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STUDY OF DIFFERENT MACHINING PROCESS ON METAL MATRIX COMPOSITES

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***Abstract** –The use of Metal Matrix Composite is increasing day by day, because of having superior physical and mechanical properties. The main problem is to regulate their cost while maintaining their features as light weight, high strength, toughness etc. The objective of this sort of research is to find out the influence of machining factors like orientation of particles, tool wear, morphology of chip, surface finish, cutting speed of tool etc through conventional and non-conventional machining process. And then final results should be examined so as to modify their uses in different applications. As per the type of reinforcements in Metal Matrix Composite, different machining techniques should be performed to improvise their performance.*

***Keyword** — Metal Matrix Composite, SiC particles, Tool life, Polycrystalline Diamond Tools.*

1. INTRODUCTION

Composite materials are those materials having more than one phases and thus exhibit different properties as high specific strength, high stiffness, low friction, light in weight etc **[1]**. Now days, hybrid metal matrix composite are also used in automobile and aerospace fields and they are generally fabricated by stir casting. Mostly Aluminum 6061 was used as matrix material over zirconium dioxide because it possess properties like high wear resistance, good compatibility in defense and automobile sectors **[2]**. Metal Matrix Composite have different application like in compressor blades, railways, satellite, sporting goods, frames of bicycle etc **[3]**. The machining parameters like feed rate, cutting speed, tool geometry, tool material etc affect the machinability of Metal Matrix Composite **[4]**. Different types of conventional machining process as drilling, turning, grinding, milling etc are used for machining of Metal Matrix Composites (MMCs) **[5]**. Although non-conventional machining processes like Electrical Discharge Machining (EDM), Abrasive Water Jet (AJM), Electrochemical Machining (ECM), etc are used for machining of MMCs **[6]**. Generally solid state and liquid state techniques are used to fabricate Metal Matrix Composites but mostly liquid state process are adopted because it has several benefits as less expensive, able to produces parts having complex shapes etc **[7]**. The schematic representation of different types composites are shown in Figure 1:

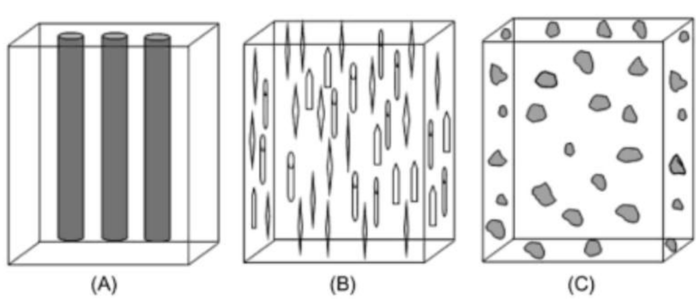

Figure1. Types of metal matrix composites, (A) Fiber reinforced (B) Whiskers short fiber reinforced (C) Particle reinforced Composite **[8]**

2. LITERATURE REVIEW

Metal Matrix Composites are costlier than Polymer Matrix Composites. The matrix materials which are generally used are magnesium, copper, titanium, aluminum. The processing of MMCs involved mainly two steps: firstly the introduction of reinforced particles into the matrix along with operation of shaping at elevated temperature **[9]**.

2.1. Studies on non-conventional machining of MMCs

Hung et al. [10] worked on the machinability of cast Aluminum Metal Matrix Composite reinforced with SiC (Silicon Carbide).As the Silicon Carbide protects the Al alloy matrix from eroding action of sparks generated during Electric Discharge Machining. The heat affected zone was analyzed with the use of special etchant and also through TEM (Transmission Electron Microscopy). Generally EDM was chosen preferably over other machining process to produce complex shapes.

Wang and Yan [11] performed blind hole drilling followed by EDM to evaluate the machinability of Al2O3 / 6061 Al while machining. MRR was affected by peak current and other electrical parameters. As per their results, MRR increases with increase in speed of rotation of electrode, increase in flushing pressure and also in the presence of two eccentric through holes in the electrode.

Singh et al. [12] discussed the changes occurred in metal removal rate while machining of Al-10% SiCp as cast MMC. It was found that as supply of current increases, tool wear rate and metal removal rate also increases. And MRR also increases with decrease in flushing pressure due to less chances of short circuiting while it decreases with increase in flushing pressure due to ignition delay.

Yan et al. [13] analyzed that 6061Al alloys and 10vol% Al2O3P/6061 Al composite gave smoother surface finish roughness of newly machined work piece, where in 20 vol%/Al2O3P/6061Al generate rough surface roughness due to degradation of surface by Al2O3 particles. They also found in their experiment that the main cause of wire breakage was due to reduction in tensile strength of brass wire at high temperature. So to prevent breakage of brass wire there should be of the following characteristics – low tension in wire, flushing rate should be high, wire speed should be high.

Purohit at al. [14] discussed the effect of grain size of Silicon Carbide (SiC) particles, rotation speed of electrode, diameter of hole on metal removal rate (MRR),tool wear rate (TWR) and radial over cut (ROC). And found that MRR and TWR increases with increase in hole diameter of electrode, increase in rotation speed of electrode and also with decrease in grain size of particles of Silicon Carbide. Thus machining of 7075Al – 10wt% Silicon Carbide particulates Composites was done with the help of rotary brass electrodes followed by EDM.

Zhenlong et al. [15] analyzed from the surface morphology that the thermal splintering was responsible for the removal of ceramic particles and formation of resolidified layer was also responsible for the deterioration of surface. Also the thickness of resolidified layer (recast layer) increases with increase in discharge energy. And finally found that the newly machined surface has surface roughness of 0.774 μm and thickness of recast layer 3 μm is obtained.

Sankar et al. [16] investigated that the material removal rate increases with increase in concentration of electrolyte up to 20% and further it decreases because after this level electrochemical reaction tales place between the work piece and the tool. They also observed that the supply of Silicon Carbide abrasives with the electrolyte lowers the material rate. Other machining parameters as radial overcut of material, increases with increase in concentration of electrolyte due to extreme dissolution throughout the reinforced particle. And also surface roughness increased with increase in concentration of electrolyte.

Mardi et al. [17] analyzed that non-conventional machining like Electrical Discharge Machining (EDM), Laser Beam Machining (LBM), Abrasive Water Jet Machining (AWJM), Electrochemical Machining (ECM) are used for machining of MMCs. But somehow problems like formation of recast layer in case of EDM obstructs the process so powder mixed EDM are used to improve surface finish and thereby reducing the problems of tool wear and deformation in tool. In case of AWJM, size of abrasive and reinforced particles played an important role in surface finish of work piece.

2.2 Studies on conventional machining of MMCs

Looney et al. [18] analyzed that for machining of MMCs, uncoated carbide tools are not suitable and also Kyon and Silicon Nitride tools were never be taken due to severe tool wear. They also concluded that polishing of work piece provide better surface finish.

Yanming et al. [19] explored that abrasive wear is mainly responsible for wear on flank face of tool, edges and cornered points while cutting SiC particles reinforced with Al – matrix composites. As volume fraction of SiC increases there is greater chances of flank wear thus tool life also decreases. Low speed is generally adaptable for coarser SiC particles and also it lead to the formation of Built up Edge whereas high speed is allowed for cutting of fine Silicon Carbide particles reinforced MMCs.

Davim et al. [20] discussed that abrasive wear is predominant during machining of Particulates Metal Matrix Composites (PMMCs). As if feed force increased, the amount of flank wear also increases while drilling PMMCs. They also developed a numerical model, which is to be used to optimize the condition during drilling of PMMCs. So with the help of this model, multiobjective problem was formulated so as to study the effect of different parameters of machining.

Davim [21] observed that abrasive wear play an important role in machining of MMC by diamond tool. Durability of PCD insert tools And K10 diamond tools are obtained through tool life equation. Generally PCD insert tools are used for longer tool life and good surface finish while machining MMCs reinforced with Silicon Carbide particles. And PCD takes more time to impose flank wear whereas CVD tools take less time to reach at point of flank wear.

Zhong [22] proposed that for rough grinding of alumina composites, SiC wheels are preferred because their grains are harder and are of less cost than diamond whereas diamond wheels are preferred for fine grinding of alumina composites. They also observed that for rough grinding, grinding force decreases with increase in grinding speed whereas for rough grinding, it decreases with increase in grinding speed due to different grit sizes and types of abrasives.

Karakas et al. [23] investigated that as cutting speed increases the rate of flank wear on tool also increases. As higher the cutting speed of tool causes rise in temperature and thus reduces the adhesion of material on tool. On the other hand, lower the cutting speed decreases the temperature and thus causes strain hardening. Formation of BUE protects the surface of tool from abrasion and adhesive wear and size of BUE decreases with increase in cutting speed of tool.

Pramanik et al. [24] proposed a mechanical model to predict the forces while machining Al-alloy based Metal Matrix Composite reinforced with ceramic particles. And also found that the cutting and thrust forces for chip formation, particle fracture, were calculated on the basis of slip line field theory, Merchant's shear plane analysis and Griffith theory.

Kannan et al. [25] discussed that MMCs are better than non reinforced alloys in terms of physical and mechanical properties. As they have good abrasive properties so that's why they are categorized into hard to machine materials. As the volumetric wear rate varies linearly with average size of particulates and also it increases with increase in cutting speed and feed rate in both the cases i.e. 2–body and 3-body abrasion.

Jani [26] analyzed the effect of various parameters as surface of tool, flank wear, machined surface etc on machining of Si – MMC through different types of polycrystalline diamond (PCD) tools at varying speed. In their experiment they found that good surface finish is obtained while machining with PCD tools. They also analyzed that by using coolant, adhesion of particles reduces the surface finish.

Kumar et al. [27] found that stir casting and hot rolling at temperature of 400^0C,are used to synthesize Al- 6061- ZrB_2 in-situ composites. These composites show well defined grain structure both in stir casting and hot rolling with the help of optical and scanning electron micrograph. There is increase in hardness of hot rolled composite in comparison to cast alloy. If the content of ZrB_2 increases in Al-6061 alloy, then ductility goes to decrease in both i.e. hot rolled and cast condition. Hot rolled composites show better ductility and high Ultimate Tensile Strength while comparing with cast alloy.

Teng et al. [28] found that while machining of micro MMCs, the size of particle and their location played an important role, while machining nano MMCs there is less significant effect of size of particle on chip formation. Continuous chips were formed during machining of micro MMCs while discontinuous chips were formed during machining of micro MMCs. Better surface finish is obtained while machining nano MMCs.

Baia et al. [29] discovered that with the help of ultrasonically assisted turning, there is sufficient reduction of cutting forces. As the use of lubricants did not show any noticeable improvement of the cutting forces, neither in the surface roughness nor in the texture of machined surface. The chip formed in ultrasonically assisted turning (UAT) was of semi – continuous and continuous type. High quality surface finish was obtained in UAT.

3. CONCLUSIONS

The following conclusions are drawn after reviewing the above mentioned literature:

- Surface finish could be easily improved through non-conventional machining process. And EDM would be generally chosen to produce complex shapes.
- MMCs are better than other composites because of having superior physical and mechanical properties. PCD tools are used to cut hard-to-machine materials as they give better surface finish also.
- Abrasive wear is mostly responsible for the tool failure.

4. FUTURE SCOPE

- The study should be done on different metal matrix composites so as to find out their more applications of metal matrix composites in different areas.
- Different tests wear test, fatigue test etc could also be performed to evaluate their properties in such field.
- Complexity in different machining operations should be analyzed so as to estimate various machining parameters like feed, speed, depth of cut etc.

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