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A Review on machining parameters for better surface finish of MMC material

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ABSTRACT
Metal matrix composites have superior mechanical properties contrary to metals over a wide range of working conditions. This makes them a prominent option in replacing metals for different engineering applications. These materials are developed for engine blocks, bearing propeller vanes, steering systems, drive shafts in aircraft. Particle reinforced aluminium MMCs have received considerable attention due to their excellent engineering properties like high strength to weight ratio, high toughness, high impact strength etc. But these materials are usually regarded as extremely hard to machine, because of the abrasive characteristics of the reinforced particulates. It is also acknowledged that their machining behaviour is not fully understood. Amongst all machining processes, turning is the most frequently useful for composite materials due to the need for processing manufacturing workpieces. The literature reviewed here is the effect of cutting parameters like cutting speed, feed rate etc. on the quality of the surface finish of the workpiece. The surface finish characteristics were reviewed in terms of cutting forces, tool wear, and the surface quality of the workpiece and their improvements
Keywords - Metal matrix composites, surface roughness, wear mechanism.

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I. INTRODUCTION

Metal–matrix composites are a relatively new group of materials characterised by the lighter weight and greater wear resistance than those of conventional materials. These materials have been considered for use in automobile brake rotors and a range of components in internal combustion engines. The machining of MMCs is very complex due to the highly abrasive nature of the ceramic particulate reinforcement. The distinctive reinforcing ceramic materials are Silicon carbide (SiC), aluminium oxide (Al2O3), zirconia (ZrO2), boron carbide (B4C), and graphite (Gr) have been the broadly used particulate reinforcements.

J. Paulo Davim (2001) stated that the cutting tool materials must be carefully selected to minimize wear due to the hard abrasive elements of the reinforcing phase in the work material. Machining of a composite material depends on the properties and relative content of the reinforcement and the matrix materials also on their response to the machining process. Classification of MMCs into the following categories depending on the types of reinforcements: particle reinforced MMCs, whiskers or short-fibre reinforced MMCs, and long-fibre or continuous fibre-reinforced MMCs

Table 1 shows typical varieties of reinforcement used in each category of MMC. Usually, the Manufacturing of these composites is done by following three techniques namely solid-state, liquid state and powder metallurgy. Amongst them, liquid state is the most extensively used due to its low cost and natural production process. Some new methods like melt-stir casting, continuous casting, direct-chill casting etc., have been stated by several researchers for the production of MMC materials.

Types of MMC	Particle reinforced	Continuous fibre reinforcement	Whiskers
Reinforcement	Al_2O_3	Al_2O_3, SiC, B	Al_2O_3, B, C
	SiC, WC	C, Al_2O_3+	Al_2O_3+
	TiC, B, C	SiO_2, Nb-Ti	SiO_2, SiC, TiB_2
		Nb_2Sn, Si_2N_4	

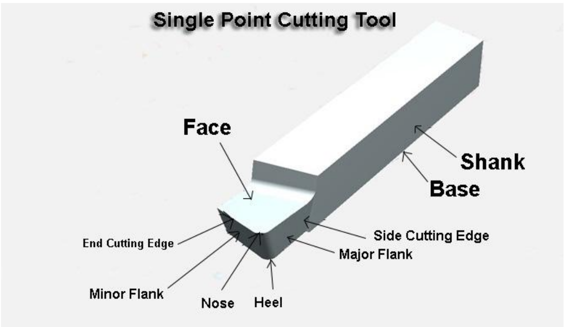
Table 1 Different reinforcement used in different MMCs

Ravi Shekhar (2015) worked on the turning mechanism with metal matrix composites and also they provide an overview of their work. Their review focused on the auto and aerospace sectors for metal matrix composites promise to shape the technological advancements of the 21st century. Nowadays, there is an increasing focus on MMCs reinforced with nanoparticles like carbon nanotubes, graphene, and nano-SiC. Other attempts are directed toward the investigation of hybrid composites, composed of multiple matrices and/or reinforcement materials.

G. Lane (1992) described that the most promising problem with particulate MMCs is that they are difficult to machine, because of the hardness and abrasive nature of the SiC or other reinforcing elements. The particles reinforced in MMCs are harder than tungsten carbide (WC). Polycrystalline diamond (PCD) is an exception, as its hardness is almost three to four times that of silicon carbide (SiC); hence PCD is recommended by many researchers.

II. TURNING OF MMC

The turning operation is a basic metallic removing operation this is used broadly in industries managing metallic slicing. In a turning operation, an excessive-precision single point cutting device is rigidly held in a device post and is fed beyond a rotating workpiece in a direction parallel to the axis of rotation of the paintings piece, at a consistent fee, and unwanted material is removed in the form of chips giving upward push to a cylindrical or extra complex profile. This operation is finished in a lathe device either manually beneath an operator's supervision or employing a controlling computer application. There are two types of motion in a turning operation. One is the slicing motion that is the round movement of the paintings and the other is the feed movement which is the linear movement given to the device. The nomenclature of single point cutting device is shown in fig 1.



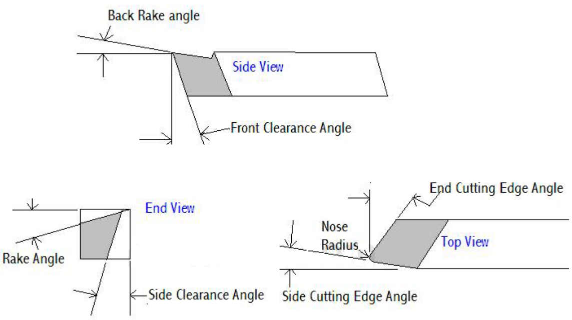


Fig.1 Single point cutting tool [www.themachinedesign.com]

Extensive research in the field of turning of MMC had been done to improve tool life and optimize the cutting conditions for different cutting parameters. The type of machine used for fabricated MMC turning is a lathe machine with high rigidity. The turning operation was carried out under a dry cutting environment. Dry turning has been considered as the machining of the future due to concern regarding the safety of the environment. A dry-cutting environment was used for the experimentation process. The dry cutting process uses no coolant during machining. By the use of dry cutting, costs of cutting fluid were alleviated.

III. WEAR MECHANISM AND TOOL LIFE

Tool wear can be defined as the unwanted removal of tool material from the cutting edge leading to unwanted changes in the cutting edge geometry of the tool. Thrust and torque depend upon cutting tool wear and various angles as well as feed rate and cutting speed. The chemical wear is diffusion wear and dissolution wear, while mechanical wear is adhesion wear, abrasive wear and delaminating wear. It is important to note that different tool materials have different responses to different wear mechanisms

Abrasion wear theory is based on the idea of hard inclusions in the work material indenting the tool surface by the action of sliding chip or rolling in the shear zone, friction occurring between the tool flank and work material (Dixon and Wright, 1985; Bhattacharyya and Ghosh, 1964). Distinctive damage from abrasion consists of long straight grooves, as when a surface is lapped and polished with a hard abrasive. Damage of this type is rarely seen on worn carbide surfaces. Adhesion wear can also be known as attrition wear, occurred when the metallic surfaces are brought into close contact under moderate loads, thus, a metallic bond between adjoining materials takes place. The strength of the bonding at the points of adhesion is often high such that while attempting to free the surface, the separation takes place not along the interface but in one of the materials itself shifting and removing materials often with the sliding member of the pair (Bhattacharyya and Ghosh, 1964).

Diffusion wear is observed to occur if the mechanical process involved in adhesion is capable of increasing the localized temperature of the cutting area. Solid-state diffusion is the mechanism by which atoms in a metallic crystal shift from one lattice point to another causing relocation of the element in the direction of the concentration gradient (Bhattacharyya and Ghosh, 1964). Diffusion wear is associated with the chemical affinity between the tool and workpiece materials under the high pressure and temperature occurring during the machining process. It is dependent on the diffusivity of tool material into the work materials in the chip rolling over the tool surface. Diffusivity increases with an increase in temperature during chip formation (Trent, 1991). Naerheim and Trent (1977) observed that the crater wears on the rake face when cutting steel using carbide tools is a result of atomic diffusion into the work material sliding over the surface.

Eyup Bagci et. al, (2008) showed that the Tool wear leads to adverse consequences such as reduction in cutting edge strength and surface finish, increased tool forces and power consumption, increased cutting temperatures, loss of dimensional accuracy, and finally loss of productivity. The tool wear rate will be contingent on the mechanical properties of composites volume fraction, the reinforcement morphology, distribution and volume fractions, as well as the matrix properties are all factors that affect the whole cutting process. Several researchers have also indicated that polycrystalline diamond (PCD) tools are the only tool material that is proficient in providing a useful tool life during the machining of particulate MMCs. PCD is adequately harder than most of the ceramic reinforcements and has no chemical affinity to react with the workpiece material. A PCD tool has larger grain structures that withstand more abrasion wear by micro-cutting compared to tools with smaller grain sizes. Tomac and Tonnessen (1992) investigated the machinability of Al-SiC MMCs using PCD, chemical vapour deposition (CVD), and coated tungsten carbide tools. The investigation discovered that abrasive wear is the main mode of tool failure. The PCD tools had over 30 times higher tool life than carbides for similar cutting conditions. More recently Kishawy et al. (2005) presented an analytical model for calculating tool flank wear evolution during turning of particulate reinforced MMCs. The equation was developed to determine the flank wear: It has been predicted that a precise and reliable tool can increase cutting speeds from 10-50%, compared to worn-out tools and a suitable hardened tool reduces the machine downtime by allowing it to be slated in advance and an overall increase in savings between 10-40% (Adam, Dr. Jin Jiang and Dr. Peter, 2004).

Chowdhury S.K (2000) did numerous surveys of machining on metals; the tool wear is mainly due to abrasion at lower speed conditions. When the cutting speed is increased, temperature increases under dry machining conditions. Thus, diffusion is considered as the governing wear mechanism for tools at higher cutting speeds. The atoms that are diffused from the tool to the chip are carried away by the flow of work material along the contact surface. This will consequently lead to a substantial reduction in tool life.

IV. CHIP FORMATION

The material in front of the cutting tool edge is subjected to severe plastic deformation and successive shearing results in chip formation. Chip formation during the turning of metal matrix composites differs somewhat in some aspects. The reinforcement particles or fibres are dispersed randomly at and about the tool edge. The manifestation of hard reinforcements alters the plastic deformation characteristics of the soft matrix material compared with conventional alloy. Thus, the change in mechanical properties coupled with reinforcement, pattern and distribution in the matrix determines the mechanism of chip formation (shearing, plowing, particle interface debonding, pull out and cracking) and therefore the machinability of MMCs. Pramanik (2006), described the chip development forces during turning depend on the strength of the material, cutting conditions and tool geometry. Speed and feed influence the strength of the workpiece material in the deformation zones through temperature, strain and strain rate. In drilling, chip formation is controlled by the rake angle of the tool cutting conditions. Hence, the experimental shear strength values, τS, for both the aluminium alloy and MMC at different machining conditions were determined using the equation.

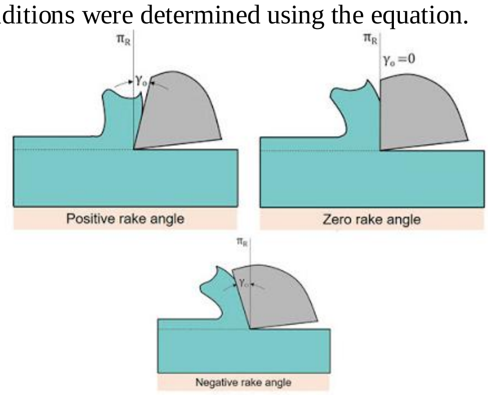


Fig 2. The effect of rake angle in chip formation [www.mechanicalwalkins.com]

When a positive rake angle takes place, it can shear off the work material hence requires little amount of force. However, when the rake angle is negative shearing does not take place. Thus, the tool thrusts the material ahead of it.

A. Pramanik (2008) studied that at low feed (cut- thickness), the area of cut is small and the entire cut area may have been work-hardened by preceding tool pass. This will result in a higher τS value at lower feed than that at a greater feed. For the MMC, a chip shape varies over the substantial range for different speeds and feed.

J.P. Davim (2007) found that the measured Fcc and Fct (chip formation forces in cutting and thrust directions, respectively), and Φ (shear angle) depend on the cutting conditions. Hence, the experimental shear strength values, τS, for both the aluminium alloy and MMC at different machining conditions were determined using the equation.

V. SURFACE FINISH

Mostly the machine tool rigidity, work material, cutting tool geometry, coolant, feed, speed and depth of cut are the key factors influencing surface finish. The reliability of the process in achieving the required surface finish is important as otherwise it adds to the cost of manufacture with rejection and reworks. Many researchers have explored the relationship between surface roughness and cutting speed. Some of the obtained results were complementary while some showed a contradiction to the remaining. Outstanding surface finish can be produced when machining with a PCD tool.

An excellent surface finish is difficult to achieve because of the fracture and pull-out of particles during machining of an MMC. Hence, the effect of machining parameters on machined MMC surface may be different from that on a non-reinforced material.

Various Parameters affecting the performance
a) Feed Rate

Paulo Davim & Conceicao Antonio (2001), had suggested that at a constant cutting speed, the surface finish of the holes of the drilled samples deteriorates with increasing feed rate. Tamer ozben et al. (2008) reported that the cutting speed is the most important machining parameter on cutting tool wear and the tool wear increases with cutting speed as shown in Fig. 3.

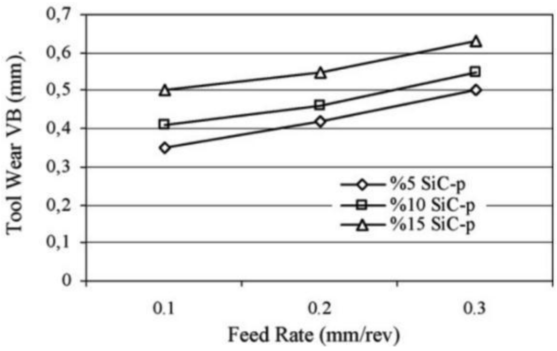


Fig. 3 Effect of feed rate on tool wears at V=50 by Tamer ozben (2008).

Coelho et al. (1995) had examined the various cutting parameters and selection of cutting tools for drilling of Al-based MMCs and described that the low feed rates produced rapid flank wear on the tool.

b) Cutting speed

N. Satheesh Kumar et al. (2012) concluded that the better surface finish may be achieved by turning carbon alloy steels at low feed rate and high spindle speeds. Researcher used various carbon steels like EN8, 19, 24, 47 for experiment to find out effect of various factors such as vibration of machine, obliqueness in workpiece, tool wear, temperature of workpiece and variation in material composition. It should also be noted that the turning operation for all work pieces carried out sequentially. Ramulu et al. (2002) had assessed the drilling characteristics in terms of drilling forces, tool wear, surface finish etc. and reported that the lowest surface roughness parameters occurred at the lowest feed rate with the highest cutting speed.

Sasan yousefi et al. (2019) obtained results from their experiment analysis showed that feed rate is the most important factor affecting the surface roughness, while cutting depth and spindle speed has no considerable effect on the surface roughness. On the other hand, the effect of cutting depth and spindle speed on the dimensional accuracy is significant, whereas nose radius has no considerable effect on the dimensional accuracy. From tool wear and vibration analysis also they found that effect of vibration on the dimensional accuracy is considerable compared with the tool wear effect on the dimensional accuracy. It was also observed that by increasing the feed rate from a particular value, the surface roughness not only has no significant changes, but in some cases, the surface roughness decreases significantly. The best surface roughness of 0.312 μm was obtained at the nose radius of 1.2 mm, the spindle speed of 2000 rpm, the feed rate of 0.08 mm/rev, and 0.5 mm cutting depth, which is comparable with that obtained by the grinding operation.

Tamer ozben et al. (2008), reported that the cutting speed is the most significant machining parameter on cutting tool wear and the tool wear increases with cutting speed as shown Fig. 4.

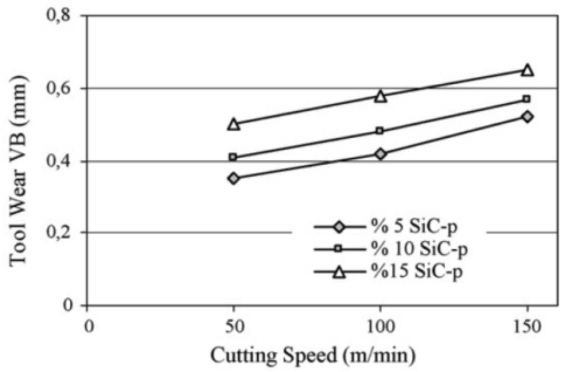


Fig. 4 Effect of feed rate on tool wear at V=50 by Tamer ozben *et al.*

VI. CONCLUSION

Review on effect of various parameters like sutting speed, feed, material properties etc effect on turning operation is presented in this paper. Direction of research on this phenomenon will improve performance of cutting operations, cutting forces and specially surface roughness. It can be possible by changing cutting parameters, tool materials and continues analysis of operations, taguchi method. By improving of mechanical properties of existing aluminium alloy with adding of different content, increment in surface roughness can be possible and it is our area of reaserch for further investigation.

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