg–11Si) (wt.%).
Characterization by XRD of the SiC powders reveals the presence of small amounts of SiO$_2$ with the cristobalite structure in the SiC$_p$ (black). It was also found that magnesium content in the aluminum alloy does not affect formation of Al$_4$C$_3$. However, it does influence the residual porosity and consequently, the impact strength of the composites. Moreover, the impact strength is enhanced when Mg content varies from 6 to 9 wt. % and decreases when the Al$_4$C$_3$ phase is present [Ortega-Celaya et al., 2007].

Dense SiC (97.3–99.2% relative density) of 1.1–3.5 µm average grain size was prepared by the combination of colloidal processing of bimodal SiC particles with sintering additives (Al$_2$O$_3$ plus Y$_2$O$_3$, 2–4 vol%) and subsequent hot-pressing at 1900–1950 ºC. The fracture toughness of SiC was sensitive to the grain boundary thickness which was controlled by grain size and amount of oxide additives. A maximum fracture toughness (6.2MPa$m^{1/2}$) was measured at 20 nm of grain boundary thickness. The mixing of 30 nm SiC (25 vol%) with 800 nm SiC (75 vol%) was effective to reduce the flaw size of fracture origin, in addition to a high fracture toughness. This led to the increase of flexural strength [Yoshihiro Hirata et al., 2010].

The effect of age-hardening on the microstructure and mechanical properties of SiCp/Al–Si–Fe particulate composites have been studied. 5 and 15% SiC additions were used for the production of two grades of composites. The composite samples were solution heat-treated at 500 ºC for 3 hours and quenched in warm water at 65 ºC. The samples were then aged at 100, 200 and 300 ºC for various ageing times between 1 and 11 hours. The microstructure obtained reveals a dark ceramic and white metal phases, which resulted into increase in the dislocation density at the particles–matrix interfaces. The mechanical
properties of the two grades of composites produced are higher in the age-hardened samples than that of the as-cast samples. It was found that hardness increases with increasing weight fraction of silicon carbide in the alloy and decreases with increasing ageing time after the peak ageing time have been exceeded [Hassan.et.al.,2008].

The tensile and fatigue properties of a 25 vol % SiC particulate-reinforced 6090 Al composite were investigated at 300°C. Fatigue cracks initiate primarily within the matrix or at random sites less than 1 µm in size. However, they occasionally initiate from sites with SiC agglomeration. At 300°C test samples exhibit large ductility during high-cycle fatigue; deformation strain increases with increasing cycles-to-failure. The macroscopic fatigue fracture mode at 300°C, changes from slip band formation at low cycles to intergranular fracture at high cycles. Crack growth occurs through plastic deformation of the matrix without particle fracture or particle/matrix de cohesion. The major change in fatigue response of 6090/SiC/25p (T6) with change in temperature from 20°C to 300°C appears to be the mechanism of fatigue crack growth. Fatigue crack initiation mechanisms remain largely unchanged [Nieh.et.al., 1995].

2.4 MACHINING OF METAL MATRIX COMPOSITES

2.4.1 Surface Roughness

The work material under investigation was Al6061/SiCw composite with 15 % and 20 % volume fractions of SiC whisker. Mono-crystal diamond tools were used for machining. The results indicate that the surface roughness of the cutting surface is affected by both the type and the volume fraction of the reinforcement. Better surface finish can be
achieved with whisker reinforced composite than that for particulate reinforced composite [Cheung et al, 2002].

El-Gallab and Sklab [1998] carried out machining investigations using Duralcan F3S.20S Al/SiC metal-matrix composite and polycrystalline diamond (PCD) tool. The SiC particles had an average diameter of 12 µm. They found that the built-up edge is formed during machining, which can protect the cutting tool from abrasion wear. However, the unstable built-up edge may induce tool chipping and adversely affect the surface finish.

LM6 Mg15 SiC-Al-metal matrix composite as casted with average particle size (APS) 23 µm, was used as composite material. Different sets of experiments were performed on a combination turret lathe. Uncoated tungsten carbide (WC) (HW-K10) insert was used for turning. Results indicated that cutting speed, feed and depth of cut are having equal influence on the surface roughness characteristics, i.e. Ra and Rt. High speed, low feed rate and low depth of cut was recommended for achieving better surface finish during turning of Al/SiC-MMC using tungsten carbide insert [Manna and Bhattacharayya 2005].

Rods of Al Si 7Mg2 material reinforced with 5, 10 and 15 wt % of SiC-p of particle size 30–60 µm were produced, 90 mm in diameter and 150 mm in length. TiN coated WC (K10) tool was used for turning. Machinability of MMC was very different from traditional materials because of abrasive reinforcement element. This was because abrasive element causes more wear on cutting tools. Flank wear of cutting tool had also increased with increase in reinforcement ratio. Influence of feed rate was not as effective as cutting speed on tool wear, but as the feed rate increased, the wear of cutting tool also
increased. In turning of AlSi7 Mg2-MMC samples, surface quality improved when cutting speed decreased. Surface roughness increased due to increasing feed rate values. It was found that increase in particle ratio affects roughness negatively [Tamer. et al, 2008].

The Work dealt with the surface integrity of machined Al 20% SiC particulate metal-matrix composites (PMMC). Dry high-speed turning tests at different cutting speeds, feed rates and depths of cut were conducted in order to investigate their effect on the surface quality and the extent of the sub-surface damage due to machining. The cutting tests were carried out using polycrystalline diamond tools (PCD). It was found that machining of this type of composite is most economical and safe at a speed of 894 m/min, a depth of cut of 1.5 mm and feed rates as high as 0.45 mm/rev, when the surface roughness (R_{max}) did not exceed 2.5 μm [El-Gallab and Sklad 1998].

2.4.2 Cutting Forces

Manna, and Bhattacharayya [2005] carried out an experimental investigation on the machinability of silicon carbide particulate aluminium metal matrix composite (LM6Mg15SiC_p) during turning using fixed rhombic tools. The influence of machining parameters, e.g. cutting speed, feed and depth of cut on the cutting force and surface finish criteria were investigated during the experimentation. Results indicate that cutting forces are more or less independent of cutting speed in range of 60 to 150 m/min. The flank wear rate is high at low cutting speed due to the generation of high cutting forces and formation of BUE during machining of Al/SiC-MMC.
20 vol% SiC particles with particle size 6–18 µm in 6061 aluminum matrix was taken as work material. The material was first direct chill (DC) cast and then hot extruded. Polycrystalline diamond (CTH025 grade from Element-6) tipped TPMN 160304 inserts were used on tool holder CTGPR2525-M16. The nose radius was 0.4 mm while rake and approach angles were 5° and 90°, respectively. The cutting edge (without edge hone) radius was measured to be 5.42 µm. A mechanics model was developed for predicting the forces when machining aluminum alloy based MMCs reinforced with ceramic particles. The force generation mechanism was considered to be due to three factors: (a) the chip formation force, (b) the ploughing force, and (c) the particle fracture force. The chip formation force was obtained by using Merchant’s analysis but those due to matrix, ploughing deformation and particle fracture were formulated, respectively, with the aid of the slip line field theory of plasticity and the Griffith theory of fracture. A comparison of the model predictions with the experimental results and those published in the literature showed that the theoretical model developed has captured the major material removal/deformation mechanisms in MMCs and describes very well the experimental measurements. The predictions revealed that, the force due to chip formation is much higher than those due to ploughing and particle fracture. A comparison between predicted and experimental force results showed excellent agreement [Pramanik.et.al, 2006].

AA6061 and AA7075 were taken as matrix material. 10 and 15 vol % alumina particles were used as reinforcement material. Particle size was 9.5 µm, 20 µm and 25 µm. An experimental investigation was carried out to study the generated forces and the changes in the microstructure of the matrix as a result of cutting. The obtained data revealed that the forces generated during cutting of MMCs can be correlated to the average dislocation
density in the matrix. This change in the microstructure, in terms of average dislocation density in the matrix, is due to the various mechanisms operating as a result of changes in the cutting conditions, material compositions and reinforcement volume fraction and sizes. It has been shown that the increase in the cutting force as a result of increasing the particle size and volume fraction can be correlated to the increase in the average dislocation density. In addition the amount of deformation in the matrix is dependent on the type of material matrix as well as the volume fraction and the average particle size [Kannan.et.al, 2009].

Work present the relationship between cutting forces and tool wear of polycrystalline diamond (PCD), measured when machining the composite A356/20/SiCp-T6 (aluminium with 7.0% silicon, 0.4% magnesium reinforced with 20 vol.% particles of silicon carbide (SiC); heat treatment: solutionising and ageing T6 for 5 h at 1548°C). The experimental work was developed considering the turning operations, through the continuous measurement of the cutting forces with appropriate piezoelectric dynamometers. The wear type was identified and its evolution with cutting time was measured. The wear mechanism was analysed by a scanning electron microscope (SEM). In turning, correlations were obtained between the evolution of flank wear of the insert and the feed and depth forces. The predominant wear was the one which developed in the flank face of the tools. The crater effect, which is common in steel machining, was not observed [Davim and Baptista, 2007].
2.4.3 Power Consumption

An experimental investigation was conducted on the machinability of fabricated aluminum metal matrix composite LM-25 (A356/SiC/10p) during continuous turning of composite rods using medium grade polycrystalline diamond (PCD 1500) inserts. Cutting conditions and parameters such as surface roughness, specific power consumed, and tool wear were measured. Machining was continued till the flank wear land on the tool crossed 0.4 mm. Results indicated that higher cutting speeds result in relatively easier removal of the hard SiC particles, resulting in better surface finish. The steady low values of Ra and Rz at a cutting speed of 400 m/min over the entire tool life span makes high speed finishing of MMC possible [Muthukrishnan et al, 2008].

2.4.4 Tool wear

Li and Seah [2001] studied machining behaviour of Aluminium alloy 2024 as the matrix, containing various percentages (2.5, 5.0, 7.5, 10.0, 12.5 and 15.0%) of silicon carbide (SiC) particles of different mean diameters (15, 38, 53 and 75 µm). They observed that coated carbide tool wear becomes acute when the percentage of reinforcement in the MMC substrate exceeds a critical value, which is determined by the density and size of the particles.

Three 2014 Al + 16SiC metal matrix composites (MMCs) with SiC particles of 30, 45 and 110 µm in mean sizes were produced using a melt stirring-squeeze casting route. Machining tests were carried out on the MMCs using cubic boron nitride (CBN) cutting tools at various cutting speeds under a constant feed rate and depth of cut. The effect of
reinforcement particulate sizes and cutting speeds on tool wear was investigated. Furthermore, surface roughness measurements were also carried out on the machined surfaces. The results showed that tool wear was mainly dominated by flank wear and strongly influenced by reinforcement particulate size. The MMC containing SiC particles of 110 µm proved to be unsuitable for the machining operation using CBN cutting tools due to the heavy fracture of the cutting edge and nose. In the composites reinforced with SiC particles of 30 and 45 µm, 150 m/min cutting speeds led to the lowest tool flank wear values while 100 and 200 m/min cutting speeds resulted in higher tool flank wear values. Both abrasive and adhesive wear mechanisms seem to be dominant in the tool wear. [Ibrahim et al, 2004].

CVD diamond-coated tools, 30 µm thick on tungsten carbide substrates, were investigated by outside diameter turning of A359/SiC/20p composite. Cutting conditions ranged from 1 m/s to 6 m/s of cutting speed, 0.05 mm/rev to 0.3 mm/rev feed, and 1 mm to 2 mm depth of cut. Tool wear was measured and compared at different machining conditions. Worn diamond-coated tools were extensively characterized by scanning electron microscopy. Cutting forces, chip thickness, and the chip–tool contact area were also measured for cutting temperature simulation by finite element analysis. The results show that tool wear is sensitive to cutting speed and feed rate. The dominant wear mechanism is coating failure due to high stresses. The catastrophic coating failure suggests the bonding between the coating and substrate is critical to tool performance. High cutting temperatures will induce greater interfacial stresses at the bonding surface due to different thermal expansions between the coating and substrate, and plausibly result in the coating failure [Kevin Chou and Jie Liu, 2005].
LM 25 aluminium alloy reinforced with green bonded silicon carbide particles of size 25 µm with different volume fractions was used for experimentation. The machining experiments were conducted on the lathe using tungsten carbide tool inserts (K10). It was concluded that feed rate has the greater influence on surface roughness, followed by cutting speed and % volume fraction of SiC [Palanikumar and Karthikeyan, 2007]. Investigation on the wear of polycrystalline diamond (PCD) and polycrystalline cubic boron nitride (PCBN) tools in the machining of Al-SiC MMC (9.27 Si, 0.15 Fe, 0.55 Mg, Al balance) 20% volume SiC, particle size 12.8 µm was carried out by turning. The binderless PCBN tools showed the highest fracture resistance. PCD tool exhibited higher wear resistance than PCBN tools and lower propensity for work material adhesion. During machining with PCBN tools without coolant, the severity of transfer material on the tools increased significantly with cutting speed. The adhesion property of the tool and the work material, apart from the tool wear appeared to have a major influence on the surface finish. One of the factors that governs the notch wear is the hardness of the workpiece. The increase in the hardness the workpiece due to a drop in the temperature brought about by the coolant may possibly be responsible for the increase in the notch wear [Ding et al, 2005].

In this study, A356 homogenised 5 wt %SiC-p (average particle size 24 µm) aluminium MMC material was selected for an experimental investigation of tool wear and surface roughness. Two types of K10 cutting tool (uncoated and TiN-coated) were used at different cutting speeds (50, 100 and 150 m/min), feed rates (0.1, 0.2 and 0.3 mm/rev) and depths of cut (0.5, 1 and 1.5 mm). In dry turning condition, tool wear was mainly affected by cutting speed. It increased with increasing cutting speed. Surface roughness is
again mostly affected with cutting speed. Higher cutting speed produced better surface finish. Feed rate was an effective machining parameter on surface roughness. Higher feed rates produced poor surface quality. TiN-coated cutting tool provided better results. It decreased tool wear and provided smoother surface finish. Homogenized heat treatment affected material adversely, it increased tool wear and surface roughness. Tool wear occurred on the flank face of the cutting tool. The tool wear mechanism was abrasion. There was no sign of the chemical wear [Kılıckap. et.al, 2005].

Machinability analysis of A356-SiC(20p) particles of mean diameter 55 μm to 80 μm (MMC) with Poly Crystalline Diamond (PCD) insert of grade 1300 was carried out. The main focus of investigation was to determine minimum power consumed by main spindle, good surface finish and minimum tool wear. The worn out insert was also analyzed under Scanning Electron Microscope (SEM). Surface roughness is good as the cutting speed increases. This is because of the stability of the tool at higher cutting speed and easy removal of material at this stage. PCD 1300 grade performs well in metal removal rate, but wear is more. The machining with the low feed of 0.108 mm/rev has resulted decrease in cutting force. Machining with high feed rate of 0.368 mm/rev with high depth of cut has resulted good amount of metal removal. 1300 grade insert is giving satisfactory result in many attributes. Increase in cutting speed improves surface finish. As the feed increases surface finish improves only up to certain level after that it starts deteriorates. Over all this insert is not suitable for machining the above said Al-SiC(20p)(MMC) [Venkatesh.et.al,2009].
Al-2124 was taken as matrix. Reinforcement particles were SiCp Vol. fraction (%) 20 and 30 (mesh size 220, 600). PCD/CBN inserts were used. Taguchi method-based design of experiment, the L27 (3^13) orthogonal array, was performed independently on composites. Results of investigation indicated that the size and volume fraction of reinforcement significantly influences the chip formation mechanism [Uday and Suhas, 2009].

The Al/SiCp composites with 10 and 30% of the volume of reinforcement required for this experimentation were fabricated using a liquid metallurgy route consisting of rheocasting followed by squeeze casting and hot extrusion. A rotary tool holder was designed and fabricated for this work. Magnitude of flank wear, magnitude of face wear, Surface finish and magnitude of forces were taken as response variables. Experiments were designed using Taguchi Methods to analyse the influence of various factors and their interactions on the flank wear of rotary carbide tools during machining. Results of analysis have indicated that, all the four factors selected for the analysis were found to be statistically significant in influencing the absolute magnitude of the flank wear. The cutting speed was found to have the most predominant influence. As wear progresses from the primary to secondary zone, it results in: Reduction in the contribution of the inclination angle, Reduction in the feed rate–inclination angle (A×C) interaction, Increase in the contribution of the feed rate, Interaction of cutting speed with feed rate and inclination angle becomes significant Volume of reinforcement significantly influences flank wear during both stages of wear [Joshi.et.al,1999].

2.4.5 Tool life

Machining of eutectic Al-Si (LM6) and hypoeutectic Al-Si (LM25) alloys reinforced with 10, 15, and 20% SiCp of two particle sizes using conventional high-speed steel (HSS) and tungsten carbide (WC) tools was carried out by varying cutting speed, feed,
depth of cut, and environment. Tungsten carbide tools had a longer tool life than HSS under all the different conditions studied [Narahari et al, 1999].

An experimental machinability study of the metal–matrix composites (MMCs) A356/SiC/20p with brazed polycrystalline diamond (PCD) tools or chemical vapour deposition (CVD) diamond coated tools was carried out. The experimental procedure consisted of turning operations, during which cutting force; cutting tools flank wear and surface roughness obtained in composite workpiece were measured. The obtained life curves showed that feed performs opposite to the cutting speed. Its growth means an increasing tool life, what does not occur with cutting speed. Actually, CVD diamond coated tools show short life, as tools wear evolution becomes very fast after coating rupture. The tools with PCD inserts are essential for machining MMCs reinforced with SiC to obtained long tool life and good surface roughness [Davim 2002].

Work material used in this study was particulate reinforced Al matrix composite (PAIMC). Tool material used was K20 carbide (both as sintered and microwave irradiated). Work material used in the present study was 2124 Al alloy (hardness: 100HB) (Cu: 4.4%, Mg: 1.5%, Mn: 0.6%, rest Al). 30 vol. % of SiC particulates, 5μm size (hardness: 2700 HV) was taken as reinforcement. K20 carbide (as sintered) SNMA 120408; K20 carbide and (microwave irradiated) SNMA 120408 tools were used. For post processing of cemented carbides, conventional multimode cavity type microwave equipment was used in the present study. The frequency of microwave radiation was 2.45 GHz. Dry turning operations were carried out on particulate reinforced Al matrix composite with a high-speed lathe (18kW, 140–5600 rpm stepless) using both traditional
sintered and microwave irradiated sintered carbide inserts with a wide range of cutting conditions. Results showed that Irradiation of cemented carbide tool with microwave energy imparts densification and phase transformation that results in improved hardness. [Varada Rajan et al 2006].

Metal matrix composites including various volume fractions of SiC particles were produced by liquid metallurgy method. 2014 Al alloy was used as the matrix material, while SiC particles with an average size of 110, 45 or 29 µm were used as the reinforcement material. The composites were fabricated by a molten metal of aluminium alloy using an electric induction furnace, which is 2 kW powered under protected argon gas. For manufacturing of MMCs, 10 and 20 wt.% SiC particles were used. It is shown that the tool life decreased with increasing the cutting speeds in all cutting conditions. The life of the tool A (Al₂O₃ coating on K15 carbide grade), was significantly longer that that of tool B (not having any chip breaker geometry and an Al₂O₃ coated on K15 carbide grade). In addition, it was observed that the major wear form of the tool wear was the mild abrasion and edge chipping on the flank face of the tools [Sahin, 2003].

2.5 MODELING AND OPTIMIZATIONS OF MACHINING PARAMETERS

Uday.et.al [2007] studied the surface integrity as a function of process parameters and tool geometry by analyzing cutting forces, surface finish and microstructure of the machined surfaces on Al/SiC/10p and Al/SiC/30p composites by using Taguchi method. The composite material was fabricated using liquid metallurgy route consisting of rheocasting, squeeze casting followed by hot extrusion. The composites were given
solution treatment such that the Al 2214 matrix material in them is devoid of copper precipitation. This way, the effect of reinforcement on the machining forces could be clearly understood. The results showed that the magnitude of cutting forces with the use of wiper inserts is lower than the corresponding wiper less inserts by about 10%. Thich could be due to larger contact length between the tool cutting edge and the work piece and consequently higher thermal softening. The statistical analysis of the cutting forces indicates that feed rate is the most significant factor influencing magnitude of cutting forces in both the composites. But the effect of depth of cut was evident only in the case of Al/SiC/30pcomposites. Similarly, feed rate was found to influence the machined surface roughness in both the composites. The microstructural analysis of the machined surface shows that the number of feed marks, pits and cracks on the machined surface are significantly reduced using the wiper inserts, especially in the case of Al/SiC/30p composites. The presence of matrix coated fragments of reinforcement particles was evident on the machined surfaces. The state of residual stresses changes from tensile on the unmachined surface to compressive on the machined surfaces. Also, machining with wiper inserts at higher depth of cut induced higher compressive residual stresses on the machined surfaces than that of wiperless inserts for the same cutting speed and feed rate conditions.

Muthukrishnan and Paulo Davim [2009] analyzed the surface roughness of Al–SiC (20 p) by turning the composite bars using coarse grade polycrystalline diamond (PCD) insert under different cutting conditions. Experimental data collected was tested with analysis of variance (ANOVA) and artificial neural network (ANN) techniques. Multilayer perceptron model was constructed with back-propagation algorithm using the input
parameters of depth of cut, cutting speed and feed. Output parameter is surface finish of the machined component. On completion of the experimental test, ANOVA and an ANN were used to validate the results obtained and also to predict the behavior of the system under any condition within the operating range. In ANOVA, it was revealed that the feed rate has highest physical as well as statistical influence on the surface roughness (51%) right after the depth of cut (30%) and the cutting speed (12%). ANN was used to learn the collected data. Neural network configuration (3-10-1) was trained using 18 patterns. The results of neural network model shows close matching between the model output and the directly measured surface roughness. This method seems to have prediction potentials for non-experimental pattern additionally. ANN methodology consumes lesser time giving higher accuracy. Hence, optimization using ANN is the most effective method compared with ANOVA.

Silicon carbide dispersed aluminum alloy 6025 MMC with 20 vol % silicon carbide was chosen for the study. Turning experiments were performed on the hot workpiece of 55 mm diameter and 400 mm length. The tool insert used was K20 series. It has a thick layer of Al$_2$O$_3$ on top of the medium-sized Ti(C, N) layer. The total thickness of the coating is approximately 10 µm. This investigation was aimed at proposing a new methodology for the optimization of hot machinability of a material using the dynamic material model (DMM) stability criteria. The constitutive flow behavior of Al-20 % SiC has been evaluated in the temperature range 50 °C to 350 °C and the cutting velocity in the range from 25 and 300 m/min with the view to optimizing its machinability using the DMM instability parameters. The DMM instability parameters predicted a narrow region around 150 °C and 150 m/min as the optimum domain for machining this material. It has been
observed that the tool wear is minimum at optimal conditions. This investigation proved that the machinability could be optimized through the DMM [Mohan.et.al.2008].

The Al–2124/SiCp composites with 20 and 30 vol % of SiCp reinforcements and of 220 and 600 mesh sizes were fabricated by the powder metallurgy route. The surface roughness was considered as a dependent variable. The magnitudes of feed-rate (10, 60 and 110 mm/rev) and depth of cut (50, 100 and 150 mm) were chosen such that they are closer to the size of reinforcement (15 and 65 µm). The tool-nose radius (0.2, 0.4 and 0.8 mm) was selected based on the available geometry of PCD tools. A response surface-based D-optimal design consisting 29 experimental runs, that considers five factors of which two are at two-levels and the remaining three at three-levels was found to provide the suitable framework for this experimentation. A total of 58 experimental runs (including one replication) as per the design were performed. Analysis of machined surface quality and development of an ANN based model to predict surface roughness in machining of composites shows that; the size of reinforcements in the composite material influences roughness of the machined surfaces significantly; when its magnitude is comparable to that of the feed-rate and the tool-nose radius employed during machining of the composite material [Basheer.et.al, 2008].

Genetic Algorithm (GA) was used for the selection of cutting conditions and tool inserts in multipass turning operations. A comprehensive criterion including major machining performance measures was used in the optimization process. The user can control the optimization process by configuring weighting factors for different machining performance measures. A total objective function combines all the machining
performance measures in all passes of the operation. The aim of the optimization process is to make a trade of among these passes and to give combinations of optimum cutting conditions in different passes. The results show that this methodology can balance the cutting conditions very well between passes and it is effective for determining optimum cutting conditions as well as for the selection of cutting tool inserts for multipass turning operations [Wang et al., 2002].

In constrained optimization problem like turning process, real coded genetic algorithm (RCGA) approach is necessary to get the optimum solutions faster. This would be helpful for a manufacturing engineer to choose machining conditions for desired machining performance of a product. With the known boundaries of surface roughness and machining conditions, machining could be performed with a relatively high rate of success, with selected machining conditions. Integration of the proposed approach with an intelligent manufacturing system will lead to reduction in production cost, reduction in production time, flexibility in machining parameter selection and overall improvement of the product quality [Srikanth and Kamala, 2008].

2.6 MULTI CHARACTERISTIC OPTIMIZATION

This work optimises the multiple characteristics (tool life, cutting force, surface roughness and power consumption) in CNC turning of AISI P-20 tool steel using Principal Component Analysis (PCA). Five controllable factors of the turning process were studied at three levels each viz cutting speed, feed, depth of cut, nose radius and
cutting environment. L27 Orthogonal array was used for conducting the experiments. The single response optimisation was conducted by Taguchi method. PCA was employed to Correspond to multi response cases. The optimum combination of process factors based on first principal component was determined which was subsequently studied by extracting more then one principal component and integrating into comprehensive index. Finally, the Analysis of Variance (ANOVA) was used to find out the most influential CNC turned parameter for multiple response problems. It was concluded that middle level of cutting speed (160 m/min) and nose radius (0.8 mm) and lower level of feed (0.1 mm/rev) and depth of cut (0.2 mm) can yield optimal result. Both single response and multiresponse optimization has proved that cryogenic machining environment (D3) is favourable in increasing tool life and reducing surface roughness, cutting force and power consumption compared to wet (conventional coolant ILO cut 154 Indian Oil recommended for CNC machine) and dry machining [Aman Aggarwal.et.al, 2008].

2.7 IDENTIFICATION OF GAPS IN THE LITERATURE

On thorough scrutiny of the published work on the fabrication, characterization and machining of MMCs, the following observations have been made:

- Although, stir casting process has been used for fabrication of Al alloy SiC composite, little work has been done to fabricate 7075 Al alloy SiC composite with varying % of SiC, which also has minimum porosity.

- Literature lacks in furnishing consistent and sufficient investigation about the coefficient of thermal expansion, Young's modulus and peak frequency of 7075Al alloy composite.
• Compressive strength of 7075 Al alloy and 7075 Al alloy composite fabricated by stir casting has not been investigated.

• Some work has been reported about the machining of Aluminium-SiC composite. No investigation has been done about Machining of 7075 Al alloy SiC composites on Computerised Numerical Controlled (CNC) Turning Machine.

• Optimization of process parameters during machining of 7075 Al alloy SiC composites has not been studied.

• Multi characteristics optimization of process parameters during machining of 7075 Al alloy SiC composites has not been studied.