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Fabrication and Machining of Metal Matrix Composite Using Electric Discharge Machining: A Short Review

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Abstract: Metal Matrix composite is a metal reinforced with two or more constituents which can be any other materials either metal or non-metal. Metal matrix composites (MMCs), which are inherently intelligent, are lightweight and high-performance, ever-expanding materials. The structural and functional properties of these materials may be modified by industrial requirements. Researchers and the industry are attracted by the process technology used in the production and processing of these products. The hybrid-electric discharge process for MMCs is a promising and the most effective non-conventional process. It has greater expertise in manufacturing complex shapes with greater precision. This paper gives an updated analysis of the development and advantages of various routes for composite manufacturing and machining. It reports on several realistic analyzes and study results, including various manufacturing and processing problems for MMC. Since the last few years, hybrid electrical discharge machining has been an active field of research in critical and nonconventional machining. This paper includes annual research in production, traditional machining, unconventional machining, and hybrid MMC machining. The final part of the paper addresses conclusions and future scope.

Keywords: Metal Matrix Composite, Electric discharge machining, Parameters, Technology, and Composite metal.

1. Introduction

The above study is based on the fabrication of the metal in the composition of electric discharge machining. The desired approach of the study is used to evaluate the property of the expansion of thermal materials. The phase of composite material describes the functions on the property of different practices which are supported by the technology of the system. The components of metal matrix composition fabricate the strategy of electric discharge machining. The strength and the models of metal create estimation on the management of thermal expansion. The increased use of the metal describes the function on the phase of the different capabilities of the applications. The average range of the metal generates the function on the need of the metal. The properties of the metal are related to the problems in terms of the fabrication of different metals. There is a performance evaluation of EDC on MMC on the integration of the surfaces.

1.1 Fabrication of Composite Metal

The process of fabrication of metal matrix composite

depends on the parameters of three states such as solid, liquid, and vapor phase. The composition of the system is used to analyze the estimation based on the distribution of a suitable metal. The state of the liquid phase increases the level of performance on the strategy of the infiltration methods. The matrix system creates a function on the needs of the metals which are used to change the method of the different particles. During the process of the liquid phase, the range of the system provides material based on suitable aspects¹⁻³⁾

2. Literature Review

To understand the flow of the literature review, a flowchart has been designed as shown in Figure 1. According to Aharwal and Krishna (2018)⁴⁾, the functions of the particles are used to hold in the position of metal by performing the methods of metal matrix composite i.e. MMC. The fraction of the metal describes the function of the operation of the low concept of viscosity metal. The high cost of operation is suitable in demonstrating the particles of EDM. The fabrication of the metal is decomposed of different particles of the molten matrix to

modify the different perspectives used in filtering the cost of low fabrication. There are different ranges of fabrication of MMC that are given with the help of the infiltration process. Fabrication of MMC with range by the process of infiltration is indicated in Table 1. As per Patel and Maniya (2018)⁵⁾, in the given table below, there is a fabrication of a metal matrix composite based on the range of different functions in the process of infiltration. There are three functions of fabrication such as piston, molten metal, and the reform strategy with a suitable range of composition.

Table 1. The constituents of CNG

Sr.No.	Fabrication of MMC	Range of MMC by the process of infiltration
1	Piston	20-25
2	Molten Metal	50-75
3	Reform	81-94

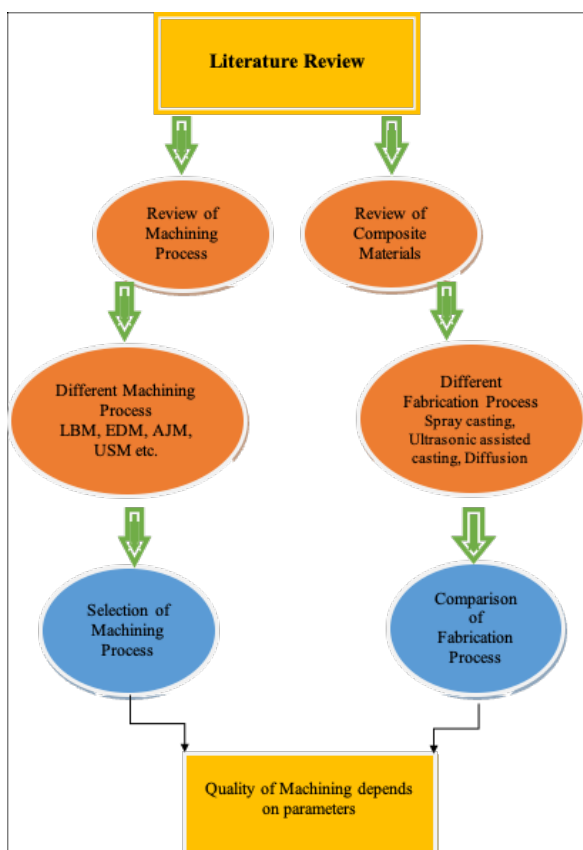


Fig. 1 Flow Chart of the Review process

The range of performance helps in reducing the ability of the system with a function of 20 to 94 C. The material of the matrix composite increases the concept of the criteria of different temperatures. The particles are heated on the surfaces of different sequences of operation on the density of the system⁶⁻⁸⁾

Panwar et al.⁹⁾ stated that the distribution of the system is uniformly spread based on suitable characteristics of the system. The fabrication of metal matrix composite evaluates the presence of different systems on the structure of a suitable crystal. The given diagram of the metal consists of some applications on the solutions of the given system. The exploration of the system helps to manage the functions based on different levels of approaches. The formation of the process is mainly used to describe the factor of suitable functions on the formulation of the metal. The minimum strategy of the process is required to control the overall level of temperatures. Various fabrication methods of MMC are represented in Figure 2.



Fig. 2: Fabrication of metal matrix composite

According to Li and Laghari (2019)¹⁰⁾, the surface of the molten metal requires a particle on the appearance of the system to examine the different particles of the process. The surfaces of the particles require a function on the method of suitable approach of the study. The stability of the system increases the level of estimation by providing a filter on the range of different approaches. The degradation of the system helps to provide various factors on the property of different interfaces of the metal consisting of various components. The number of different metals describes the properties of the efficiency of the given system^{11, 12)}. Despite these comparisons between few other fabrication methods are illustrated in table 2.

Table 2. Comparison of different Fabrication processes.

Route	Cost	Application	Comments
Spray casting	Medium	Friction materials, electrical brushes, and contacts are used in this process. Cutting and grinding	The reinforcement process is particulate by this fabrication method, as well as this method can

		tools are a useful component of the Spray casting method.	produce full density materials.
Ultrasonic assisted casting	Medium	Net-shaped fabrication of metal is maintained by this fabrication method. This method is used to maintain mass production.	The reinforcement process is particulate by this fabrication method, as well as this method can produce full density materials.
Diffusion bonding	High	Sheets, blades, structural components, and vane shafts are maintained by Diffusion bonding.	The distribution and good dispersion of reinforcement particles are uninformed by this fabrication method.

However, Electron discharge machining is a better method of metal matrix composites. EDM can cut the metal in proper shape, which can increase the efficiency of this technology. On the other hand, abrasive reinforcement policies are involved in the EDM process, which can increase the efficiency of these processes. Conventional machining of MMC is maintained with the involvement of this aspect. On the other hand, geometric tolerance of metal is increased with the involvement of EDM. Based on this information it is easy to say that EDM is between that fabrication processes. Moreover, a lot of work has been reported by several researchers in the field of fabrication of different composites including MMC, Fiber-based, and polymers¹³⁻²⁷.

3. Widely used metal matrix composite

Aluminum MMCs have widely used metal matrix composites. Few important examples of Aluminum metal-matrix composites are aluminum-graphite composite, aluminum-beryllium composites, and others. EDM process is used increasingly to maintain the production of Aluminum metal-matrix composites. EDM is treated as the most widely used non-traditional machining process, as well as EDM is the most important unconventional machining technique. Production of Aluminum MMCs is maintained with the involvement of Wire EDM. EDM is treated as an effective cost-effective process, which is conducted with the involvement of proper machining speed.

3.1 Performance evaluation of EDM on MMC

As per Prashanth et al. (2017)²⁸, the concept of electric discharge machining evaluates the criteria of performance on the function of metal matrix composition. The process of EDM generates the functions on the ability of MMC to influence the approach of the study. The demonstration of the process typically examines the material at the rate of electrical properties. The parameters of the properties consist of current, pulse polarity, voltage as well as the variable of different functions. The measurement of the system enhances the mechanisms on the particles of the metal during the functions of the EDM. The composition of the process increases the properties of the metal²⁹⁻³².

Senthil Kumar and Murali Kannan (2019)³³ stated that

there is typical reinforcement is used in the composition of a metal matrix approach to analyze the functions of the system. The affection of the EDM process evaporates the functions on the matrix of suitable particles. The expansion of the composite materials contributes to the factor of different approaches on the analysis of suitable methods. The different surfaces of MMC indicate the parameters based on the effect of current and pulse polarity. The machining process of particles affects the dimensions of the system to enhance the approaches of the process. The reduction of the different parameters is used in the postulates of reinforcement strategy^{9, 34, 35}

The given table 3 shows reinforcements that are used in the composition of metal matrix analysis based on the aspect ratio of the metal.

Table 3. Comparison of different metals with their aspect's ratio and diameter.

The strategy of the metal	Aspects Ratio	Diameter	Different examples
Particle	1-2	1-25 nm	Sic, WC
Short fiber	10-1000	1-5 nm	C, Al ₂ O ₃
Continuous Fiber	>10000	<100 nm	Nb+Ti

According to Yang et al. (2020)³⁶, the strategy of the metal consists of some aspect ratios based on the diameter of different ranges of the metal matrix. The functions of the particle, short fiber, and continuous fiber consist of different terms based on the approach of suitable estimation. The percentage of the given metal evaluates the composition between the factors to increase the overall strategy of the system. The contents of Al₂O₃ investigate the effect on the function of current, voltage, and the polarity of the pulse. The different variation of the material helps to remove the rate of functions by

increasing the efficiency of the pressure.

As per Wang et al. (2017)³⁷⁾, the amount of different materials reduces the density of electric discharge machining on the ability of MMC. The overall formulation of the system depends on the intensity of the system by creating a huge amount of information. The concept of EDM rapidly evaluates the performance on the contribution of the different materials. The amount of metal has significantly analyzed the approaches to decrease the accuracy of the process. The efficiency of the metal relates to the process of development by analyzing the machining parameter of EDM. The optimization of Al₂O₃ and SiC provides a complexity to propagate the given network^{38, 39)}.

3.2 EDM surface integrity

Qudeiri et al. (2020)⁴⁰⁾ stated that the integration of electric discharge machining i.e. EDM surfaces evaluates the functions on the factors of different aspects of the system. The components of the different metal matrices are used to observe the functions to optimize the efficiency of the process. The parameters of EDM create a layer to minimize the functions of the overall system. The different machining surfaces of EDM helps to integrate the context of a metal matrix based on the technique of different parameters. The components of the given surfaces consist of some layer that generally occurs to transfer the methods of integration⁴¹⁻⁴³⁾.

There are three distinct surfaces used that help to reveal the approach of suitable methods of the functions. The property of the EDM surface integrity affects the criteria to increase the level of enhancement. The different layers of machined surfaces such as recast layer, HAZ i.e., heat affected zone layer, and converted layer. The functions of the given layer create a factor of decomposition based on the amount of metal that is used in the transmission strategy. The concept of recast increases the surfaces of molten metal with an insufficient amount of transmission⁴⁴⁻⁴⁶⁾.

Khosrozadeh and Shabgard (2017)⁴⁷⁾ stated that the medium of different EDM surfaces is used to increase the process on the ability of the system which is used to increase the level of estimation on the strategy of the system. The characteristics of the given structure evaluate the functions in terms of the decomposition of molten metal. The portion of the matrix increases the rate of evaluation which are consists of suitable approaches. Figure 3 shows the different layers of EDM surface integrity. The different layers of the given process estimate the concept of pulse and current which are carried out to change the methods of EDM. The consequences of the system are used to cause the method on the approach of suitable estimation⁴⁸⁻⁵⁰⁾.

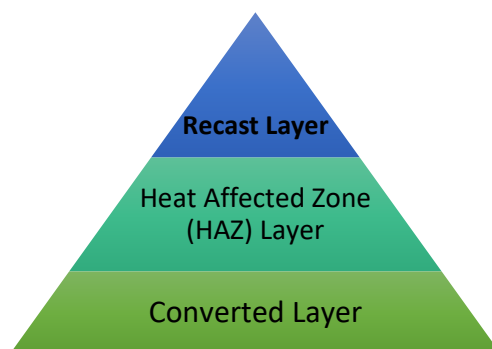


Fig. 3: Different layers of EDM surface integrity⁵¹⁾

According to Liu et al. (2019)⁵²⁾, the performance of the EDM has a vast impact on the tools of a standard electrode to obtain a desired amount of evaluation. The parameters of the process are used in the factor of predominant functions which are resulted in the integrity of machining. The speed of electrodes generally helps in combining the system on a wide range of machining parameters. The chemical composition of EDM is developed in the process of different methods which are used to reduce the functions of the given process. In the given pie chart, there is a function of EDM on the different contexts of MMC.

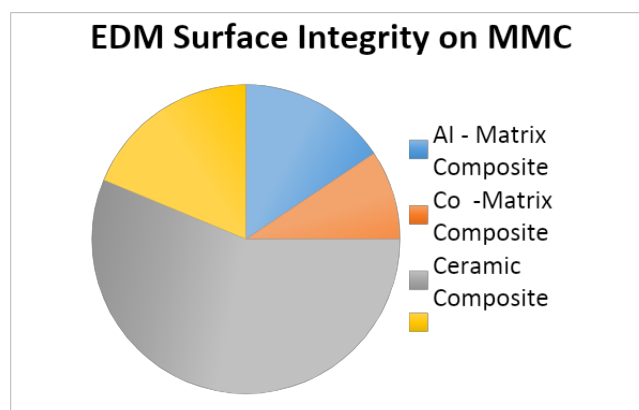


Fig. 4: Electric discharge machining surface integrity on Metal matrix composite⁵³⁾

As per Holmberg et al. (2018)⁵³⁾, the machining of the process enhances the strength of the system based on the contribution of different ranges. Electric discharge machining consists of some matrix composite on the different perspectives of the elements. There is 18% of Al-matrix composite, 7% of Co-Matrix composite, 60% of ceramic composite, and 15% of Hybrid composite are used. Figure 4 shows the Surface integrity on MMC by Electric discharge machining.

3.3 Residual Stresses

The uneven solidification of the molten metal results in residual stress which is a kind of defect found during electric discharge machining. According to Liu et al. (2018)⁵²⁾, these defects can be the reason for failure or cause corrosion during the tensile loading. The exceeding of the ultimate strength of the materials by the induced residual stress comes as a failure can be shown in the form

of cracks. The designers got attracted towards the residual stress due to the heavy structure of the sudden collapse of a bridge in Belgium in the year 1938, March⁵⁴). It was found the collapse was produced due to a welding process which results in residual stress and is shown in the form of crack. The crack became the reason for failure due to its extension to the base metal. During the electrical discharge machining, the same kind of failures was observed that happened to residual stress.

The surface integrity gets affected due to various electric and non-electric parameters. These parameters include peak current, material properties of electrodes that contain the workplace as well as tools, pulse durations, voltage, dielectric effect, and polarity. According to Casavola et al. (2017)⁵⁵, the early failure of the structure can be easily detected by using surface integrity and it is used by the researchers in the area of non-destructive testing methods. One of the most popular destructive techniques is known as X-ray diffraction whose resolution is about 20µm vertically and 1mm in-plane. The neutron diffraction penetration is found in Al about 20mm and in Ti 4mm with a resolution of 500µm. The penetration of ultrasonic is greater than 10 cm and the resolution is about 5mm. The penetration of passive magnetic techniques found penetration of about 20 mm and a resolution of 1mm. Eddy current techniques and active magnetic techniques also have penetration of 1mm mm and resolution of 1mm⁵⁶).

The effect of the residual stress on the surface integrity and fatigue life has been explained in the research. The recent advancement in measuring tools has been also found in the research. The evaluation of the residual stress in the EDM machine has not been found yet figure 5 shows the Residual Stress Variation. The bending deflection was used for measuring the residual stress in the EDM. According to Honnige et al. (2018)⁵⁷, the measuring of the residual stress in the EDM gave the results that the maximum value of the residual stress and tensile should be below the machined surface and as the discharge energy varies, then the magnitude and depth of the residual stress will also vary accordingly. In the EDM machine steel, some of the researchers used X-ray diffraction.

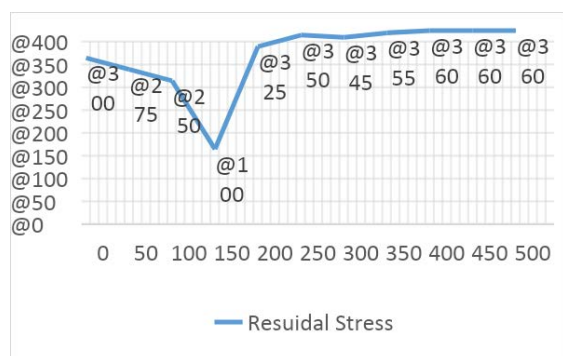


Fig. 5: Residual Stress Variation ⁵⁸⁾

4. Overview of Electric discharge machining

Electric discharge machining methods are used to

overcome the problems with the traditional machining methods. According to Syed et al. (2019)⁵⁹, traditional machining methods get failure after some limitations and cannot give high accuracy to the materials. Electrical Discharge Machining is applicable for all the conductive materials and provides high accuracy to them. Thermal energy is used in electrical discharge machining to remove the materials from the workpiece. Mechanical force is not required in the EDM for the removing process such as laser cutting. EDM is considered as non-traditional contrary as it does not require any mechanical force for the cutting process as like the traditional methods required⁶⁰⁻⁶²). EDM is widely used in the field of tool and molding making as it can be easily applicable for hard materials such as titanium. The EDM can be used to achieve complex shapes which cannot be achieved through milling.

Electrical Discharging Machining is a non-conventional electro thermal machining process where an electrical spark is generated through the electrical energy and thermal energy of the spark is used to remove the materials. The high resistant alloys and difficult-to-machine materials used EDM for removing the metals from the theme. Electrically conductive in EDM is done through Work material. Four basic components of EDM include pulse power supply system, electrode feeding system, dielectric supply system, and electrode and the workpiece⁶³⁻⁶⁵). There is no direct connection made between the electrode and the workpiece in the EDM due to which it reduces the vibration problem and mechanical stress chatter during machining.

Metal is removed by using the EVL through the electric spark erosion. Electric Discharge Machining used an electric spark as a cutting tool to cut the material and act as an erode from the workpiece and produced a desirable well-furnished shape. The process of removing the metal from the materials in EDM is done by pulsating the electrical charge through the electrode with high frequency to the workpiece. Various types of EDM are used for removing metals from materials. Sinker EDM, Wire EDM, and hole drilling EDM are the types of EDM used for removing metals from materials. Sinker EDM is used for producing complex shapes by removing metals. In the sinker EDM electrodes are made from graphite to produce shape by sinking into the workpiece.

Wire EDM is used for cutting the workpiece and the wires act as electrodes. In the wire EDM, the spool is used for bringing the wire constantly from the automated feed during the period of machining. According to Kumar et al. (2018)⁷, whole drilling EDM is used for drilling the holes and compared to the traditional drilling techniques this method can produce deep and extremely small-sized holes. The holes which are done through the hole drilling EDM don't require any deburring. The Use of EDM offers various advantages as the first advantage is that it can be used on all types of materials. The second advantage of using EDM is that it can be used on the hardest materials as the workpiece used in the EDM is titanium which allows it to provide any shape to the materials. The normal cutting tools do not allow producing certain shapes and

depths as they can produce some limited shapes and depth.

4.1 Working principle of EDM

Electrical Discharge Machining provides the desired shape to the workpiece by generating sparks through discharge⁶⁶. Two electrodes are separated through the dielectric liquid and a voltage is applied to produce a periodic and fast-changing current to remove the metals from the materials. The two electrodes are known as pole head or tool electrode and the other electrode is known as a workpiece electrode. During the whole process, there is no connection between both electrodes. Molybdenum and copper wires are the main wire cutting materials used as electrodes and the products and the electrode starters corroded at the same time^{67, 68}.

The degree of corrosion is smaller in electrodes as compared to the products. Liquid coolant acts as a discharge medium which is used for cooling the materials during the processing. Pulse voltage is used between both electrodes and creates a proper gap between both electrodes.

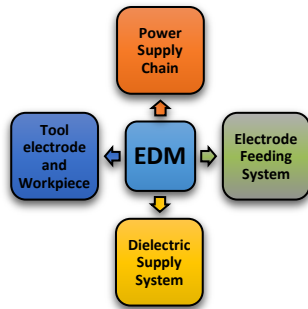


Fig. 6: Basic Components of EDM⁶⁹

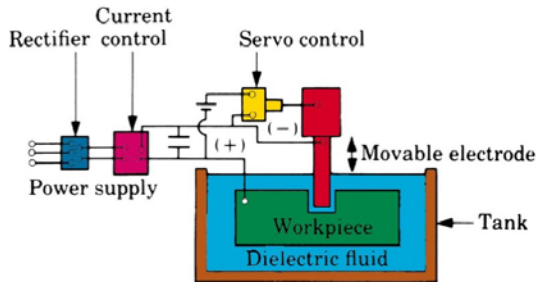


Fig. 7 Shows a schematic diagram

Figure 6 shows the basic components of EDM and Figure 7 shows a schematic diagram. The medium between both electrodes gets broken by the current which results in the appearance of the discharge channel. The high temperature will be generated by the discharge channel which leads to melting the workpiece. A huge electrical pit appears and the electrode returns to a safe distance after completion of one EDM⁷⁰⁻⁷².

4.2 Parameters of the EDM process

The EDM process involves two kinds of parameters known as process parameters and response parameters. In the process parameters, two kinds of variables are present which include the electrical parameters and non-electrical process parameters where the response parameters include

only dependent parameters. The electrical parameters of the process parameters include electrode gap, pulse duration, pulse interval, and duty cycles. During the process of EDM, there is a gap between the electrode and the remaining part, and that remaining part is known as the electrode gap. In response to average gap voltage, hydraulic systems or electro-mechanical systems are used. According to Kou and Han (2018)⁷³, it is needed to maintain a suitable gap for providing stability to the gap and this also helps in obtaining good performance. This will help to get the accurate shape with well finishing of the materials⁷⁴. To fix the problem of short circuits it is needed to have high speed. The average gap is used to measure the gap width. The electrode gap is also known as the spark gap. Pulse duration is the time that is measured in the microseconds and it is also known and pulse on times. Figure 6 shows the Pulse waveform of the pulse generator. The wear behavior of the electrode is affected by the machined areas which get improved by the longer pulse duration⁷⁶.

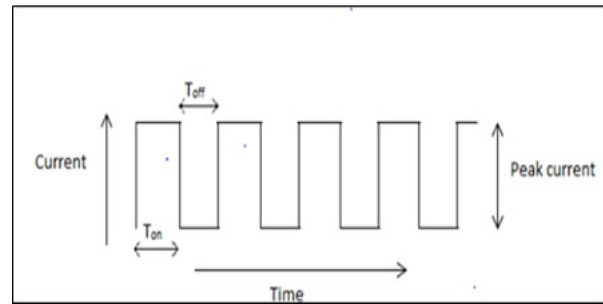


Fig. 6: Pulse waveform of the pulse generator⁷⁵.

The amount of energy applied during the on-time period is directly proportional to the metal removal. Pulse interval is the condition where the material does not find any machining and the metal from the materials gets vaporized from the setting. The MRR time gets decreased with the increment in the pulse interval. The stability and speed of the cut are affected by the pulse interval. The percentage between the on-time relative with the total cycle time is known as the duty cycle. The duty cycle indicates the degree of efficiency of operation. Table 4 shows the process parameters and response parameters.

Table 4. Process parameters with their response parameters

Process Parameters	Response Parameters
Electrical Parameters	MRR (Material Removal rate)
Electrode gap	TWR (Tool Wear rate)
Pulse duration	RCL (Recast layer)
Duty cycle	SR (Surface Roughness)
Pulse interval	Taper and overcut
Non-electric parameters	HAZ (Heat Affected Zone)
Workpiece rotation	
Flushing of dielectric fluid	
Electrode rotation	

Non-electrical parameters consist of workpiece rotation, flushing of dielectric fluid, and electrode rotation. The performance measure can be optimized by

using non-electrical parameters. The flushing of dielectric acts as a coolant and affects the SR and TWR. By using the flushing, the debris can be flushing away from the mechanical group. The crack density and the recast layer are influenced by the flushing pressures. The circulation of the dielectric fluid is improved through the workpiece rotary motion³⁶).

5. Conclusion

The present work illustrates the findings and research done in the field of metal matrix composite, considering the fabrication and machining of hybrids using EDM. The key findings of the work have been listed below:

- The need for advanced hard materials for industrial applications also creates scope for preparing new hybrids with enhanced mechanical properties.
- The difficult-to-cut hard materials, specifically composites are always treated and point of research for being machined. A lot of unconventional machining processes are available for the machining of such composites.
- Comparing the available machining processes, EDM stands with more benefits in terms of preserving material properties with precise cut quality.
- Moreover, the selection of correct input parameters and machine settings usually affects the performance and quality of the EDM. Hence, the selection of appropriate machining parameters and levels plays an important role in achieving optimized quality.
- Considering the disadvantages of EDM, as the EDM process uses thermal energy and reduces mechanical forces for removing the material, few deficiencies are also present in the EDM process.
- Additional time and costs are effective disadvantages of the EDM machining process. Due to the presence of electrode wear, it is tough to produce sharp concern, which can decrease the efficiency of the EDM process.
- On the other hand, the slow rate of material removal directly has an impact on the efficiency of the Electrical Discharge Machining Process.

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