Machining of Composite Materials Using Different Conventional and Unconventional Machining Processes: A Short Review

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Abstract Due to the object's diversity and heat sensitivity, as well as the high combativeness of the fibers, machining composite materials is challenging. As a consequence, the workpiece is damaged and the tool wear is quite high. Because of its outstanding physical and mechanical characteristics, the application of Metal Matrix Composite is growing. The major challenge is to keep their costs under control while preserving qualities like lightweight, high strength, and durability. Natural fiber composites are a viable substitute for synthetic fiber because of their enhanced characteristics and, more significantly, since they are biodegradable and inexpensive. The study shows these features make it feasible for modern engineering and related technologies which is usual and more effective in present era. Furthermore, due to the limitations in the manufacture and machining, large-scale production of natural composites is prone. Because of their heterogeneous and an-isotropic conduct, fiber composites have poor machinability features. Various processes and new techniques in order to achieve excellent machining in composites with natural fiber were created to solve this challenge.

Keywords Metal matrix composites · Fiber-matrix composites · Conventional · Unconventional machine tools

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1 Introduction

Composite materials are materials with more than one phase, exhibiting diverse qualities, like high strength, high rigidity, low friction, lightweight, etc. Nowadays, a composite hybrid metal matrix is also utilized in the automotive and aerobatic industries and is typically produced by stir casting. Aluminum 6061 is typically utilized as a matrix above zirconium dioxide, as it has characteristics such as strong wear, high defensive compatibility, and automotive compatible. Metal matrix Composite has various applications, such as compressor blades, trains, satellites, sports goods, bike frames, etc. Metal matrix composite's machinability is influenced by characteristics such as feed rate, cutting speed, tool shape, tool material, [1]. For the milling of metal matrix composites, many types of traditional machining, etc. techniques are utilized, such as boiling, turning, grinding, milling, etc. (MMCs). While non-Conventional Machining Proceedings (EDM), Electrochemical Machining (ECM), etc. are used to machine MMCs, Abrasive Water Jet (AJM). Through the ages, this development in materials began with the discoveries of iron, copper, metal, and polymers. In recent times, due to its excellent features, the application and use of composite materials have been aggressively increased. The composite materials are two or more chemically distinct materials, generally a matrix and strengthening. In the composite, the matrix material is present in a continuous phase, whereas the strengthening is intermittent. The matrix material can be in any form either a polymer or a metal, or a ceramic. The polymer matrix is the plastics that may be thermoplastic or thermoset. In polymer composites, fiber is the material that is used as reinforcement, in some cases, filler materials are also used as reinforcement [2].

2 Metal Matrix Composites

The composites of the metal matrix (MMC) are a type of material consisting of one metal that is fused to another. The two components are chemically and physically separate in different periods [3]. The basic material is a metal matrix, whereas the other component appears to be working as fibers or particles. The objective of making this material is to improve, as with other metal matrix composites, the existing characteristics of the metal matrix, by adding additional functionality provided by the reinforcement, as shown in Fig. 1.

3 Fiber-Matrix Composites

The best and most promising material in this century has been determined to be composites. Composite materials with synthetic or natural material fibers currently take on more relevance as requirements are rising for lightweight materials of

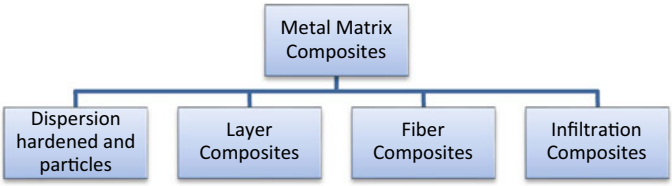

Fig. 1 Different composite material

high durability for specific purposes. Composite Fiber-reinforced polymer offers not only a high strength/weight ratio but also great durability, steadiness, damping characteristics, bending strength and corrosion resistance, wear, impact, and firing. These varieties of properties have led to the development of composite materials in the automotive, building, aviation, automotive, pharmaceutical, and marine sectors [4–16].

4 Conventional Machining of Metal Matrix Composites

Uncoated carbide tools are not appropriate for MMC machining, and Keyon and Silicon Nitride tools are also not used for serious surface roughness. They are analyzed. They also determined that workpiece polishing provides a superior finish on the surfaces. Investigated wear rate tools, borders, and cornered dots, when the use of Al matrix composites in sic particles has been cut. As Sic content grows, the likelihood of flank wear is increased, thereby reducing tool life. Low speed is usually suitable for the production, of course, Sic Particles, and Developed Edge, while the cutting of fine Silicon Carbide Particles reinforced MMC is permitted at high speed. During the processing of metal particles, wear mechanism is prevalent (PMMCs). The degree of flank wear also rises as feed force increases while PMMCs is boiling. They have also created a mathematical method that will optimize the situation during PMMC drilling. Thus, this model was used to create several objectives in order to evaluate the influence of various machining factors [5]. In the machining of MMC by diamonds tool abrasive wear play a vital function. PCD insertion tool durability And K10 diamonds instruments are achieved using the equation of tool life. PCD insert tools are usually utilized in the machining of MMCs enhanced with silicon carbide particles for extended tool life and a superior surface finishing. It takes longer to impose flank wear on PCDs, while CVD instruments require less time to attain wear mechanisms. A rougher grinding of aluminum composites is favored by Sic wheels, since their particles are more difficult and less expensive than diamonds, while by fine grinding of alumina composites, diamond wheels are preferable. The study also discovered that the grinding force reduces for rough grinding with an improvement in grinding speed while the rough grinding decreases owing to varied sizes and adhesives. The rate of flank wear on the device likewise rises with a cutting

speed. As the cutting speed of the tool increases, the temperature increases and the material adhesion to the tool diminishes. The lower the cutting speed, on the other hand, lowers the temperature and therefore produces stress hardening. BUE formation preserves the tool surface from abrasion and decreased adhesive wear and size of the tool by increasing the tool's cut speed. A Mechanical framework for prediction of forces when working with ceramic particles reinforced alloy-based metal matrix composite [6]. And it was also discovered that cutting and thrust forces, which were based on slip-line set theory, shear-plane analyses from Merchant, and the Griffith concept, were estimated for the production of a chip. From perspective of physical and mechanical characteristics, MMCs are superior to non-enhanced alloys. Because they have good abrasion characteristics, they are thus classified as tough materials. As the wear rate changes linearly with the average particle size and in the case of 2-body and 3-body abrasions the rate of cut-off and feed rises. The influence of several factors like tool surface, dimensional deviation, processed surface, etc. on the machine tools of the Si—MMC by various types of PCD tools at changing velocity. They observed in their experiments that during machining using PCD instruments, good surface finishing is acquired. We also studied how coolant lowers the surface polish by adhering to particulates. Micro MMCs played an essential role in the machining of particles, the size of particles, and their position when nano MMC's are being machined. During the processing of micro MMCs, continuous chips were produced whereas interrupted chips were generated while micro MMCs were machined. Better finish is achieved when nano MMCs are processed [7].

5 Unconventional Machining of MMCs

Cast aluminum metal matrix composite machinability enhanced with Sic (Silicon Carbide). The Alloy matrix protected from degrading the effect of sparks produced during electrocution hazard processing by Silicon Carbide. With the use of special gravity and TEM, the thermal zone concerned was analyzed (Transmission Electron Microscopy). EDM was generally preferably selected for the production of complicated forms over other processes. Boiling of blind hole followed by EDM in order to assess machining performances of Al2O3/6061 Al. Large voltage and other electrical factors impacted MRR. According to its data, the MRR rises with the speed of the rotation, the flushing pressure, and two eccentric holes inside the electrodes. The electrode increases. The modifications happened while processing Al-10% SiCp, as cast MMC, in the metal removal rate. The source of current rises also increased the wear rate and the rate of metal loss. And MRR also rises owing to a lower risk of short circuits due to reductions in the flushing pressures due to the delay in inflammation. The impact of the grain-specific surface area of Silicon Carbide (Sic), the electrode rotation speed, layer thickness, the tool wear rate (TWR), and the radial cut (ROC). And it was observed that MRR and TWR increase the wall thickness of the electrode, the speed of the electrode rises as well as the grain size of Silicon Carbide particles decreases [8]. This process was carried out with the aid of EDM followed

by rotating brass electrodes to machine Silicon Carbide Particulates composites of 7075A–10 wt%. Furthermore, a degradation was due to the surface morphology that was caused by the thermal division for the removal of ceramic particles and re-solidified layer development. Non-conventional machining is used for the machining of MMI like Electric Discharge Machining (EDM), Laser Beam Machining (LBM), or Abrasive Water Jet Machining (AWJM). However, issues like the development of recasting layer in case of EDM hinder the process in order to enhance surface finishing by using powder mixed EDM and therefore reduce the difficulties of tool wear and tool distortion. The AWJM has played an important role in the surface finishing of workpieces in the size of abrasive and reinforced particles [2, 9].

6 Conventional Machining of Fiber-Matrix Composites

The diverse characteristics of the composites of the fiber-matrix challenge the traditional method. Conventional machinery such as boiling, friction, rotation polishing, and milling of composite materials creates further matrix and reinforcing material failures. In addition to the material characteristics, material failure also affects the machining parameters. In determining the cutting force, the orientation of natural fibers is essential. The natural fiber reinforcements are resistant to tool penetrating, resulting in fiber pull out and delamination. Furthermore, the surface fiber injuries produce surface waviness [10]. In fiber-matrix composites the production of chips is not predictable; the cutting process is difficult to detect. The increasing temperature during the drilling process melts the matrix, producing a poor surface area and affecting material performance. With the exception of material failure of machining, traditional machining impairs the worker's assistance owing to the production of dust during milling. The equipment is one of the most essential factors in the traditional machining operation. The tool is usually worn during machining and even plastic deformation takes place. The tool material is worn during chopping due to the destructive fiber nature of the fiber reinforcement, as shown in Fig. 2.

7 Unconventional Machining of Fiber-Matrix Composites

The unconventional machining method is being increasingly used in the machining of fiber composites with a goal to produce high-quality machining in fiber-matrix composites. Modern technologies of machining have increased machined quality characteristics, decreased machining time, and flaws in various composite fibers. In an unusual machining operations material is removed by the phase transformation mechanism, i.e., using specific equipment, which is entirely different from traditional material removal procedures by using high, medium, and high-frequency vibration temperatures. While a variety of unusual processes are practically applicable such as water jet processing, ultrasonic machine tools, laser machining, and electrochemical

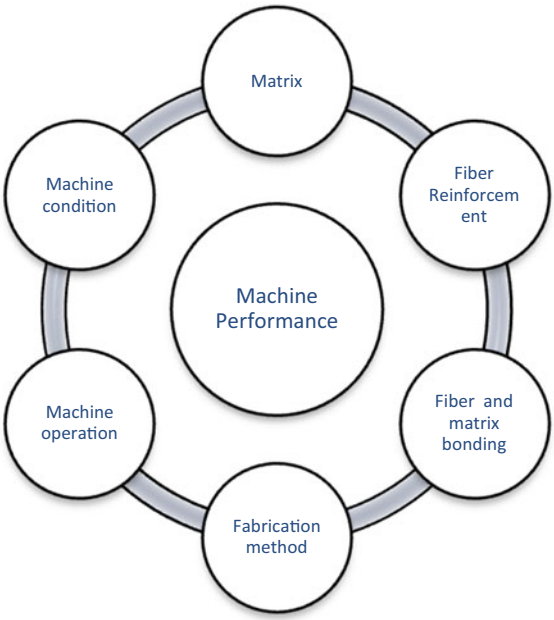

Fig. 2 Different machine operations

machining, only a restricted method for the machining of fiber-matrix composites is employed. In particular, several researchers have examined the abrasive waterjet process effect (AWJM) of fiber-matrix composites [9, 11].

8 Equivalence of Conventional and Unconventional Machining Processes

Most individuals do not realize that two groups, main and secondary processes, constitute the manufacturing process. The fundamental form and size of the material are created by the primary process, while the secondary—sometimes known as the machining process—ensures a greater control of measurements, surfaces, etc. You need to grasp the distinction between conventional and non-conventional processes to comprehend the secondary manufacturing processes [12].

- **Accurateness**: The conventional process has a lesser consistency and surface finish, whereas a better accuracy and surface finish is provided for non-conventional processing.
- **Used Tool**: Conventional machining must always be provided with a mechanical equipment. For example, in a Lathe machine, a cutting tool. However, in a non-conventional machining process, there may be no physical tool available.

For instance, laser beams do the work in laser machinery while electrochemical milling demands a physical instrument.

- **Machining Process**: Conventional machining generally includes altering the form of a workpiece using a hard-working tool. Using conventional methods for machining hard metals and alloys, time and energy consumption are raised and prices are therefore enhanced. In some instances, it may not be possible to work conventionally.
- **Conventional machining adds**: consequences in terms of tool wear and product quality loss due to generated stress distribution during production. Evermore attention to non-conventional machining processes has increased with the rising demand for production of hard alloys and metals.
- **Contact tool and part of work**: The conventional technique of machining includes direct tool-work part contact while the non-conventional approach does not need direct tool-work part contacts.
- **Waste Material**: The conventional machining method is also likely to produce more waste because of the high surface contact and wear of tools with lower lifetime. Non-conventional machining has reduced waste products because of little or no wear using tools having a longer life [3, 13].

Limitations of Machining Process have Been Listed in Table 1.

The latest machining methods such as NC, CNC, DNC, FMS, etc. have been developed to overcome these drawbacks [6, 14].

Advantages of machining process have been listed in Table 2.

Table 1 Limitations of machining process

1	The precision of the produced components depends on the operator's effectiveness
2	There is no uniformity in production. Therefore, the element must be inspected at 100%
3	The operator's subjective requirements decrease output rates
4	The labor difficulty will also be considered because of the enormous number of workers employed
5	Extreme systems are difficult to produce, such as parabolic curvature components and cube curvature components
6	The present arrangement cannot include frequent modifications in the component

Table 2 Advantages of machining process

1	You may get a high surface polish
2	Machining is conducted on wood, plastic, composites, and materials, but not simply on metals
3	Various geometrical characteristics like screw threads, high straight edges, precise circular trousers, etc. are conceivable
4	Good size precision

9 How Unconventional Machining Process is Better Than Conventional Machining Process

On the other side, non-conventional machines are those having computer-based operations autonomously and no human interaction or operator is necessary. Usually, these are operated by an automated robot or computer [15]. For examples vehicle painting in automotive production facilities, soldering car units, and production procedures, where the severe heat and the extremely low temperature are involved that people are unable to resist are activities that employ non-conventional machinery [16]. The conventional machining process requires that the tool and the work material have a direct contact. For example, for cutting an aluminum bar, a quick spinning iron cutter is essential [17]. This procedure involves direct contact between the cutting instrument and the substance to be sliced. In contrast, the method of non-conventional machining uses state-of-the-art optimization algorithms. No-touch between tools and material is involved in this procedure. Examples of utilized tools that are not traditional are infra-rot, laser beam, electric arc, plasma cutting, and electric beam [18]. The two differences are as follows.

10 Results and Discussion

The term "conventional machining" refers to a technique that employs mechanical force various forms of technologies are used in non-traditional machining. Thermal, chemical, and electrical energy are the three primary types of energy utilized in non-conventional machining. Turning, boring, milling, shaping, broaching, slotting, grinding, and other traditional machining techniques are examples. Similarly, non-traditional machining methods include Abrasive Jet Machining (AJM), Ultrasonic Machining (USM), Water Jet and Abrasive Water Jet Machining (WJM and AWJM), and Electro-discharge Machining (EDM). Non-conventional machines, across the other hand, are those that perform computer-based activities without the need for human contact or operation. These are generally controlled by a computer or a robot. Non-conventional machinery is used in activities such as automobile painting in automobile manufacturing facilities welding automobile units, and manufacturing processes where high heat and extremely low temperature are engaged and employees are unable to withstand.

11 Conclusion

A comprehensive examination of the processing of metal matrix combinations and fiber-matrix composites has been carried out in this article. The review highlighted the differences between conventional and unconventional machining and highlighted

benefits and limitations. The study describes the standard methods of machining of both composites and unusual machining processes of the two composites. Finally, we will illustrate how unconventional processes are superior to traditional processes.

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