

Effect of composition and grain structure on machining performance in EDM-A review

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Abstract- Nowadays, MMC materials are in trend. EDM process fulfills the requirement of manufacturing product of MMC. MMC materials have a wide range of composition. The machinability of materials varies with the composition and grain size. The machining property of metals and alloys have been tested on EDM. But testing machinability of each MMC material on EDM is very difficult due to the variation in composition, composition percentage and grain structure. This difficulty can be eliminated by a universal equation. Determining the effect of composition, composition percentage and grain structure in EDM and plotting with respect to machinability of the material will give a universal equation. This equation will be valid for all materials machined by EDM process. Hence, this will leads to determine the theoretical machining performance of the new MMC material. It will decrease the sample testing time for machinability.

1. Introduction

The advancement of industries, technology and innovations demand Metal matrix composite (MMC) materials. The advancement in material shows that a group material needs to suit the requirement. There are various field in which more advanced materials needed like aerospace, automobile industries, surgical equipment etc. [1,2] these industries also have a dual demand for performance and economy. The trend of material and advancement in the material at a different stage of the requirement are shown in following ways base metal, alloys, composites, MMC and now hybrid MMC.

The most important material selection criteria are high specific modulus. Aluminum is one of the most suitable material which can fulfill the desired performance as well as the economy for all the above mention fields [3]. Its physical properties such as high strength, low density, good fatigue strength, corrosion resistance, and good castability are far better than others but it also has some limitations in use such as hardness and strength. To overcome this, some other materials such as carbides- B₄C, SiC and TiC [4–7], oxides- Al₂O₃ and MgO [2,8,9] and nitrides- AlN and Si₃N₄ [10,11] added known as reinforcement of materials into the Parent material. The reinforced materials improved various properties



like graphite help to enhance machinability etc. Due to the presence of carbide and oxide elements creating 3D shape component is difficult [12]. The loss of material in convention process is high makes it uneconomical as the cost of MMC material is high. To overcome this problem, Electrical discharge machining can be used to machine hybrid MMC materials. EDM is a non-conventional erosion process and material removed from the workpiece by spark erosion process. It is also called electrical spark erosion process [13]. In this machining process, any conductive material parts regardless of their toughness and hardness can be machined [14]. Generating 3D shape component and complex cavities are easy and product made is very precise in EDM [15,16]. All the above-mentioned properties of MMC materials and machinability of EDM provide a wide field of research. The machining quality of EDM further can be improved. Which will make it more suitable for industry and MMC materials.

2. Literature Review

Singh et al. [17] used Al/10SiC MMC to studied the effect of input process parameters on the responses. In this investigation, it was found that high MRR (Material Removal Rate) obtained at high peak current and high pulse on time. TWR (Tool Wear Rate) is higher than MRR as well as poor surface roughness obtained at high peak current. The investigation also reveals that flushing process has a considerable effect on machining performance.

Gopalakannan et al. [18] fabricated Al/10B₄C MMC (Metal Matrix Composite) material and optimize the EDM (Electrical Discharge Machining) process parameters. The result shows that peak current and pulse on time are significant parameters for MRR and surface roughness. Kumar et al. [19] studied the effect of distilled water on the machined surface of Al/5SiC/(0,5,10B₄C). It was found that increasing pulse on time and pulse duration surface roughness increases. Talla et al. [20] used aluminum powder suspended kerosene dielectric to machine MMC material. Investigation result shows that a better MRR and a significant reduction in surface roughness obtained in comparison to the conventional EDM. Jeswani [21] used graphite mixed kerosene dielectric and investigate the effect. The powder mixed in dielectric reduces breakdown voltage which leads to the improvement of MRR and TWR. As breakdown voltage affect the machining performance. Xi et al. [22] performed an experiment and the result shows that Kalman filter can improve discharge gap and reduce machining time. After investigating the various advantageous effect of dielectric and methods, a new technique called PMEDM (Powder Mixed Electrical Discharge Machining) comes into existence which replaced conventional EDM. It has a different mechanism than conventional EDM. The machining performance improved in PMEDM at same time surface roughness also improved by selecting proper discharging parameters. Kunieda et al. [23] used multi-spark EDM in which higher MRR obtained at low energy consumption in comparison to the conventional EDM. Hu et al. [24] compare the result of conventional EDM and PMEDM. The result was remarkable as surface roughness decreases by 31%, hardness increases by 40 and wear resistance almost 100%. Figure 1 and 2 shows the comparative result of EDM and PMEDM. Khan et al. [25] studied the effect of the rotational and non-rotational electrode on machining Al/SiC MMC through EDM process. It was found that rotary electrode improves the MRR. Yeh et al. [26] machined 6061Al/20Al₂O₃ and optimized the responses using grey relational analysis (GRA). This research shows, a particular arrangement of input parameters can give better responses which are impossible to obtain by other methods. Kumar et al. [27] used a cryogenically cooled electrode to machine Al/10SiC MMC through EDM process and compare the result with convention EDM. Investigation shows that cryogenic cooled electrode improves the TWR as well as surface roughness. Figure 3 and 4 shows the effect of conventional and different PMEDM [28].

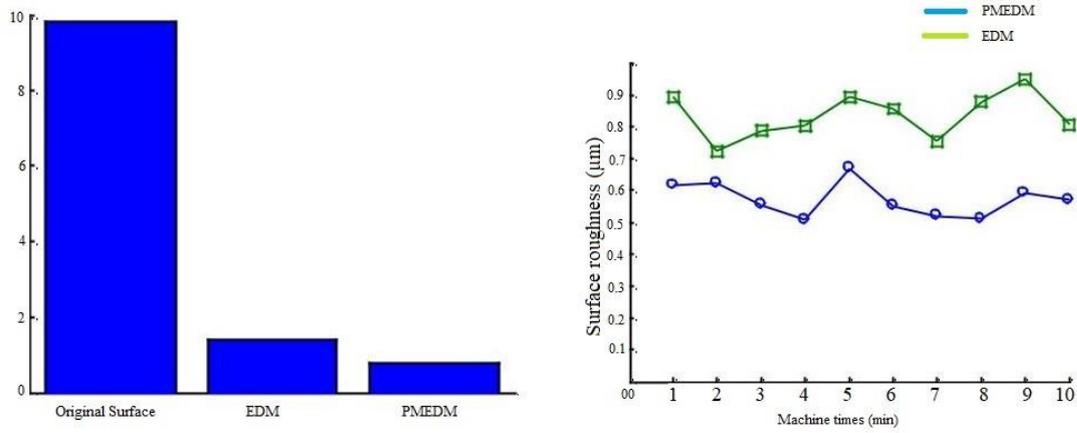


Figure 1. Wear mass comparison [24]. Figure 2. Roughness comparison between EDM and PMEDM [24].

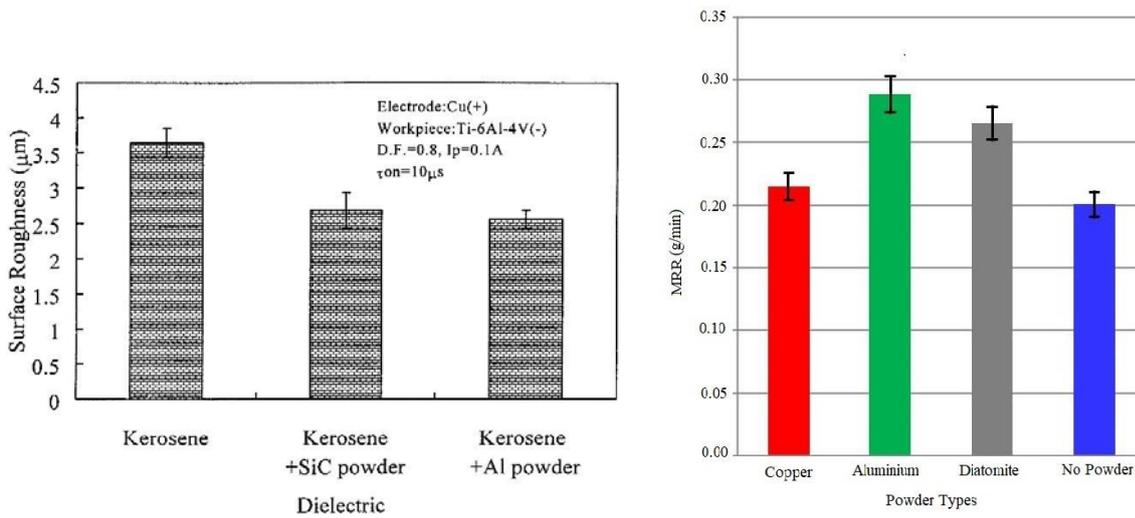


Figure 3. Surface roughness with different dielectric [29]. Figure 4. Effect of different dielectric in EDM [28]

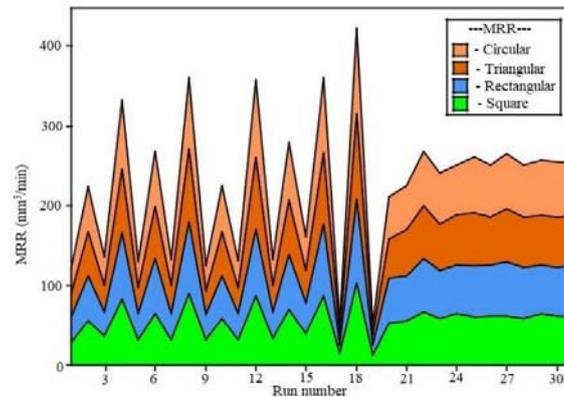


Figure 5. Area graph of MRR for different tool shape [31].

3. Result and Discussion

From the literature review, researchers have done a lot of study to improve machining performance. In all the cases, to improve the machinability, researchers used different dielectric, tool and powder mixed EDM. It was also noticed that machining performance varies with the composition. Figure 6 shows that at same machining condition, the different material has a different result.

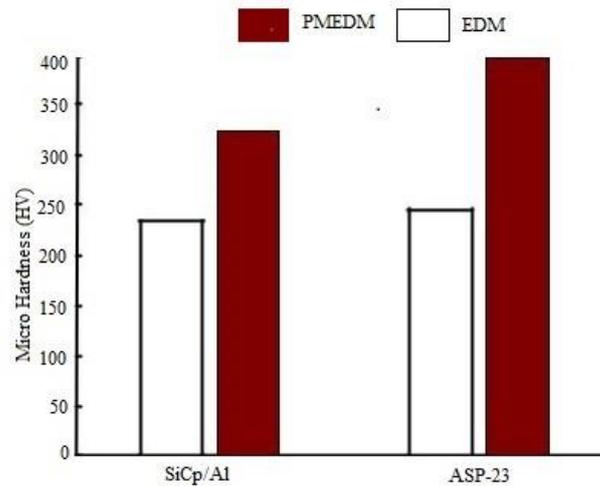


Figure 6. Microhardness comparison [24].

As different grain structure of same composition material have different physical properties. Therefore, same composition material may have different machining performance at different grain structure. So, Composition and grain structure may be the reason of variation in machining performance. To investigate the exact reason. Machining the workpiece material after heat treatment can reveal the exact reason. Because Heat treatment refines the grain structure as well as enhance the hardness [32]. Tempering decreases hardness with varying heating temperature changes the microstructure or the material [33]. Preheating of Al base metal component reduces chemical segregation of cast structure and also improves workability [34]. It was found that at the high-temperature strength of MMC drops remarkably and better performance obtain between 200 – 250 °C [2]. So, after performing all these operation machining

operations performed on EDM. Analysis of the obtained responses will clearly indicate the effect of grain structure and composition.

4. Conclusion

As different material have different machining performance at same process parameters in EDM. The effect of grain structure and composition can be determined by the above-mentioned process. Which may lead to enhance the machining performance. Findings may provide a universal equation of machining performance for all material. There are various MMC materials coming into existence day by day. This equation will give a pre-knowledge of machining performance without performing any machining operation.

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