MACHINING OF METAL MATRIX COMPOSITE: A REVIEW

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ABSTRACT

This paper gives an overview of the present knowledge about the machining of metal matrix composite which is major concern. There is an increase demand of the development of advanced material for many industrial applications,to meet such demands composites are the right solution. Metal Matrix Composites (MMCs) have higher strength to weight ratio and their properties can be tailored as per the industrial requirements, MMC's are highly abrasive and tools can wear rapidly, machining of these materials attracted researchers and industrial community a lot.The main purpose of machining is to produce a product ofdesired shape and size with specific quality and surface finishby removing a material in the form of chips and it is effected by cutting parameters like cutting speed, feed, depth of cut and also the selection of cutting tool plays a major role.

Keywords: *Machining;MMC; Reinforcement; cutting tools; cutting speed*

1.Introduction

For any engineering applications the right selection of high performance materials is very important for its success and almost eighty percent manufactured parts need machining before they are ready to use.[1]Aluminium alloys are widely used in manufacturing aerospace and automobile structures is well recognized today. This is due to some superior properties of these materials such as high strength- to- weight ratio, superior low temperature performance, corrosion resistance, high machinability index and comparatively low cost. But aluminium alloys cannot meet all engineeringrequirements. Their main weaknesses are poor high-temperature performance and low wear resistance. To overcome these problems new engineering materials have been developed by reinforcing aluminium alloys with ceramic particles/ whiskers these are known as metal matrix composites (MMCs). [2, 3]Metal Matrix Composites (MMC's) are the major innovation in the development of advanced materials but hard and abrasive nature of the reinforcement particles in MMC's causes rapidly tool wear and deteriorate surface roughness during machining. [4]The metal matrix materials of MMCs are aluminium alloys, titanium alloys, copper alloys and magnesium alloys while the reinforcement materials are silicon carbide, aluminium oxide, boron carbide, graphite etc. in the form of fibres, whiskers and particles.[5]According to Broutman and Krock"A composite material is formed by a close combination of at least two chemically and physically distinct materials which should remain separate and distinct while a good and continuous interface between them is maintained: the reinforcing components in the whole volume of the matrix should be as uniform as possible".[6]The research on the machining of MMCs was first reported in 1985 and there is the investigation regarding performance of various tool materials during machining of an aluminium alloy reinforced with 40 vol % SiC particles (Al/40% SiC MMC) and concluded that edge cracking due to mechanicalchipping was the main cause of tool wear and that poly crystalline diamond (PCD) was superior to any other tool material for machining MMCs. Also in the same year the research committee of japan society for precision engineering (JSPE) started a cooperative research program on cutting and grinding of MMCs and published a summarized report in 1989, comprehensive research on machining of aluminium-alloy- based MMCs started from the 1990s. The presence of reinforcement makes metal matrix composites different from monolithic materials and leads to superior physical properties of MMC, these reinforcement particles are responsible for complex deformation behaviour, high tool wear and inferior surface finish when machining MMCs hence the applications of these materials has been limited in many fields.

2.Literature Survey

As MMCs contain certain amount of hard abrasive and ceramic reinforcementshence they are considered as most difficult materials for machining.The study done by Kathirvel M. and Purushothaman [7] on machining of hybrid Al-SiC metal matrix composite using polycrystalline diamond (PCD) tool on a CNC lathe they concluded that % volume fraction of SiC shows more effect on forces, whereas spindle speed and feed rate are highly affected parameters for flank wear and surface roughness.Gurpreet Singh et al [8] perform experimental investigation of turning of Al/SiC/Gr MMC component and concluded that surface roughness increases with the increase in feed rate and depth of cut.N Muthu Krishnan et al. [9] perform investigation on the machining behaviour of metal matrix composite using PCD inserts and concluded that PCD 1600 grade is subjected to less force due to the fine grains and its stability at high cutting speeds, the machining with low feed has resulted in decreased cutting force in all grades of PCD. [10] Machining of MMCs can be classified in two major groups: (a) particulate reinforced and (b) fibre reinforced. Depending on the type of reinforcement the cutting mechanics differ considerably,hence the tool – reinforcement- matrix interaction play a major role in the machinability of MMC's and affect the surface roughness, cutting forces, tool wear and the subsurface damage.The most commonly used tool material is polycrystalline diamond (PCD) also cubic boron nitride (CBN), alumina, silicon nitride and tungsten carbide (WC) tooling are used as cutting materials. Cutting speed, feed and depth of cut in machining of particulate MMC's have a similar effect on tool life and surface finish to that of machining metals but some differences are noticeable due to the ceramic particles. The ceramic- reinforced particles tend to dislodge from the matrix and roll in front of the cutting tool hence plowing through the machined surface and generating grooves on it.In many cases cutting speed doesn't significantly affect the cutting forces there are some differences in reports on the effect of cutting speed on the cutting forces. During machining of MMC's built - up edge (BUE) has been seen by many researchers while machining these composites at low cutting speeds, due to the built – up edge the cutting force at low cutting speeds is lower than the cutting force observed at higher cutting speeds. The presence of BUE increases the actual rake angle of the tool resulting in a lower cutting force, there are some reports which have shown a decrease in the cutting forces with an increase in the cutting speed. [11]For broad machining applications there is wide range of cutting tool materials of different properties and performance capabilities are available today. These include High speed steels, Satellite, cemented carbides (coated & uncoated), Ceramics, Cubic Boron Nitride (CBN) and Diamond (synthetic& natural) as MMC's have high hardness, CBN and diamond are also referred as super or ultra-hard materials.

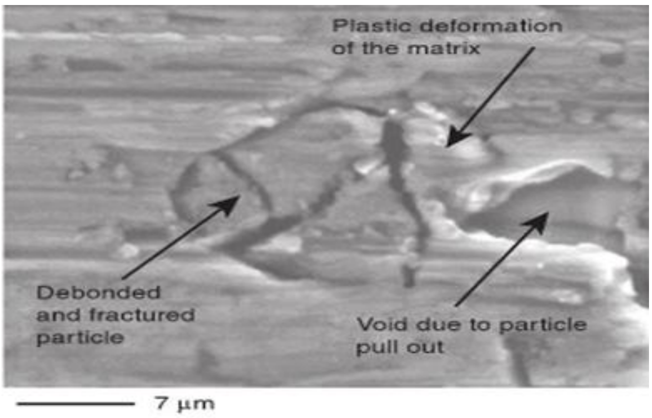

Figure 1: Scanning electron microscopy (SEM) image showing different deformation mechanism in a MMC[12]

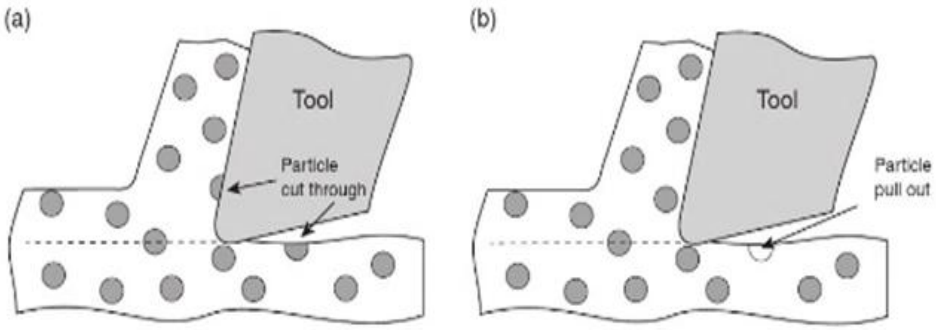

Figure 2.1 Schematic diagrams for cutting MMC's (a) particle cut through (b) particle pull out[12]

Fig 2.1 shows simplified illustration conditions encountered by the particles in front of the tool tip during machining MMC when the particle is sheared a better surface finish is obtained, where as poor surface finish is usually observed when particles are pulled out due to the formation of cracks and pits on the machined surface.The published research on the machining of particulate MMC's indicates that only cutting tools harder than the reinforcements have acceptable performance. The poly-crystalline diamond (PCD) tools given their high hardness compared with most of the common reinforcements provide longer tool life but due to high cost of PCD tools other tools such as cemented carbides and ceramics are also been used to machine particulate MMC's.[12].According toTomac N. et al [13] ceramics tools were perform unsatisfactory while the carbides were preferred over other types when machining at low cutting speeds and high feed rates[13]. Some researchers observed the effect of different coatings on the performance of carbide cutting tools during machining MMC's and suggested that coatings with less hardness than those of the reinforcement do not improve tool performance [14, 15]. Many researchers have observed that the change in average particulate size and volume fraction of reinforcement greatly affects the machining characteristics of MMC's [16, 17].The available coated tools having coating such as titanium nitride and titanium carbide perform well while cutting steel but show very poor performance in cutting MMC's. AlsoTiAIN coated tools show mediocre results in machining of Al + 20% SiC[18].According to Li and Seah the tool wear increases rapidly when the percentages of reinforcement particles in the MMC exceed a critical value. This critical value is determined by the size and density of the reinforcement particles [19].By the use of conventional single-point cutting tool during machining, a small part of the cutting edge is continuously subjected to extremely high temperatures and cutting forces due to this there is excessive wear along the area of contact[20].Shaw et al in their study of a lathe type cutting tool in the form of disc that rotates around its centre, due to continuous spinning of the tool around its centre allows for the use of the whole circumference of the insert, due to this a fresh portion of the cutting edge is provided and therefore a better distribution of tool flank wear over the entire cutting edge is generated. The spinning action of the tool also provides a way for carrying the cutting fluid to the tool point [21].While machining the composite materials researchers accepted the surface integrity as a term to describe the nature and condition of the machined surface to assess the quality of machined surface, optical and scanning electron microscopy are commonly used to find the presence of surface damage in the form of cavities, macro cracks, scratch marks etc. [22].

3.Conclusion

- From literature survey it is concluded that the metal matrix composite has unique properties due to which they are replacing traditional metals and alloys in several applications, there widespread applications is limited due to the difficulty in machining because of the presence of reinforcement particles which are hard, stiff and abrasive in nature.
- Many researchers indicated that poly- crystalline diamond (PCD) is the only tool material which gives useful tool life while machining SiC/Al particulate metal matrix composite, also the selection of appropriate grade poly- crystalline diamond (PCD) tool is a right decision while considering tool lifeand quality of machined surface required.
- Several researchers used self- propelledrotating tools while machining MMC's and compared with conventional cutting tools and observed that rotating cutting tools shows excellent performance in terms of progression of tool wear and tool life and at high feed and cutting speeds rotary tools shows super wear resistance.
- For the improvement of production rate rotary tools are the best suitable candidate, as poly– crystalline diamond (PCD)most commonly used tool material although cubic boron nitride (CBN), alumina, silicon nitride and tungsten carbide (WC) tooling are also used as cutting materials.

4.References

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