A Study on Non - Traditional Machining Investigation on Hybrid Metal Matrix Composites - A Review

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Abstract: *This paper presents 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 non-conventional 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 terms of process parameters used, and their influences on machining performance, modeling and optimization of the processes, techniques used, their efficiency and summary of the review are presented.*

Keywords: *Machinability, MMC, conventional, non-conventional, fabrication*

1. INTRODUCTION

Continuous reinforcement uses monofilament wires or fibers such as carbon fiber or silicon carbide. Because the fibers are embedded into the matrix in a certain direction, the result is an anisotropic structure in which the alignment of the material affects its strength. One of the first MMCs used boron filament as reinforcement. Discontinuous reinforcement uses "whiskers", short fibers, or particles. The most common reinforcing materials in this category are alumina and silicon carbide.

- Carbide drills are often made from a tough cobalt matrix with hard tungsten carbide particles inside.
- Some tank armors may be made from metal matrix composites, probably steel reinforced with boron nitride. Boron nitride is a good reinforcement for steel because it is very stiff and it does not dissolve in molten steel.
- Some automotive disc brakes use MMCs. Early Lotus Elise models used aluminum MMC rotors, but they have less than optimal heat properties and Lotus has since switched back to cast-iron. Modern high-performance sport cars, such as those built by Porsche, use rotors made of carbon fiber within a silicon carbide matrix because of its high specific heat and thermal conductivity. 3M sells a preformed aluminum matrix insert for strengthening cast aluminum disc brake calipers, allowing them to weigh as much as 50% less while increasing stiffness. 3M has also used alumina preforms for AMC pushrods.
- Ford offers a Metal Matrix Composite (MMC) driveshaft upgrade. The MMC driveshaft is made of an aluminum matrix reinforced with boron carbide, allowing the critical speed of the driveshaft to be raised by reducing inertia. The MMC driveshaft has become a common modification for racers, allowing the top speed to be increased far beyond the safe

operating speeds of a standard aluminum driveshaft.

- Honda has used aluminum metal matrix composite cylinder liners in some of their engines, including the B21A1, H22A and H23A, F20C and F22C, and the C32B used in the NSX.
- Toyota has since used metal matrix composites in the Yamaha-designed 2ZZ-GE engine which is used in the later Lotus Elise S2 versions as well as Toyota car models, including the eponymous Toyota Matrix. Porsche also uses MMCs to reinforce the engine's cylinder sleeves in the Boxster and 911.
- The F-16 Fighting Falcon uses monofilament silicon carbide fibers in a titanium matrix for a structural component of the jet's landing gear.
- Specialized Bicycles has used aluminum MMC compounds for its top of the range bicycle frames for several years. Griffin Bicycles also makes boron carbide-aluminum MMC bike frames, and Univocal briefly did so as well.
- Some equipment in particle accelerators such as Radio Frequency Quadrupoles (RFQs) or electron targets use copper MMC compounds such as Glidcop to retain the material properties of copper at high temperatures and radiation levels.
- Copper-silver alloy matrix containing 55 vol. % diamond particles, known as Dym alloy, is used as a substrate for high-power and high density multi-chip modules in electronics for its very high thermal conductivity.

Metal-matrix composites can be processed by several techniques. Some of these important techniques are described below.

- **Casting or liquid infiltration** involves infiltration of a fibrous or particulate reinforcement preform by a liquid metal.
- ***Squeeze casting or pressure infiltration*** involves forcing a liquid metal into a fibrous or particulate preform .Pressure is applied until solidification is complete.
- ***Diffusion bonding*** is a common solid-state processing technique for joining similar or dissimilar metals. Inter-diffusion of atoms between clean metallic surfaces, in contact at an elevated temperature, leads to bonding.
- ***Deformation processing*** can also be used to deform and/or density the composite material.
- ***Powder processing*** methods in conjunction with deformation processing are used to fabricate particulate or short fiber reinforced composites. This typically involves cold pressing and sintering, or hot pressing to fabricate primarily particle- or whisker- reinforced MMCs
- ***Sinter-forging*** is a novel and low cost deformation processing technique (12). In sinter- forging a powder mixture of reinforcement and matrix is cold compacted, sintered, and forged to nearly full density.
- ***Deposition techniques*** for metal-matrix composite fabrication involve coating individual fibers in a tow with the matrix material needed to form the composite followed by diffusion bonding to form a consolidated composite plate or structural shape.

2. LITERATURE REVIEW

While machining of Al,SiCp MMCs by conventional machining like turning, milling, drilling etc. high rate of tool wear has been achieved due to abrasive nature of SiC reinforcement. Also other difficulties like poor surface roughness, difficulties in achieving dimension constraint and complex shapes, increased machining cost have been observed which restrict the utilization of this conventional machining method[1]. So, different researchers have been utilizing different nonconventional machining methods like electro discharge machining, electro chemical machining, laser machining, abrasive water jet machining etc. for effective machining of these composites. Though for rough cutting operation laser machining shows effective productivity, but there are limitations like striation patterns on the cut surface, burrs at the exit of the laser and poor surface quality. Similarly abrasive water jet machining is very acceptable for rough cutting operations but it also has some disadvantages like slotted-edge damage on the top of the cut surface, relatively rough surface. Also these methods are used for only linear cutting operations [2]. In comparison to these in EDM, ECM better surface quality, machining of complex shape and structure, high precision and dimensional constraints for finishing operation can be achieved very efficiently. There is neither subsurface damage nor tool wear while machining under correct conditions [3].

One of the most exclusively utilized advanced material removal processes is Electro discharge machining (EDM). English physicist Joseph Priestley in 1970 first accomplished the erosive effect of electrical discharges. EDM is especially used for machining of hard metals and advanced materials or those that would be very difficult to machine with conventional machining methods. EDM, generally also termed as spark eroding, spark machining, die sinking or wire erosion. Its exclusive aspect of utilizing thermal energy to machine electrically conductive parts disregarding the hardness has been its unique advantage in the manufacture of die, mould, aerospace, automotive and surgical components. In addition to these, in EDM there is no direct contact between the electrode and the work piece removing the mechanical stresses, vibration and chatter problems during machining [4].

During EDM, material is removed from the work piece by a series of rapidly recurring spark discharges between two electrodes (tool electrode as cathode and work piece as anode), separated by a dielectric fluid and subjected to an electric voltage. When a suitable voltage in range of is applied, the dielectric breaks down and electrons are emitted from the cathode and the gap gets ionized when a suitable voltage and inter electrode gap is applied. In fact, a small ionized fluid column is created leading advancing an avalanche of electrons in the spark gap. When fluxes of electrons are collected in the gap it results in resistance drop causing electric spark to jump from tool to work piece surface. The generation of compression shock waves due to spark develops a local rise in temperature which is sufficient to melt a part of metals. Once the current flow stops, new dielectric fluid is usually flushed into the inter-electrode volume enabling the debris to be carried away and the insulating properties of the dielectric to be restored commonly known as flushing [5].

3 NON-CONVENTIONAL MACHINING OF HYBRID MMC

The traditional machining of hybrid composites causes excessive tool wear rate and the production process becomes uneconomical. Researchers have attempted to employ non-conventional machining processes such as EDM, WEDM and AWJM, which are used for machining hard and high strength alloys. Machining investigations using different hybrid composites and optimization of process parameters for single or multiple performance objectives were reported in the literatures.

Researchers have performed machining investigation on Hybrid MMCs using conventional machining processes such as drilling, turning and milling, and non-conventional machining processes like EDM, WEDM and AWJM. The research work reported on machining investigation mainly on aluminum based MMCs as well as magnesium based composites. Tool wear rate, cutting force and surface roughness is mainly considered as process performance in conventional machining process. Material removal rate (MRR), surface roughness and cutting speed is mainly studied by various non-conventional machining processes.

4. CONCLUSION

The optimal setting for Non-conventional machining is found to be most beneficent. The proposed procedures are simple, effective in developing a robust, versatile and flexible mass production process. In the context of optimization method there is no need for checking the correlation among responses as no individual weight has been assigned to responses. FIS can efficiently take care of these aspects into its internal hierarchy thereby overcoming various limitations of existing optimization approaches. This approach can be recommended for continuous quality improvement and off-line quality control of a process of manufacturing industry. In order to achieve best quality characteristics and satisfactory process performance yield; the machining parameters in EDM of work piece material Al, 10 % SiCp MMCs need to be optimized.

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