Investigation Analysis Of Machining Process In Metal Matrix Composites: A Review

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Abstract- *Metal Matrix Composites (MMCs) are materials that offer tailor-made property combinations required for wide range of engineering applications. MMCs are composed of a soft metal matrix and hard reinforcing particles. In hybrid composites two or more reinforcement materials with different properties are mixed at molecular level in continuous metal matrix phase and these composites are more homogeneous than the traditional composites and offer improved properties. The review of machining investigations of hybrid MMCs employ conventional machining processes such as drilling, turning and milling as well as nonconventional machining processes like electrical discharge machining (EDM), wire cut EDM (WEDM) and abrasive water jet machining (AWJM). Conventional machining of these composites exhibits poor machinability, faster tool wear and uneconomical production process. This paper reviews machining investigation of various hybrid MMCs in conventional and unconventional machining process.*

Keywords- MMCs, Drilling, Milling, EDM, WJM.

I. INTRODUCTION

Metal Matrix Composites (MMCs) has the potential to fulfil the recent demands of the advanced engineering applications. Predominantly, the use of MMCs has been extended from automobile and aerospace to marine, defence, sports and recreation industries. MMCs are materials that constitute of metal base with ceramic or organic compounded reinforcement materials dispersed in the form of particulate in the metal matrix. They have found important industrial applications due to their high strength-to-weight ratio, high toughness, lower coefficient of thermal expansion, good wear resistance, and capability of operating at elevated temperature. Particle reinforced MMCs have become very important as they are inexpensive compared to whiskers and sheet reinforced MMCs. Lighter metals such as aluminum, magnesium and titanium are most commonly used to form metal matrix while ceramic based abrasive particles like SiC, B4C, Al2O3, TiC, Gr, CNT and ZrO2 are used for reinforcement. Hybrid composites contain two or more discrete reinforcement particles dispersed into matrix base. They are non-homogeneous and anisotropic in nature due to presence of abrasive reinforcements which render their machining difficult. The advantages of hybrid MMCs include balanced strength and stiffness, balanced bending and membrane mechanical properties, balanced thermal mechanical distortion stability, reduced weight, improved fatigue resistance and wear resistance, reduced notch sensitivity and improved fatigue toughness, improved damping capabilities and good shielding to nuclear radiations. These materials are widely used in aerospace applications due to their outstanding properties. The properties of the composites are generally controlled by the matrix, the reinforcement materials, its proportion and the interface. The most popular types of MMCs are aluminum alloys reinforced with ceramic particles such as SiC and B4C[1].

II. MACHINING PROCESS

Development of machining processes for the production of high-performance composites has been reported in many research studies. Figure 1 illustrates various machining techniques that were in use for the last few years. The following methods are most common for fabrication of the MMCs at large-scale industrial level.
1. Conventional machining processes.
2. Unconventional machining processes.

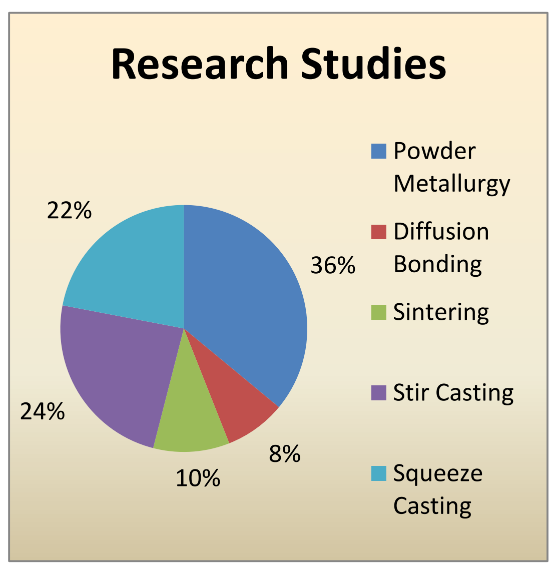


Fig 1. Research studies of different MMCs machining process[2].

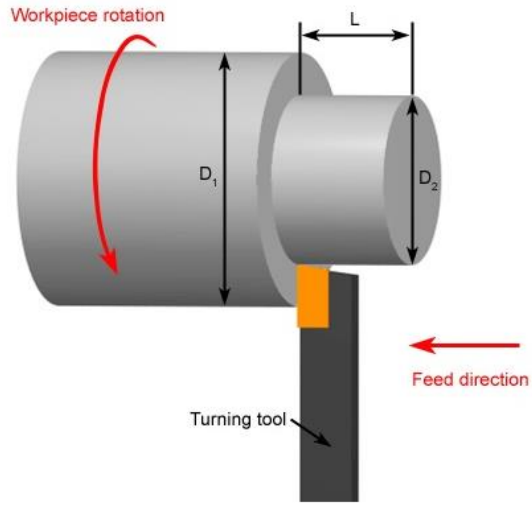
III. CONVENTIONAL MACHINING PROCESSES

Conventional machining uses tools, such as lathes, milling machines, boring machines, drill presses, or others, with a sharp cutting tool to remove material to achieve the desired geometry. Usually there is a direct contact between the tool and raw material. three of the most common operations including: turning, drilling and milling. Machining is a very common and versatile manufacturing process. Thus, it's possible to machine various types of material using these three methods. Metals, plastics, composites, and wood are all possible workpiece materials[3].

Turning

Turning is a form of machining, a material removal process, which is used to create rotational parts by cutting away unwanted material. The turning process requires a turning machine or lathe, workpiece, fixture, and cutting tool. The workpiece is a piece of pre-shaped material that is secured to the fixture, which itself is attached to the turning machine, and allowed to rotate at high speeds. The cutter is typically a single-point cutting tool that is also secured in the machine, although some operations make use of multi-point tools. The cutting tool feeds into the rotating workpiece and cuts away material in the form of small chips to create the desired shape.

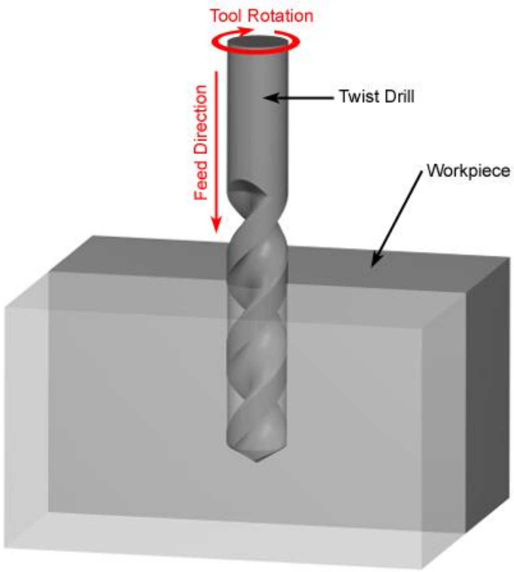
Turning is used to produce rotational, typically axi-symmetric, parts that have many features, such as holes, grooves, threads, tapers, various diameter steps, and even contoured surfaces. Parts that are fabricated completely through turning often include components that are used in limited quantities, perhaps for prototypes, such as custom designed shafts and fasteners. Turning is also commonly used as a secondary process to add or refine features on parts that were manufactured using a different process. Due to the high tolerances and surface finishes that turning can offer, it is ideal for adding precision rotational features to a part whose basic shape has already been formed[4].

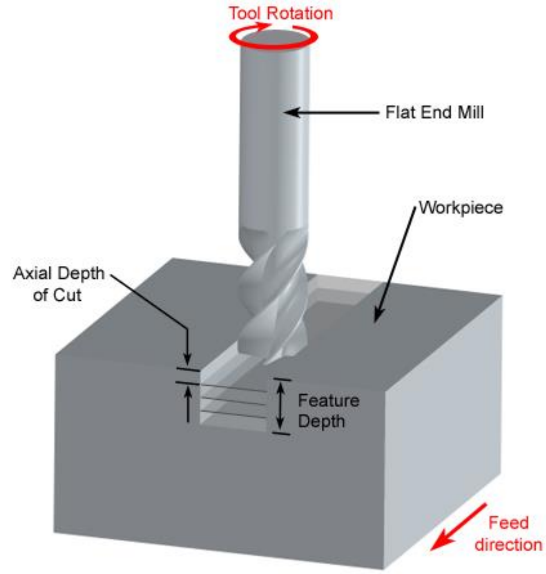


Drilling

Hole-making is a class of machining operations that are specifically used to cut a hole into a workpiece. Machining, a material removal process, creates features on a part by cutting away the unwanted material and requires a machine, workpiece, fixture, and cutting tool. Hole-making can be performed on a variety of machines, including general machining equipment such as CNC milling machines or CNC turning machines. Specialized equipment also exists for hole-making, such as drill presses or tapping machines. The workpiece is a piece of pre-shaped material that is secured to the fixture, which itself is attached to a platform inside the machine. The cutting tool is a cylindrical tool with sharp teeth that is secured inside a piece called a collet, which is then attached to the spindle, which rotates the tool at high speeds. By feeding the rotating tool into the workpiece, material is cut away in the form of small chips to create the desired feature.

Hole-making operations are typically performed amongst many other operations in the machining of a part. However, hole-making may be performed as a secondary machining process for an existing part, such as a casting or forging. This can be done to add features that were too costly to form during the primary process or to improve the tolerance or surface finish of existing holes[5].





Milling

Milling is the most common form of machining, a material removal process, which can create a variety of features on a part by cutting away the unwanted material. The milling process requires a milling machine, workpiece, fixture, and cutter. The workpiece is a piece of pre-shaped material that is secured to the fixture, which itself is attached to a platform inside the milling machine. The cutter is a cutting tool with sharp teeth that is also secured in the milling machine and rotates at high speeds. By feeding the workpiece into the rotating cutter, material is cut away from this workpiece in the form of small chips to create the desired shape.

Milling is typically used to produce parts that are not axially symmetric and have many features, such as holes, slots, pockets, and even three dimensional surface contours. Parts that are fabricated completely through milling often include components that are used in limited quantities, perhaps for prototypes, such as custom designed fasteners or brackets. Another application of milling is the fabrication of tooling for other processes. For example, three-dimensional molds are typically milled. Milling is also commonly used as a secondary process to add or refine features on parts that were manufactured using a different process. Due to the high tolerances and surface finishes that milling can offer, it is ideal for adding precision features to a part whose basic shape has already been formed[6].

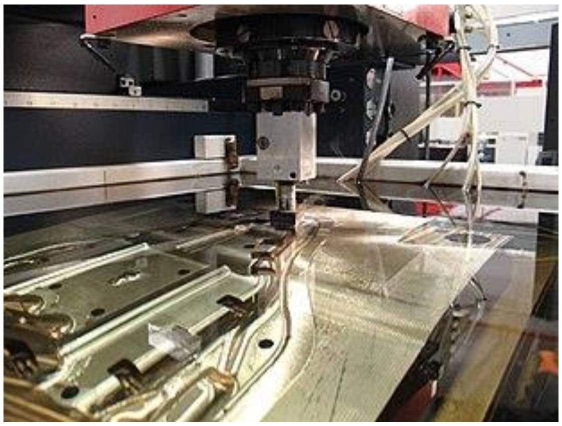
IV. UNCONVENTIONAL MACHINING PROCESSES

An unconventional machining process (or non-traditional machining process) is a special type of machining process in which there is no direct contact between the tool and the workpiece. In unconventional machining, a form of energy is used to remove unwanted material from a given workpiece[7].

Electrical Discharge Machining

Electrical discharge machining (EDM), also known as spark machining, spark eroding, burning, die sinking, wire burning or wire erosion, is a manufacturing process whereby a desired shape is obtained by using electrical discharges (sparks).[1] Material is removed from the work piece by a series of rapidly recurring current discharges between two electrodes, separated by a dielectric liquid and subject to an electric voltage. One of the electrodes is called the tool-electrode, or simply the "tool" or "electrode," while the other is called the workpiece-electrode, or "work piece." The process depends upon the tool and work piece not making actual contact.

When the voltage between the two electrodes is increased, the intensity of the electric field in the volume between the electrodes becomes greater than the strength of the dielectric (at least in some places), which breaks down, allowing current to flow between the two electrodes. This phenomenon is the same as the breakdown of a capacitor (condenser) (see also breakdown voltage). As a result, material is removed from the electrodes. Once the current stops (or is stopped, depending on the type of generator), new liquid dielectric is usually conveyed into the inter-electrode volume, enabling the solid particles (debris) to be carried away and the insulating properties of the dielectric to be restored. Adding new liquid dielectric in the inter-electrode volume is commonly referred to as "flushing." Also, after a current flow, the difference of potential between the electrodes is restored to what it was before the breakdown, so that a new liquid dielectric breakdown can occur[8].

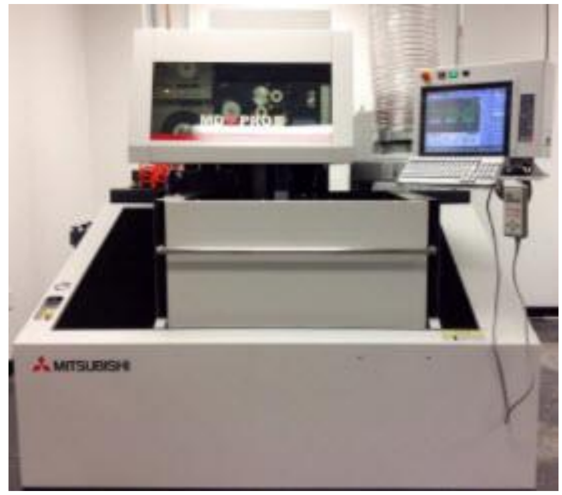


Wire EDM

Wire EDM provides first-class Wire EDM machining services, producing precision parts that match the dimensional tolerances of your designs within ± 0.0001". With state-of-the-art wire EDM machining equipment and advanced programming, we can manufacture even the most intricate parts with perfect accuracy and repeatability, whether you need prototypes, short production runs, or quantities in the tens of thousands.

Wire electrical discharge machining is a high-precision method for cutting nearly any electrically conductive material. A thin, electrically-charged EDM wire held between upper and lower mechanical guides forms one electrode, while the material being cut forms the second electrode. Electrical discharge between the wire and the workpiece creates sparks that rapidly cut away material. Submerging the workpiece and wire in deionized water, allows cutting debris to be flushed away[8].

As the charged wire never makes physical contact with the workpiece in EDM machining, there are no cutting forces involved, making it possible to manufacture extremely small and delicate parts. Parts that require levels of accuracy and intricacy that traditional machining cannot achieve can easily be produced via wire EDM[9].



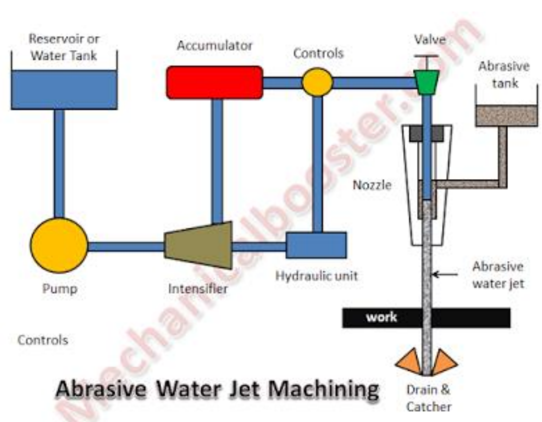
Water Jet Machining

Water Jet Machining (WJM) also called as water jet cutting, is a non-traditional machining process in which high velocity jet of water is used to remove materials from the surface of the workpiece. WJM can be used to cut softer materials like plastic, rubber or wood. In order to cut harder materials like metals or granite, an abrasive material is mixed in the water. When an abrasive material is used in water for the machining process, than it is called as Abrasive Water Jet Machining (AWJM).

It is based on the principle of water erosion. When a high velocity jet of water strikes the surface, the removal of material takes place. Pure water jet is used to machine softer material. But to cut harder materials, some abrasive particles mixed with the water for machining and it is called as AWJM

Abrasive Materials

The most commonly used abrasive particles in AWJM are garnet and aluminum oxide. Sand (Si02) and glass bead is also used as abrasive. The function of abrasive particle is to enhance the cutting ability of water jet[10].



V. CONCLUSION

The machining investigations of hybrid MMCs researched mainly on Al-alloys (Al-356, Al-2219, Al-6061, Al-6063 and Al-7075) based matrix composites due to its wide application in the industry. Number of reinforcement particles like SiC, B4C, Al2O3, TiC, Gr, CNT and ZrO2 are used for reinforcement**.** The SiC with other reinforcements such as B4C, Gr and Al2O3 were mainly combined in various proportions for preparing hybrid MMCs. Both conventional and non-conventional machining processes are used for production of MMC components. The machining investigation and optimization of hybrid MMCs reveal the effect of reinforcement type and its proportion in the composites. The following are the conclusions of the present review work. Variety of hybrid MMCs were investigated by drilling, turning and EDM processes but only little research has been reported in milling, wire cut EDM and AWJM processes.

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