Effect of Process Parameters on Overcut During Assistive Die Sinking Electro-Discharge Machining

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Abstract

This study investigates the machinability of nonconductive Aluminium nitride (AlN) ceramics using die sinking Electro-Discharge Machining (EDM) machine. A three layers coating consisting of silver by Physical-Vapour Deposition (PVD), carbon layer and silver nano-powder were deposited on the ceramics materials to aid in conducting the EDM operation due to the conductive properties of the coating. Scanning electron microscope and optical microscope were used to characterise the machining parameter. The effects of the process parameters such as peak current, pulse on time, and duty cycle were studied on the overcut of the hole generated on the surface. It was found that, with the increase of peak current value, the overcut value increases, whereas, with the increase of pulse off time the overcut decreases.

1 Introduction

Ceramics materials are well known for their inherent properties of hardness, wear resistance and bio-compatibility. Nevertheless, these materials are difficult to machine, using conventional machining, due to the brittleness and toughness associated. Additionally, conventional machining faces challenges in terms of accelerated tool wear while machining ceramics materials. Therefore, non-conventional machining such as electro-discharge machining (EDM), has become one of the most common mean to machine ceramics materials. EDM is an electro-thermal process which does not rely on the consideration of materials hardness, but rather their electrical conductivity. EDM has limitations when non-conducting ceramics are machined. Indeed, EDM requires certain level of conductivity of the material to be able to machine the workpiece [1, 2]. The conductivity of ceramics materials can be altered by adding conductive particles, known as doping, that makes the workpiece machinable by EDM process as it was demonstrated by Yoo et al [3]. Researchers have modified the EDM process to enable the machining of non-conductive materials. An alternative technique is assisting electrode method [4] where conductive layers deposited on the non-conductive materials are exposed to the electrical discharge. High temperature generated during the EDM process causes cracking of hydrocarbon originating from either the dielectric or the coating material to combine with certain elements of ceramics materials. Thus, EDM of non-conductive ceramics becomes possible due to the layer of materials deposition. Currently there is limited research focusing on non-conductive material machining using EDM process. This study, assistive EDM using three layers of conductive elements on the AIN ceramics was investigated to identify the effect of process parameters such as peak discharge current, pulse on time and duty cycle on hole overcut.

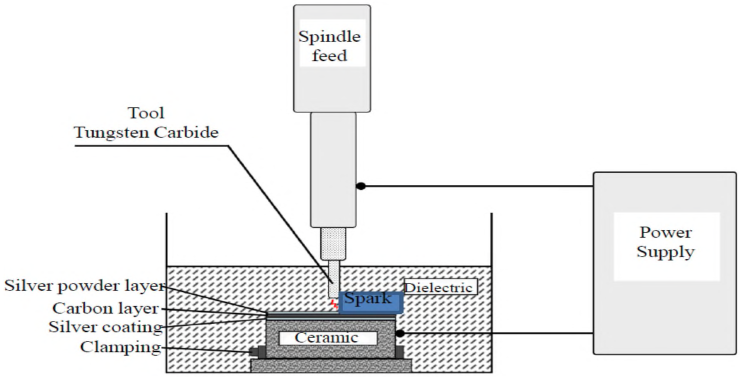


Figure 1. Schematic Experimental set up

Figure 1. Workpiece preparation for assistive EDM.

2. Experimental set up

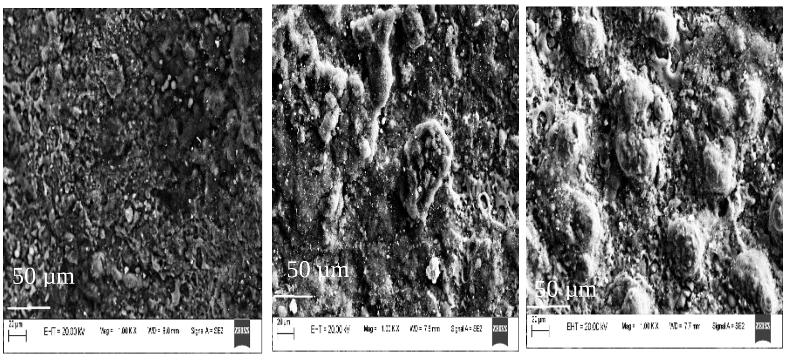
Experiment on AIN ceramic using EDM was conducted by die-sinking EDM machine ENC35. AIN sample of 20x20x3 mm and 1.9mm Tungsten carbide (WC) tool were used. Figure 1 shows the schematic of experimental set up. Table 1 shows the materials composition of the specimens. A layer of 5 µm of silver was first deposited by PVD, followed by a 150 µm carbon tape and lastly, silver nano-powder were deposited on the ceramics to create a conductive layer. After machining, samples were cleaned using ultrasonic cleaner and observed using scanning electron microscopy (SEM) and optical microscope.

Table1: Material composition

Electrode	Material	Composition
Tool	Tungsten Carbide	WC 92%, Cobalt 8%
Workpiece	Aluminium Nitride	Al 65.81%, N 34.19%

3. Results & Discussions

As can be seen from Figure 2 (a), (b) and (c), successful materials removal on AIN surface was achieved for various current using a modified Assistive EDM. The plasma channel generated during the EDM process eroded the coating material initially and also decomposed dielectric oil. Subsequently, carbon and silver particles that remained on the surface contributed in maintaining the EDM sparks, thus material was removed by thermal spalling.



(a) (b) (c)

Figure 2: FESEM image of closer view on the machined surface (a) 10A current (b) 8A current (c) 6A current. (Pulse on time 3µsec, Duty cycle 7)

The overcut is half of difference between the diameter of tool and produced hole. The hole overcut affects the dimensional accuracy as well as the surface quality. A lower overcut is desirable for better prediction of the final dimensions. Figure 3(a) (b) and (c) shows the effect of the current, pulse on time and duty cycle on the hole overcut. As can be seen, the overcut increased with increasing current due to the increase of the discharge energy (D.E). Higher D.E. resulted in larger crater size which resulted in more than anticipated material removal. A similar trend was reported by Pradhan et al [5]. Figure 3(b) shows that the increase of pulse on time reduced the overcut initially and then it increased again. Based on the data currently available it seems that 5 µs might be the optimum value for machining this type of ceramics. Assisted EDM cannot be conducted with larger pulse on time as it will vaporise whole conductive layer and EDM process will stop without the presence of conductive elements on the surface of the workpiece. However, too short pulse on time will result in longer machining time, therefore higher became the overcut value. Figure 3 (c) shows the effects of duty cycle on overcut. As, duty cycle, which is the ratio of pulse on time and total cycle time, decreases (or pulse off time increases), overcut tends to reduce. This is because, increased pulse off time removes debris materials thus reduces secondary sparking as well as overcut.

Conclusions

With this new technique currently under development, EDM of nonconductive Aluminium nitride was successfully demonstrated, as stray conductive particles aid in continuous spark generation. As per the results, increasing value of peak current causes up to 47.87% increment of the overcut, whereas, with increasing value of pulse off time causes overcut to be decreased up to 15.8%.

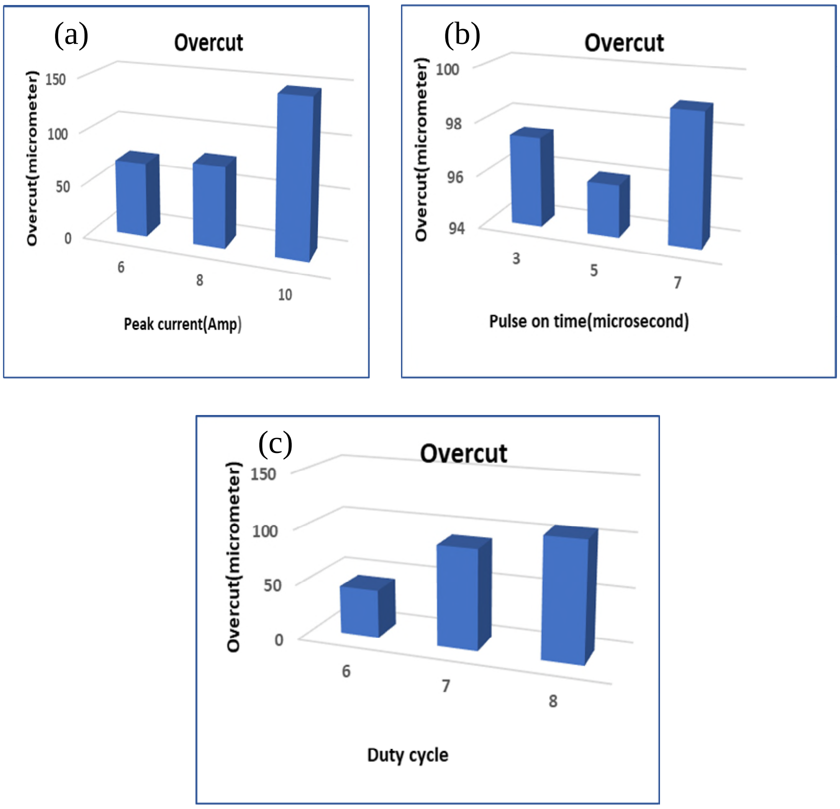


Figure 3. Effect of (a) peak current on hole overcut (b) pulse on time on hole overcut (c) duty cycle on hole overcut.

Acknowledgement

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