MICROSTRUCTURAL CHARACTERISTICS AND MACHINABILITY OF Al7075 METAL MATRIX COMPOSITES – A REVIEW

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Abstract : Metal matrix composite offers a tailormade combination of properties currently required for huge range of engineering applications. In hybrid metal matrix composites, various reinforcement with desired properties are added to incorporate the properties to the base matrix. Mostly the machining of this hybrid MMC's are machined by conventional and nonconventional machining ranging from drilling, milling, turning to electric discharge machining (EDM), wire cut EDM, abrasive water jet machining. This paper reviews the fabrication techniques, microstructural analysis, mechanical properties and machinability properties of the Al7075 metal matrix composites.

***IndexTerms* – Hybrid MMC's, Microstructural, Machinability, Tensile strength.**

I. INTRODUCTION

Metal Matrix Composites (MMCs) plays a major role in the recent demands of advanced engineering applications. MMCs are used widely in aerospace, automobile, sports, recreation industries and defence. These MMCs has a less density and higher strength and stiffness due to the combination of two or more materials correspondingly matrix and reinforcements. Mostly metals like aluminium, magnesium and titanium are used metal matrix and the reinforcements such as Tic, Al_2O_3, B_4C, Gr, ZrO_2. Of these any two discrete reinforcements are used then they form Hybrid Metal Matrix Composites, which are non-homogenous and anisotropic but they have balanced strength, stiffness, wear resistance, reduced notch sensitivity, high fatigue toughness, high damping capabilities. The properties of these MMCs depend on the matrix and reinforcements and their proportions. Mostly aluminium is used as matrix and the TiC, SiC are used as reinforcements.

Researchers have reinforced various materials and have studied about their strength and machinability properties. This paper reports the review of various research works on aluminium matrix with different reinforcements. The microstructural characteristics, strength and the machinability were studied.

II. FABRICATION TECHNIQUES

Lakshmi et al. (1998) fabricated Al -TiB_2 metal matrix composites using K_2TiF_6 and KBF_4 salts by exothermic reaction at 850^o C for a period of 10 to 40 minutes [1]. The studies reveal that the TiB_2 salts up to 14.7 weight percentage is formed by the exothermic reaction between the Ti and B salts in the aluminium. C. Raja et al. (2014) synthesized Al7075 and Al_2O_3 by high energy ball milling process [2]. Al7075 powders were blended with 10 vol% Al_2O_3 compacted at 400MPa and degassed at 350^o C for 30 minutes and then sintered at 600^o C under argon atmosphere for 120 minutes. It was concluded that the ball milling improves the distribution of alumina particles throughout the matrix and decrease the crystallite and reinforcement particle size. It is further stated that milling improves the corrosive resistance. Cuaguang Chen (2015) synthesized the Al matrix composites reinforced with hexagonal boron nitride (h-BN) by semi solid powder metallurgy technique with nearly full densification mechanism [3]. It was noted that the densification makes the material ultimately denser. Deaquino-Lara et al. (2011) synthesized the Al7075 graphite composite from elemental powders by milling processes followed by hot extrusion [4]. The mechanical properties were found higher than plain Al7075 alloy due to the increase in the Graphite particles.

Lakshmanan et al. (2015) fabricated aluminium alloy-nano boron carbide metal matrix composite (AA6061/nano-B_4C_p) by ultrasonic cavitation casting process [5]. It is noted that nanocomposites show refined matrix grains compared to unreinforced alloys. Peng Yu et al. (2003) synthesized Al-based metal matrix composite reinforced with Al_2O_3 and TiC submicron particle by hot isostatic pressing [6]. The results revealed the elimination of brittle Al_3Ti_3 plates and to a more uniform distribution of fine reinforcement in Aluminium Matrix. Nassim Samer et al. (2015) synthesized Al-MMCs by reacting Al_3Ti and Graphite by ball milling process followed by compaction [7]. This composition resulted in a promising mechanical property.

Kazunori Asano (2015) fabricated short alumina fiber-reinforced aluminium alloy composites by squeeze casting method [8] and studied the reinforcements and concluded that the formation of dislocation indicates that the interfacial bond between the fiber and the α aluminium due to the SiO_2 binder is strong. Veeresh Kumar et al. (2010) fabricated Al6061-SiC and Al7075-Al_2O_3 metal matrix composite by liquid metallurgy technique [9]. The results revealed that the densities of the composites were found higher than their base matrix. Kannan Chidambaram and A S S Balan (2017) [10] synthesized unreinforced aluminium alloy (Al7075) and hybrid nanocomposite (Al7075 reinforced with 0.5wt% Boron Nitrate and 1wt% Al_2O_3 nanoparticles).

III. MICROSTRUCTURAL ANALYSIS

Jerome et al. (2010) synthesized Al-TiC composite by In-situ technique by mixing K_2TiF_6 and Graphite powders[11]. The microstructural studies of Al-10wt% (Fig. 1a) revealed that the white color phase corresponds to Al_3Ti and black color phase corresponds to the TiC segregated in the grain boundary of the matrix.

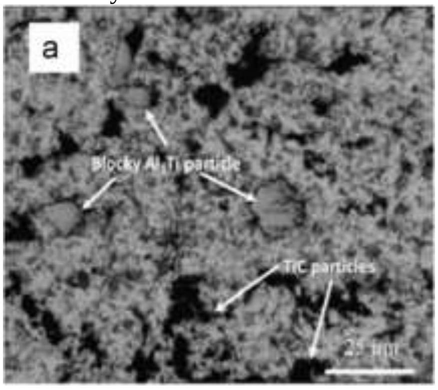

Fig 1a. Microstructural studies of Al-10wt%

Jiwei Geng et al. (2017) studied the microstructural stability of *in-situ* TiB_2/Al composite[12] during solution treatment and concluded that the nano TiB_2 particles have a strong influence on the stability of grain size (GS) and texture during Solution treatment and it further revealed that the composite had an improved stability of GS attributing to the Zener pinning of TiB_2 particles. Jeshurun Lijay et al. (2015)[13] studied the microstructural characteristics of AA6061/ TiC aluminium matrix composites synthesized by *in-situ* reaction of SiC and K_2TiF_6. The studies revealed that the *in-situ reaction* led to the formation of fine TiC particles. Possible intermetallic compounds including Al_3Ti and Al_4C_3 were detected significantly in the AMC, majorly at the intergranular regions. Santanu Sardar et al. (2018) studied microstructural properties of as-cast Al 7075/Al2O3 composite[14] and concluded that the microstructural characterizations confirm the development of ex-situ composite with near uniform distribution of 45 micrometre sized 20 wt.% Al2O3 particles in the Al 7075 matrix by stir casting method. Ambigai and Prabhu (2016) studied the microstructural behavior of Al−Gr−Si_3N_4 nanocomposites and concluded the presence of graphite in the matrix had good influence on the bonding strength[15] and hence higher hardness value was achieved for the hybrid composite. Lu et al. (1996) fabricated Al-4 wt% Cu composite reinforced with in-situ TiB particles and concluded that TiBz has been synthesized via an exothermic reaction between Ti and B salts[16]. Reinforcement with very small particle size can homogeneously be incorporated into the matrix. The formation of TiB_2 particles with size in the range of 0.5 to a maximum of about 1 pm have been confirmed by X-ray diffraction patterns. More submicron particles were observed within the grains. However, the size of the in-situ TiB2 was not strongly dependent upon reaction duration. Owing to the presence of TiAh, very tiny TiB2 particles have been observed within the grains.

IV. MECHANICAL PROPERTIES

Tensile strength of in-situ fabricated TiB_2/ 6063Al composite prepared by high energy ball milling was studied by Zhang et al. (2015) and concluded that Higher strength enhancements are observed in the as-cast TiB2/6063Al matrix composites with high energy ball milling assisting, where tensile strength and yield strength reach 191 MPa and 115 MPa, respectively[17]. It is of great importance to note that the value of the elongation is decline from 19.66% to 10.14%. Si_3N_4 reinforced aluminium alloy was fabricated by stir casting technique by Pradeep Sharma et al. and concluded that hardness of the composites was increased from 49.5 VHN to 93.5 VHN and 31.6 BHN to 58 BHN with respect to addition of weight percentage of Si3N4 particles (i.e. from 0% to 12%). Estrada Guel et al. studied the tensile strength of the Graphite nanoparticle dispersion in Al7075 by means of mechanical alloying and concluded that The mechanically milled and extruded sample was almost 20% harder than the as-mixed sample; the differences between the milled powders are significant. R Hari Chandran and N. Selvakumar [18] performed the tensile and hardness test on (B4CC h-BN)/Al hybrid nanocomposites processed by ultrasound assisted casting and concluded that the addition of h-BN nanoparticles decreases the ultimate tensile strength of hybrid nanocomposites when compared to nanocomposites and it is 40% higher than that of unreinforced aluminium matrix. The hardness of hybrid nanocomposites increases with increasing B_4C and it is higher than that of unreinforced aluminium matrix. M.A. Baghchesara et al [19] analyzed the compressive strength and the hardness test on the Aluminium Alloy Matrix Composite Reinforced with Nano MgO Particles and concluded that the hardness values obtained from experiment show that increasing the volume fraction of magnesium oxide Nano particles in the composite, the value of hardness in most produced composites have increased. Veeresh Kumar G B et al [9] studies on Al6061-SiC and Al7075-Al Metal Matrix Composites reveals that the hardness of the composite is greater than that of its cast matrix alloy. The composites containing higher filler content exhibits higher hardness. Further, it can be observed that the hardness of the Al7075- Al2O3 composite are higher than that of the composite of Al6061-SiC and is to the fact that the matrix Al7075 and Al2O3 possess higher hardness.P. Gurusamy et al [20] studied on the Influence of Processing Temperatures on Mechanical Properties and Microstructure of Squeeze Cast Aluminium Alloy Composites and found that the ultimate tensile strength clearly depends on both melt and die temperatures. The ultimate tensile strength displays similar trend with die temperatures and the largest value of UTS was reached at the die temperature of 350°C. Brinell hardness measurements were taken for ten sample points at 10-mm interval along the height of the specimens.

V. MACHINABILITY PROPERTIES

Machining test of Al6061and its composites containing fly ash were carried out by Prakash Rao et al. (2014) and concluded that the cutting tool fails by built edge formation only instead of gradual mechanism [21]. It is observed 15% filler material at 300m/min cutting speed and 0.3mm/revolution feed least built up edge. Kemal et al. [22] analyzed particle distribution in particulate MMC. Study shows that there is usually particle clustering or agglomeration occurs in PMMC. This clustering significantly decreases the local property of the PMMC. However, uniform distribution of particles in the final product is essential in the PMMCs to obtain desired mechanical and thermal properties. Kılıckap et al. [23] investigated machining parameters on tool wear & surface roughness for 5% SiC-p Al-MMC. They found that cutting speed is the most influential machining parameter on tool wear. Feed rate is the second influential machining parameter. Higher depth of cut, slightly increased tool wear. Kannan et al. [24] investigated the effect of cutting parameters and particulate properties on the micro hardness variations of the aluminium matrix beneath the machined surface. They concluded that geometrical defects like micro cracks, voids, pits and craters were predominantly formed due to particulate fracture and/or pull-out and interfacial debonding. Pramanik et al. [25] developed a mechanics model to predict the forces for machining aluminum alloy based MMCs reinforced with ceramic particles. The resultant cutting force was considered to consist of components due to chip formation, ploughing and, particle fracture and displacement. They showed that force due to chip formation is much higher than those due to ploughing and particle fracture. Pramanik et al. [26] investigated matrix deformation and tool-particle interactions during machining using finite element method. They showed that magnitude and distribution of stresses/strains in the MMC material and interaction of particles with the cutting tool are the main reasons for particle fracture and debonding during machining of MMC. Chandrasekaran et al. [27] applied soft computing techniques in machining performance prediction and optimization. They concluded that soft computing techniques are being preferred to physics-based models for predicting the performance of the machining processes and optimizing them. Dhavamani et al. [28] applied multi-objective optimization (based on Taguchi Method) for drilling processes of composite materials, as it increases the flexibility for selecting the optimal cutting parameters. Dandekar et al. [29] concluded that for mechanics modeling of machining, methods used are: finite element modeling (for machining at the macro scale), molecular dynamics studies (simulating nano metric cutting to capture atomic interactions) and multi-scale modeling(to bridge the gap between the atomistic and continuum scale). A number of methods have been proposed to reduce the computational cost for carrying out multimillion atom simulations necessary to simulate micro machining using only MD. The hybrid FE-MD modeling provides an atomistic description (MD) near the region of interest and the FE modeling describes the rest of the substrate. Dabade et al. [30] analyzed chip formation mechanism in machining of AMMC, using Taguchi method based experimentation, and concluded that at lower cutting speed (40 m min−1) thin flakes, needle type as well as segmented chips are formed, whereas at higher cutting speed (120 m min−1) generally, semi-continuous, continuous chips are formed. The length of chip and the number of chip curls increases with an increase in feed rate at given cutting speed and depth of cut. Joshi et al. [31] both machined an aluminum matrix reinforced with SiC particles and observed that the cutting speed was one of the dominant factors in limiting the machinability of the composite. Chambers [32] conducted a study on machining of a 15% by volume fraction of SiC in A356 aluminum alloy and concluded that the depth of cut did not significantly alter the tool life, with tool life decreasing with an increase in the depth of cut. Although the effect of depth of cut on tool wear is not significant, it has a stronger effect on the tool wear as compared to the feed as shown in machining of an Al/SiCp/15% composite with uncoated tungsten carbide tools.

Tomac and Tonnessen [33] compared the performance of chemical vapor deposition (CVD)coatings of TiN, TiCN and Al_2O_3 and concluded that the inserts with TiN coating performed the best in maximizing the tool life. To improve the tool life in carbide tools, Manna and Bhattacharya [34] machined at cutting conditions that sustained as table built-up edge (BUE) so as to protect the cutting tool. To minimize the surface roughness and sub-surface damage PCD tools are preferred since the wear rate associated with them is the lowest among available tool materials. Although PCD tools are used for machining Al/SiC composites, the high cost associated with them limits their use.

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