State-of-Art Review of Ceramic Reinforced Aluminum Metal Matrix Composite and it’s Machining Characteristics

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ABSTRACT

Aluminium matrix composite (AMCs) are first generation metal matrix composite, which are the novel materials for applications in multifarious fields owing to their good tribological, mechanical and physical properties. These first generation AMCs are replaced nowadays with hybrid AMCs called as second generation or new generation MMC to satisfy the advanced engineering applications. The need at the moment is to meet the specific demands such as improved strength, hardness, stiffness, creep, fatigue, corrosion and wear properties. For these AMCs are selected ahead of the conventional engineering materials. The type of matrix material, reinforcing element and processing methods determines the AMCs’ properties. This paper outlines the overview of Al 7075 aluminium alloy reinforced with different particulates. The metallographic phenomenon of this AMCs like agglomeration, bonding strength, distribution of particulates in the matrix are discussed. Furthermore, techniques for fabricating these materials are discussed in brief. Apart from these, various machinability characteristics of these AMCs are also reviewed exclusively for better understanding the composite.

KEY WORDS: Aluminum MMC, particulate reinforcement, Mechanical properties, Metallographic study, Wear properties.

1. INTRODUCTION

Composites are materials comprising of more than two components with disparate properties and noticeable boundaries between the components (Guneri Akovali, 2011). Composites are classified into two factions. The first faction subsumes composites which are known as ‘filled materials’, the presence of some basic or matrix material is its feature and by filling it with some particles the properties can be improved. The ‘reinforced materials or advanced composites’ are the second faction of composites, long and thin fibers with high strength and stiffness are the basic components of these materials. The volume fraction of fibers in a composite is usually less than 50% which is bounded with a matrix material.

Materials that are stronger, lighter and less expensive are the Current engineering applications. For In-service performance demands, the materials with broad spectrum of properties, which are quite difficult to meet using monolithic material systems are the requirement of many modern engineering systems (Black, 2007). The alloys of light metals (Al, Mg and Ti) are utilized as common metallic alloys however, zinc (Zn), stainless steel and copper (Cu) are other metallic alloys that have been used. Superior characteristic profiles of MMCs have been obtained by the combination of the properties of ceramic reinforcements (high strength and high modulus) and the metallic alloys (ductility and toughness).

In the development of MMCs the most utilized metallic alloy, Aluminium remains as matrix material. In aircraft, aerospace, automobiles and various other fields Aluminium MMCs are widely used (Joseph Davis, 1990). High strength-to-weight ratio, superior tribological properties and corrosion resistance behavior are the well-known properties of Ceramic-reinforced aluminium matrix composite materials, by these properties they are replacing their monolithic alloys (Senthilkumar, 2015). Composition, grain size, microstructure and the fabrication process decides the strength of composite materials. Recent studies proved that by the addition of ceramic reinforcements, a significant improvement in the tribological properties (including sliding and abrasive wear, friction and seizure resistance) of aluminium alloys can be attained.

A need often exists for machining, even though MMCs are manufactured to near net shape. The reinforcement material, type of reinforcement (particle or whisker), distribution of reinforcement in the matrix, and volume fraction of the reinforcement and matrix decides the machining characteristics. Due to the presence of hard and brittle reinforcements, machining results of MMC differs from metal machining (Selvakumar, 2016). Response to machining is entirely different, while machining tool encounters matrix and reinforcement materials alternatively. The high tool wear, which leads to an uneconomical production process or makes the process impossible, is the main problem in machining MMC.

Ceramic reinforcements are used as a primary reinforcement for development of hybrid composites owing to the fact that these possess superior strength than any other type of reinforcement. Readily available nature and lower density of the hybrid composites leads to the reduction of cost by the secondary reinforcements. Optimization of material properties is achieved by the combination of properties of the hybrid reinforcements (primary and
secondary). As stir casting technique is economical, simple to perform and highly productive method it is used for the fabrication of AMCs and also this method reduce the cost of composites.

This paper reviews the development of low cost- high performance composites with high feasibility and viability, with ceramic particles as reinforcement and aluminum as matrix, suitable for aerospace and automotive applications. Furthermore, the effect of the fabrication process, type of reinforcement, effect of reinforcement fraction, particle size on mechanical and physical properties of Al matrix ceramic-reinforced composites are further investigated and reported.

Types of reinforcements in Al MMCs: Among the availability of multifarious MMCs, benefits such as low density and high specific strength are offered by aluminum matrix composites (AMCs). It is well known that significant improvements in wear and erosion resistance, stiffness, hardness and strength are lead by introducing a hard particle in an Al-matrix. AMC’s can be reinforced with silicon carbide (SiC), Boron carbide (B₃C), aluminum oxide (Al₂O₃), titanium carbide (TiC), titanium dual Boron (TiB₂), magnesium oxide (MgO), titanium oxide (TiO₂), graphite (Gr), Zirconia (Zr), flyash, Silicon nitride (Si₃N₄) etc. The ceramic reinforcements of less than 30% volume fraction are used for wear resistance and structural applications. But, reinforcement volume fraction could be as high as 70% in electronic packaging applications. Mechanical properties obtained by particle reinforced AMCs are lower compared to whisker/short fiber/continuous fiber reinforced AMCs but far higher than the unreinforced aluminum alloys. These composites are subjected to variety of secondary forming operations including forging, rolling and extrusion and they are isotropic in nature.

Preparation methods of Al MMCs: This ceramic particle reinforced AMCs are manufactured either by liquid state (infiltration, stir casting and in-situ) or by solid state (powder metallurgy processing) processes.

Powder metallurgy: Near-net or net-shape manufacturing process known as Powder Metallurgy (P/M) process, which combines the features of development of final material and design properties (physical and mechanical) with the shape-making technology for powder compaction during subsequent densification or consolidation processes (e.g. sintering). This manufacturing method is split into two main factions: conventional press-and-sinter methods and full-density processes.

The conventional press-and-sinter process technologies follow the procedure of selection of ingredients and additives, mixing the right proportion of powders followed by warm or cold compaction method. Powder is compacted in hard tooling using a vertical compaction motion, the product size and shape are limited by the constraints of available press capacity, powder compressibility, and the density level required in the product. If solid-state diffusion is the primary sintering mechanism, very little densification occurs, dimensional change is minimal, and tolerance control is very good. To yield a product as close to full density as possible, specifically the second group of powder process technologies are been formulated. This contrasts significantly with the previous conventionally processed products where attainment of full density was not the primary goal. Powder forging (P/F), metal injection molding (MIM), hot isostatic presssing (HIP), roll compaction, hot pressing and extrusion are the full-density processes. Antony and Selwin (2016), blended TiO₂ (mass fraction of 0, 4%, 8%, 12%) with Al–15% SiC composites by the process of P/M to inhibit the effect of rutile (TiO₂) content on the micro hardness and dry sliding wear behavior. Majzoobi (2015), studied the dynamic compaction and hot quasi-static pressing of Al7075-B₃C composite powder using mechanical drop hammer and single-stage gas-gun and found that Vickers micro-hardness of the compacts improved with the increased proportion of B₃C, but compressive strength doesn’t increase.

Stir casting: In stir casting process, the reinforcement filler is introduced in a continuously stirred molten matrix and then cast by sand, permanent mold, or pressure die casting (Senthilkumar, 2014). In this process, a vortex generated by an impeller mixer that draws the reinforcement from top down into melts. A vacuum or an inert atmosphere is needed to avoid entrainment of gas. Segregation and stagnating of the reinforcement in the melt, reinforcement agglomeration, reinforcement fracture at the time of stirring are the difficulties and, since the time in the melt is long, extensive interfacial reactions. Good reinforcement wetting can be a problem, and reinforcements are often pretreated prior to casting to promote wetting (Sallahauddin, 2015). Particle sedimentation and agglomeration in the melt can cause heterogeneities. Reinforcement redistribution can be caused by gravity effects and from the reinforcement which has been pushed by an advancing solidification front. Proper stirring helps to prevent many of these problems (Bhojan, 2016). Uniform distribution of particles can be achieved with mechanical stirring setup.

Infiltration: Except the usage of mechanical pressure instead of gas to promote consolidation, similarity exists between Pressure infiltration casting (PIC) and squeeze casting. In PIC, isostatically applied gas pressure is obtained by an evacuated particulate or fiber preform with molten metal. After the preheating of mold, the desired superheat temperature of aluminum melt has been reached, and then the inert gas pressure is applied in the range of 1 to 10 MPa. When the liquid aluminum infiltrates the preform, the isostatic state is approached and thus the pressure acting on the mold quickly dissipates; therefore, large and expensive molds are not needed since the mold only supports the pressure difference for a very short period of time.
Yan Cui (2016), studied the aging behaviors of SiCp/Al-Mg-Si composite fabricated by pressure less-infiltration technique with high-volume-fraction of SiCp, concluded that the aging behavior of the composite has been changed. Contreras (2000), carried out infiltration process of several alloys (Al-2024, Al-6061, and Al 7075) into preforms of TiC by sintering for one hour under argon at 1250, 1350, and 1450°C to achieve different levels of densification. Prasanth (2016), developed Al7075/SiC composite through gravity infiltration technique without the application of pressure, and performed hardness, compression test on the prepared composite.

**In-situ and Ex-situ:** Generally ex-situ processes are used to add reinforcement particles to alloy matrices, poor wettability, formation of reaction products at the interface, particle size limitation etc. are the drawbacks. The particle reinforcement is produced within the melt itself, in in-situ processes which exhibit good interfacial bonding with the matrix (Feng Wang, 2005). Due to smaller particle size (<2μm), during casting they tend to agglomerate. Including the distribution of the particles within the matrix, the composite property depends on a number of microstructural features. Bin Yang (2011), developed a technique called in situ reaction technique to prepare TiC/7075 composites for eliminating the problems of loss and agglomeration of reinforcement particles when they are in situ formed in a molten. Sivasankaran (2014), prepared an in-situ metal matrix composite AA 7075-ZrB2 by the chemical reaction of two chemical salts of Potassium Hexafluorozirconate (K2ZrF6) and Potassium Tetra fluoro borate (KBF4), to form Zirconium Boride (ZrB2) reinforcement in the matrix and observed its machining behavior.

**Microstructural Evaluation:** Microstructural evaluation was done in order to observe the particle dispersion in the matrix (Shorowordi, 2003). A typical micrograph of LM14 aluminium alloy with 33μm size B4C particle composite is shown in Fig.1, which shows the uniform particles distribution in the matrix, due to the stirring of molten metal in an inert atmosphere at 300 rpm (Siddhartha Prabhakar, 2014).

![Figure 1. Micrograph of LM14-B4C composite](image1)

The micrograph of AMC containing B4C of size 37 μm, in various proportion of such as 5%, 10% and 15% by weight in Al 7075 matrix during the stir casting process and heated up to a temperature of 750°C, for melting as in Fig.2, showing the uniform distribution of ceramics in the Al matrix (Mohankumar and Kanthababu, 2015).

![Figure 2. Micrographs of Al7075 reinforced with boron carbide (a) Unreinforcement A1 7075 (b) A1 7075+5%B4C](image2)

Density is the property that reflects the physical characteristics of composite, in which volume fraction is used to express the proportion of matrix and reinforcement. By rule of mixtures:

\[ \rho_c = \rho_m V_m + \rho_r V_r \]  

Where \( \rho_c, \rho_m \) and \( \rho_r \) are the densities of composite, reinforcement and matrix, whereas \( V_r \) and \( V_m \) are the volume fractions of matrix and reinforcements. Experimentally, densities of a matrix alloy and its composite are determined by water displacement technique. In Al7075+3% B4C reinforced with varying proportion of SiC, experimental and theoretical densities are in line with each other and confirms the suitability of the liquid metallurgy technique and density of composite is higher than the base material, and density increases with increase in filler content as in Fig.3 (Uvaraja, 2015).

![Figure 3. Density comparison of cast Al7075+3%B4C+SiC](image3)
Qiang Shen (2014), prepared Al-7075/B4C composites with high relative densities at low temperature using plasma assisted sintering method. For B4C content of 7.5 wt.%, the relative density of the resultant composite is 99.64% as shown in Fig.4.

**Figure 4. Relative densities of composites Al-7075/B4C (Wu, 2014)**

Good mechanical performance depends strongly on a non-heterogeneous distribution of the reinforcement in the end product (Rajmohan, 2013), and micrographs shown in Fig.5, reveal no porosity or flaws in either the Al-7075 matrix alloy or the Al-7075/B4C composites (Wu, 2014). It is seen that the B4C particles are distributed discretely, homogeneously and randomly in the matrix at 2.5 and 7.5 wt.% B4C; however, B4C increasing up to 12.5 wt.% produces aggregates in some regions. Representative images of samples with optimum B4C weight fractions are also shown in figure.5, which reveals a good interface between the matrix and the reinforcement with no porosity or flaws; additionally, it reveals precipitates and dislocations adjacent to the interface.

**Figure 5. Distribution of particles in Al-7075/B4C composites (Qiang Shen, 2014) and matrix/reinforcement interface in Al-7075/7.5 wt.% B4C composites**

The SEM image of LM6 composites containing hybrid reinforcement is shown in Fig.6, which again revealed the uniformity in distribution behavior. At higher reinforcement levels, the agglomeration of TiO2 particles was observed as shown in Fig.4. This agglomeration of reinforcements can produce highly anisotropic behavior of the composite materials, which further tends to decrease the properties (Rohit Sharma, 2015).

**Figure 6. SEM images showing hybrid composites with 15% (10% TiO2+5% Gr) and 20% hybrid reinforcement**

**Mechanical properties of Al MMCs**: The mechanical properties through which the Al MMCs are characterized are: tensile strength, hardness, impact strength, compression strength and fatigue and corrosion behavior. It is noticed that, improvement of mechanical properties were obtained by the addition of ceramic particles such as SiC (Jeykrishnan, 2016) and with the addition of B4C (Baradeswaran and Perumal, 2013) and also with the addition of red mud along with the ceramic particle reinforcement (Pradeep, 2014). When the content of the particles in MMC increases, the tensile strength increases because, the addition of the reinforcement particles hinders the plastic deformation in the matrix and it’s been clear that the sample with higher % of SiC absorbs more energy than other samples in impact test and is also observed that, because of the presence of the increased ceramic phase, comparison of increasing hardness of composites with the base alloy is done. With the addition of B4C reinforcements the aluminium alloys’ hardness increases as shown in Fig.7. Due to the addition of 10 wt. % B4C particles and 5% graphite hardness increases, which can be attributed to the fact that the graphite and B4C possess higher hardness and the hardness of the composite is improved due to the presence of graphite and B4C in the matrix Baradeswaran (2014).
Baradeswaran and Perumal (2013), revealed that, due to the increment of strain energy, the hardness of the composites is gained at the peripheral of the particles dispersed in the matrix. The tensile results are shown in Fig.8. On observation the tensile strength has also been increased on increasing the content of B$_4$C particle, and is significantly higher than the strength of the matrix alloy. The improvement in strength noticed with the addition of particles of B$_4$C particles, could be due to the induction of higher strength to the matrix alloy, by offering high resistance to the tensile stresses. This is due to the load transfer from the matrix to the reinforcement which increased the tensile strength of composites.

Observation of the tensile strength shows the increase with increasing B$_4$C particle content and the strength of the matrix alloy is significantly higher as given in Fig.8. Due to the induction of higher strength B$_4$C particles into the matrix alloy, the strength is improved, which offers more resistance to the tensile stress. The defeat was overcome, due to the addition of weaker graphite particles which is low (5 wt.%) compared to harder B$_4$C particles. The impact strength of SiC reinforced Al7075 alloy increases with increase in SiC addition as shown in Fig.9 (Deeparaj, 2016).

The weight loss increases as the reinforcement of boron carbide increases inside the matrix of A356. The carbon particle in the boron carbide reacts with the NaCl solution and forms rust surrounding the particle increasing the corrosion rate as in Fig.10 (Sridhar Raja and Bupesh Raja, 2015). It is owing to the presence of very little amount of iron present in the aluminium matrix alloy.

It is observed that the load bearing capacity of the composite is increased by 56.54% when the reinforcement of B$_4$C particulates is increased from 2.5% to 5% whereas the load bearing capacity of the MMC decreases by 0.97% when the reinforcement of B$_4$C particulates is increased from 5% to 7.5%. This is also due to the loss of ductile property and limitation in the plastic deformation of the aluminum metal matrix by adding more amount of B$_4$C particles as given in Fig.11 (Senthilkumar, 2014).
Composite Karunanithi (2014), studied the corrosion behavior of Al7075+TiO₂ composite through potentiodynamic electrochemical polarization technique and observed that, the microstructures of sintered Al 7075 alloy and Al 7075 alloy reinforced with varying TiO₂ composites exhibited uniform distribution of TiO₂ particles, but clustering and porosity have increased with TiO content. Studies on Al 7075 + TiO₂ composites in 3.5 wt.% NaCl solution showed that the corrosion potentials have shifted towards noble direction with the addition of TiO and there is an increase of corrosion current density beyond 10 vol.% TiO in the composites. The wear resistance and compressive strength of Al MMCs increase with the addition of Zircon sand reinforcement. The addition of flyash reinforcement in Al increases the wear resistance but decreases the corrosion resistance (Vijaya Ramnath, 2014).

Figure.11. Compression strength of Al+Gr+B₄C

Wear properties of Al MMCs: A tribometer is an instrument that measures the tribological quantities such as coefficient of friction, friction force, and wears volume, between two surfaces in contact. The simplest of the tribometer is pin-on-disc tribometer, consisting of a stationary pin that is spherical in shape, which will be in contact with the rotating disc for a given load. Coefficient of friction is determined by the ratio of the frictional force to the load applied on the pin. Wear rate is calculated by the formulae given in Equ.2.

\[
\text{Wear rate} = \frac{\Delta w}{2\pi N t} \text{ g/cm} \cdot \text{min}
\]

Where \(\Delta w\) – is the difference in weight before and after wear test \(w_1 - w_2\) (gm.), \(2\pi N t\) – is the sliding distance (cm), \(N\) – is the rotational speed of the disc (rpm), \(t\) – is the time period of wear test (min).

The hardness and wear resistance of the hybrid composites were superior to that of the matrix material and that of simple composites. Furthermore, hardness of the composites containing SiC and Al₂O₃ was higher than that of the composites with SiC and Gr due to the combined pinning effect of SiC and Al₂O₃ and the higher hardness of Al₂O₃ to that of the Gr. However, composite containing Al₂O₃ despite its hardness has inferior wear resistance to that of the composites containing Gr (Fig.12) because Gr exhibits higher solid lubricating effect than Al₂O₃ (Michael, 2015).

Figure.12. Change in wear rate with sliding distance of Al-SiC/Gr and Al-SiC/Al₂O₃ surface hybrid composite (Devaraju, 2013)

The wear rate decreases with increasing graphite content and it was found to be minimum at 5 wt.% graphite, beyond which wear rate increases and it was found to be less than that of the matrix material as in Fig.13. At higher graphite contents, a complete reversal in the wear behaviour was noticed. This reduction in wear rate due to higher graphite content may be due to the following factors; formation of a thin lubricating rich film on the tribo surfaces, addition of higher graphite content thereby increasing the porosity and cracks and deterioration of mechanical properties (Baradeswaran, 2014).

Figure.13. Wear behaviour of Al7075+ Gr composite

Fig.13, Wear behavior of Al7075+Gr composite The average coefficient of friction reduced with increasing graphite content as compared to the base alloy and wear behaviour of the composites depends upon the thickness of the graphite layer at the sliding surface Baradeswaran (2014).
Wear behavior of LM6+Gr+TiO₂ results revealed that the wear rate of the aluminium alloy increased linearly with increasing the load and show less resistance to the wear as in Fig.14. Initially COF is higher in the initial stages due to interlocking of surfaces and higher frictional force required to slide the surface over one another. With an increase in the normal load, the COF increases in linear trend for LM6 alloy except for specimens containing graphite. Further, higher reinforced composites at higher loads causes smearing of non-uniform tribo layer and causes more metal to metal contact and increases COF (Rohit Sharma, 2015).

![Figure.14. Wear behavior of Al hybrid composite](image1)

At lower sliding speeds, the COF is higher, which further reduces on increasing sliding speeds and at higher sliding speeds COF starts increasing. This behavior is due to the fact that at lower sliding speeds, higher amount of heat is generated at particular area due to higher contact time. SEM micrographs in Fig.15, shows that few dislocations and delaminations were observed owing to higher hardness and lubrication provided by graphite whereas, the surface of aluminum alloy shows the mixed mode of wear phenomena’s involving delamination, plastic deformation of surface, cracking, ploughing and micro cutting (Rohit Sharma, 2015).

![Figure.15. Wear mechanism of Al hybrid composite](image2)

TiO₂ is best suited for high temperature, high load and medium speed applications when reinforced with Al7075 alloy (Sugumar, 2015). It has durability to withstand heat and pressure. TiO₂ and flyash hybrid metal matrix composites is suitable coating material for journal bearing applications because of its low wear rate, no fluctuation on wear rate.

**Machinability studies on Al MMCs:** Anand Babu (2015), performed drilling studies on Al7075/10% - SiCp composite under MQL Condition using Fuzzy Logic using three drill bits of TiN coated HSS, TiAlN coated HSS and plain HSS with cutting fluids as dry, diesel and vegetable oil and observed that, surface roughness is observed at high cutting speed is low as compared to low cutting speed. The experimental results indicated that the surface roughness parameter is low at high feed as compared to the low feed. Effect of tool material on drilling of Al7075/10%- SiCp composite indicated that the surface roughness reduces with use of TiAlN coated tool as compared with HSS tools. Also the experimental result indicates that low surface roughness is observed for high point angle and Diesel as cutting environment. The feed is the prevailing parameter which affects the surface roughness of Al7075/10%- SiCp composite, followed by point angle, tool material, speed and cutting environment. Taskesen and Kutukde (2013), evaluated the machining parameters and optimized with grey relational analysis in drilling B₄C reinforced MMCs produced by powder metallurgy using HSS, TiAlN coated and uncoated cementide carbide drills under dry cutting conditions, for optimizing the parameters feed rate, spindle speed, drill material and wt.% of B₄C particles based on multiple performance characteristics including thrust force, torque and surface roughness. It is found that, drilling forces significantly increased with increase in B₄C fraction and feed rate. The effect of cutting speed on the surface roughness declined as particle content increased. The most effective factor on grey grade was found to be wt. fraction, followed by drill material. Sener Karabulut (2016), performed milling with two passes for all the cutting parameters on Al6061+B₄C composited and observed that the tool wear was changed with respect to the reinforcement fraction of B₄C and cutting conditions. The cutting insert failure by fracturing was not observed during the experiments and machining was stable. A small quantity of BUE formation was noticed at higher cutting speed and feed rate combination in the milling of 5 wt% B₄C. For this reason, the quality of machined surface was decreased as in Fig.16. Abrasion and cutting tool chipping were observed at higher feed rates in connection with higher B₄C volume of reinforcement particles in the matrix structure. In addition to this, surface quality was not affected adversely at lower feed rates and higher cutting speeds.
Figure.16. Milling behaviour of Al6061/B4C composites

Fig.16, Milling behavior of Al6061/B4C composites Sener and Halil (2015), fabricated aluminum alloy 7075 (Al7075)-based open-cell silicon carbide (SiC) foam composite and the machinability as investigated during milling using an uncoated carbide tool. The analysis results show that the feed rate was the most significant milling parameter affecting surface roughness of both Al7075 and the open-cell SiC foam composite. Prediction models have been developed for the surface roughness through regression analysis and ANNs. The test result showed that the three-dimensional open-pore SiC foam network reinforcement was restricted the movement of the soft matrix and provided an acceptable surface quality in the milling of MMCs.

Vamsi and Gopinath (2014), performed milling studies on Al7075+SiC MMC and predicted surface finish by correlating the machining parameters with surface roughness using multiple regression technique and optimization of machining parameters using Response surface methodology and found that surface roughness increases with the increase in cutting diameter up to certain value, then further increases at high cutting diameter. The surface roughness decreases with increase in cutting speed and further increases as the cutting speed increases. The surface roughness decreases up to a certain value and then increases with increase in depth of cut. The surface roughness value decreases with increase in feed rate Selvakumar (2016), evaluated the machinability behavior of Al–4% Cu–7.5% SiC metal matrix composite (MMC) prepared by powder metallurgy (P/M) technique. Turning operation is performed by varying machining parameters and experiments are designed using Taguchi’s Design of Experiments (DoE), and found that depth of cut is the influential parameter that contributes toward output responses. A metaheuristic evolutionary algorithm nondominated sorting genetic algorithm (NSGA-II) is applied to optimize the machining parameters for minimizing wear and maximizing metal removal considering surface roughness as constraint as in Fig.17.

Figure.17. Pareto optimal Front For combined objectives

Fig.17, Pareto optimal front for combined objective Ramkumar (2015), performed turning studies on AA 7075-3% TiB2-1% Gr hybrid in situ composite and found that, the surface roughness value of AA 7075/x% TiB2/1% Gr hybrid composite exhibited higher value with respect to higher spindle speed and feed rate when compared to AA 7075/3% TiB2 composite and by using 0.8 mm nose radius insert exhibits good surface finish compared to the 0.4 mm nose radius insert. Chip thickness increased when depth of cut and feed rate increased, and discontinuous chips formed as these parameters increased. While adding graphite to the metal matrix composite, more discontinuous chips formed. The size of these chips also decreased when the cutting speed, feed rate, and depth of cut increased, which are given in Fig.18. Less tool damage was observed in 0.8 mm nose radius insert as in Fig.19.

Figure.18. Chip morphology of Al 7075-3% TiB2-0%Gr and Al 7075-3%TiB2-1%Gr composite
2. CONCLUSION

This paper presents a state-of-art review of Aluminum metal matrix composite reinforced with ceramic particles through different processing techniques. The findings of the review are:

- A perfectly homogeneous distribution of reinforced particles is possible by stirring when processed through liquid metallurgy or stir casting technique. In the matrix phase, when the aluminum matrix composites were processed through liquid metallurgy or stir casting method. With increase in reinforcement, density of the composite increases, but with increase in porosity, density decreases.
- Hardness, tensile strength, impact strength increases with increase in ceramic reinforcement, but tends to reduce with increase in porosity.
- In-situ preparation of AMCs are preferred over ex-situ composites, due to better control of microstructure, which leads to better mechanical and wear properties.
- Wear behavior of ceramic reinforced AMCs are improved with increase in volume fraction of reinforcing materials but coefficient of friction tends to increase with reduction in lubrication.
- Machinability studies show that, for machining ceramic reinforced AMCs, advanced cutting tools are needed to obtain better surface finish, lower tool wear and power consumption and enhanced material removal rate with reduced cutting forces.

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