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Grinding of MMC using MQL based vegetable oil - Review

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Abstract. Grinding plays an essential role in obtaining high dimensional accuracy and surface finish. Therefore, a strategy to improve the grinding rate and surface finish is important for the economic production. Most important environmental hazards in machining operations are due to the use of cutting fluids. Nowadays to reduce the harmful effects coupled with cutting fluids, researchers have developed environmental cognisant machining such as dry cutting, machining with minimum quantity lubricant and Machining with vegetable based cutting fluids including other types of cutting fluids. In this review, the applicability of MQL based vegetable oil in grinding of MMC has been undertaken. The performances of with respect to the cutting force, surface finish of work piece and temperature of the cutting zone have been investigated. It has been reported in various literature that metalworking fluids, which are vegetable oil-based, could be an environmentally friendly mode of machining with similar performance attained using mineral oil-based metalworking fluids.

1.Introduction

In many developed countries and industries are continuing a research interest in MMCs for last 25 years due to its unique physical and mechanical properties. The Metal Matrix Composite is used in aircraft, automobile components, structural, Electrical, electronic applications and military industries. [1-3] Though MMCs are superior properties, but not widely applied due to their higher manufacturing cost and poor machinability. [4,5] Aluminium metal matrix composites are superior to other MMCs due to their low cost.

The Main difficulties such as fabrication and machining have to be overcome while applying composites in different applications. While machining of MMCs the subsurface damages are caused due to conventional and unconventional processes, to rectify the effect the finishing processes such as grinding is used to improve the surface integrity of the MMCs [6-8]. In conventional machining processes, limited scientific efforts directed towards the study of the grinding characteristics of MMCs. [9-13]

Grinding is used to finish workpieces to maintain high surface quality and high [accuracy](#) of shape and dimension. The grinding accuracy is 0.000025 mm; in most applications, finishing operation is very essential and removes material about 0.25 to 0.50 mm depth. The grinding wheels are made of tempered hardened steel, silicon carbide, aluminium oxide. This grinding operation is used to improve the surface finish of the workpiece by removing a small amount of material. But grinding of silicon carbide is difficult because of its low fracture toughness, making it very sensitive to cracking. The investigations and little study has been carried out on machining advanced composite materials. The studies on grinding of composites exhibit an improved grindability with respect to non-



reinforced aluminium alloy for the better surface finish and the lower tendency to clog the wheel. [14-16].

The cutting fluids have many technological advantages in grinding operation, they have serious ecological and economic problems. On the other side in dry grinding, there exist thermal damages on the workpiece surface, to rectify this effect the efficient and effective alternative method is minimum quantity lubrication (MQL) technique is shown in Fig 1. MQL technique uses a spray of small oil droplets in a compressed air jet. The lubricant is sprayed directly into the cutting zone. Therefore, it provides efficient lubrication and improves cutting performance without using huge flow of fluids. [17]

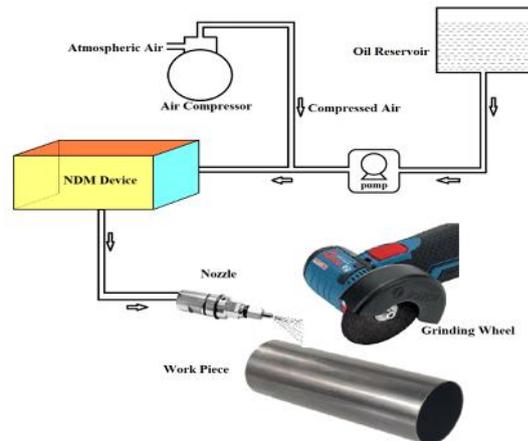


Fig 1 - Minimum Quantity Lubrication (MQL) Technique [36]

Nowadays, higher metal removal rate is used to get higher efficiency in cutting process. But the metal removal rate increase in results the tool life reduces due to increase in friction and heat generation at the cutting zone. This requires further improvement of MQL technique to meet more cooling and lubricating in high-efficiency machining. One way of enhancing the cooling and lubricating effect of MQL is to develop and employ fluids with high cooling and lubricating abilities. [18]

Recent studies have indicated that compared with conventional fluids, nanofluids and vegetable oils have high heat transfer rates and friction reduction properties. The characteristics of MQL fluids are shown in Table 1. These features make to improve the cooling and lubricating effect of MQL. The MQL with nanofluids and vegetable oils showed the benefits of reducing the grinding force and improving surface roughness and the G - ratio could be improved with high concentration nanofluids. [34,35]

Table 1 - MQL Fluids Characteristics [36]

SYNTHETIC ESTERS (VEGETABLE OILS)	FATTY ALCOHOLS (MINERAL OILS)
<ul style="list-style-type: none"> • Toxicologically harmless • low level of hazard • good biodegradability • Very good lubrication property • Good corrosion resistance • Inferior cooling properties • Vaporizes with residuals • High flash and boiling point with low viscosity 	<ul style="list-style-type: none"> • Poor lubrication properties • Better heat removal due to evaporation heat • Little residuals • Low flash and boiling point, comparatively high viscosity

2. Grinding of MMC

Muhammad *et al.*. Studied the grindability of aluminium metal matrix composite. In this the Aluminium metal matrix composite 25 volume percent of fine (2-3 μm) embedded in an AA-2124 matrix alloy, was ground using a high performance polycrystalline diamond based grinding wheel. He analyzed the surface finish of the ground Al-MMC is mainly a function of the grinding wheel. He found that the surface and subsurface microstructure revealed that the damage was confined to 0-10 μm top-layer in terms of surface cracks, loosely adhered particles and surface pits/holes. [19]

Thiagarajan *et al.*. Investigated cylindrical grinding of sic particles reinforced aluminium metal matrix composites. In this study The Al/SiC composite specimens are produced aluminium alloys reinforced with 13 μm SiC particles of the size of 30 X 200 mm and the grinding experiments are carried out on a cylindrical grinding machine. He analyzed the various grinding parameters to affect the surface integrity of Al/SiC composites during cylindrical grinding. He found a better surface finish and damage free surfaces are produced due to low grinding force at high wheel and workpiece velocities. [20]

Anand Ronald *et al.*. Deals with Temperature measurement during grinding of metal matrix composites. He observed that although the temperature measured by the pyrometer is less owing to factors like emissivity and specific heat capacity, the actual temperature prevalent of the wheel-work interface could have been higher, as confirmed from the SEM of the machined surface. [21]

Li Zheng *et al.*. investigated to develop the high-efficiency and precision machining technique of TiCp/Ti-6Al-4V particulate reinforced titanium matrix composites. In this high-speed grinding experiments were conducted using the single-layer electroplated cubic boron nitride (CBN) wheel and brazed CBN wheel. The grinding performance was analysed in terms of grinding force and grinding temperature. He found that the grinding temperature and grinding forces for CBN wheel are always less than electroplated CBN wheel. [22]

Anand Ronald *et al.*. Studied the grindability of metal matrix composites on the influence of grinding wheel bond material. He analysed the performance indicators, grinding force and Surface finish using with resin bonded and plated diamond abrasive wheels. He conclude that the resin bonded wheel performed better surface finish better compared to the electroplated wheel. [23]

Suna *et al.*. studied the grinding characteristics of SiC-particle-reinforced aluminum-based metal matrix composite In this the grinding force, grinding temperature, surface roughness are analyzed by the various advanced measuring method. He conducted Grinding experiments in different grinding conditions to obtain good surface integrity. He found that the results are of great significance for high efficiency and precision grinding of MMCs. [24]

Antoniomaria *et al.*. studied a grinding performance of SiC-aluminium composites using conventional abrasives and superabrasives. In this the grindability of metal matrix composites were analysed with different types of grinding wheels, made with both conventional abrasives and superabrasives. He found that the conventional abrasives have given better performances than superabrasives in terms of low clogging, low grinding forces and better surface finish. [25]

3. Grinding of Hybrid MMC

Jaswinder Singh *et al.*. Deals with the various aspects regarding the fabrication and wear properties of Al/SiC/Gr hybrid composites. He found that the presence of Gr particles significantly enhances the wear properties under optimum conditions and the hybrid reinforcements can be successfully incorporated into the Al matrix. Also found that the morphology and size of wear debris are controlled by the amount of Gr particles in the composite. [26]

Jaswinder Singh *et al.*. Investigated the Effect of Machining Parameters on MRR and Surface Roughness in Internal Grinding using EN8, EN31 Steel. He analyzed the characteristics of material removal rate (MRR), surface roughness and tool life for various machining parameters such as cutting force, cutting speed, depth of cut. He concluded that Comparatively, EN31 material produces minimum surface roughness and also increases the tool life. [27]

Kannayiram Ponappa *et al.*. Investigated the Grinding of magnesium metal matrix composites. In this work the Grinding performance of magnesium composite was carried out by varying process parameters. The forces were monitored using piezoelectric dynamometer and the performance of the grinding was analyzed and compared with the grinding forces. He concluded that the grinding forces were decreasing with the increase in hardness. [28]

Alakesh Manna *et al.*. Deals with the surface roughness Ra during nano finishing of Hybrid Al/(Al₂O₃+ZrO₂) MMC in grinding operation. A metal bonded diamond grinding wheel is used to for finishing internal surfaces of a cylindrical workpiece. He proved that the surface roughness height is reduced and it reveals an improvement in the surface finish of Hybrid MMC. [29]

4. Grinding of MMC using MQL

Adibi *et al.*. Studied on minimum quantity lubrication (MQL) in grinding of carbon fiber-reinforced SiC matrix composites. In this the MQL grinding performance was compared with conventional fluid and dry grinding. Also the effects of main grinding parameters, such as cutting speed, feed speed, and depth of cut, on the grinding forces, specific grinding energy, wheel wear, surface roughness, and integrity were analyzed. He found that MQL grinding reduced the grinding forces and specific grinding energy, wheel wear was lowered and G-ratio was increased. [30]

Mohsen Emami *et al.*. Studied Minimum Quantity Lubrication in Grinding Process of Zirconia (ZrO₂) Engineering Ceramic. In this work the investigation is carried out on MQL grinding of zirconia (ZrO₂) engineering ceramic and the performance were compared with MQL and conventional wet grinding. He found that in MQL grinding, the grinding force and surface roughness are decreased and increase in surface quality. [31]

Dinesh Setti *et al.*. Investigated the application of nano cutting fluid under MQL Technique to Improve Grinding of Ti-6Al-4V Alloy. He compared the results with conventional coolant and pure water, the grinding forces reduced when nano cutting fluid was used even at low concentration of the nano particles and surface finish has been found to improve with higher concentration of the nano particles. [32]

Rahman *et al.*. Investigated material removal rate and surface roughness on grinding of ductile cast iron using minimum quantity lubrication. In this the experiment was analysed according to the design of experiment principle and prepared based on central composite design. He conclude that the highest grinding ratio to be achieved in single-pass MQL and the surface quality of workpiece is mainly influenced by the depth of cut and table speed. [33]

As obvious from the review that the most of the available research work has been approved out in grinding of MMCs. Not so much work has been reported on MQL based grinding of MMCs. Many useful MMCs have not been tried as work material on Grinding using MQL process.

5. Conclusions

Sustainable manufacturing through environmentally-friendly machining begins from the steps that must be taken to apply ecological machining methods in order to create these technologies reliable, environmentally friendly and cost competent. The review centres on the performance and environmental puff of environmentally-friendly grinding for MMC. The salient features are as follows:

- MQL is an ecologically friendly and cost effective process of fluid release that can be used as an well-organized option in grinding process of MMC.
- MQL reduces the tangential and normal forces in grinding process of MMC.
- Surface roughness in MQL grinding was somewhat better than fluid grinding.
- MQL grinding generated a surface with somewhat narrower grazes and homogeneous scenery compared to fluid grinding.

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