Micro Structuring of Carbide Metals with Jet Electrochemical Machining

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Abstract

The principle of electrochemical machining (ECM) is based on the anodic dissolution of conductive work piece materials under the influence of an electric charge exchange. On the boundary surface between the metallic work piece and a liquid ion conductor, called electrolyte, the work piece material is dissolved and carried out of the machining area by the electrolyte flow. As a special procedure electrochemical machining with closed electrolytic free jet (Jet-ECM) offers the machining of work pieces with extremely high current densities and a high localization of the machined area. Referring to this the Jet-EC Machining of carbide metal alloys is investigated in this study.

1 Introduction

Carbide metal alloys are composites of extremely hard particles in softer metallic ground components. Machining these materials is highly challenging with conventional mechanical methods, because these materials exhibit special attributes such as a high hardness and brittleness. As Electrochemical Machining is independent from mechanical characteristics, it represents a potential alternative procedure for structuring such materials. Thereby ECM of these materials is very complex due to the inhomogeneous distribution of its ingredients. Dissolving and passivating effects will occur dissimilarly. Therefore the high current densities of Jet-ECM in combination with the mechanical impact of the electrolyte jet can be an approach to generate micro structures in carbide metals.

In this study the Jet-EC Machining of carbide metal is analyzed. Although the electrolytic liquid is pumped through a small nozzle thus forms a free jet, like shown in **figure 1**.

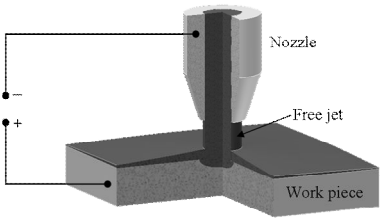

Figure 1: Scheme of Jet-ECM

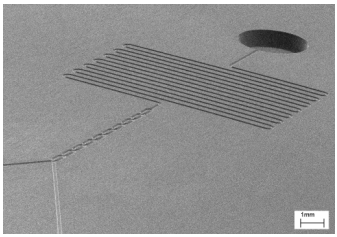

Figure 2: Jet-EC milled micro reactor in stainless steel

The electrolyte jet leaves the nozzle at an average speed of about 20 m/s and hits the work piece surface perpendicular. Forming a free jet leads to a high localization of the current density resulting in a very localized machining area direct below the nozzle, whereat current densities of up to 1000 A/cm² can be achieved. Continuously supplying a high amount of fresh electrolyte offers the possibility to use continuous direct current. This leads to higher removal rates compared to EC processes using pulsed electric current. By controlling the position of the nozzle and switching the electric current micro structured surfaces and complex three-dimensional micro geometries, as shown in **figure 2**, can be generated [1,2].

2 Design of experiments

For the investigations of Jet-EC machining of hard metals a tungsten carbide alloy - CTE12A of Ceratizit, Luxembourg – is analysed using a mixed electrolyte. The work piece material is built up of tungsten carbide with a grain size of 2,5 – 6 µm in a cobalt binding agent with a binder ratio of 6 %. The electrolyte consists of an aqueous solution of sodium nitrate (1.2 mol/l) and sodium hydroxide (0.6 mol/l), which was found as to be adequate for electroshaping both tungsten carbide and cobalt [3]. Abrasion experiments were accomplished using a Jet-ECM prototype facility, which has been developed at Chemnitz UT.

Further experimental parameters are scheduled in **Table 1**.

Table 1: Experimental parameters

Symbol	Parameter	Value
d	Nozzle inner diameter	100 µm
dV/dt	Pump delivery rate	10 ml/min
a	Working distance	100 µm
U	Electric voltage	10 V – 30 V
t	Process time	1.5 s – 3.0 s

Gap voltages from 10 V to 30 V with an increment of 5 V were used and the processing time was increased from 1.5 s to 3.0 s with a step size of 0.5 s.

3 Experimental Results

Pit abrasions, as shown in **figure 3,** were machined by leaving the electrolyte jet at its local position and applying direct voltage to the electrodes. As shown on the SEM-image the EC machining of tungsten carbide metal was successful. The eroded areas are widened due to a rising gap voltage, but varying process times hardly take effect on the calotte widths.

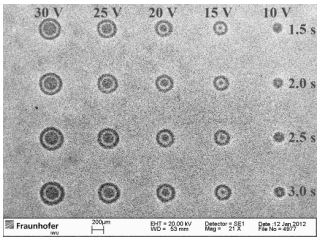

Figure 3: SEM-image of the machined calottes by rising process time (down) and increasing voltage (to the left)

The machined structures were analysed by confocal microscopy. Therefore depth profiles of each calotte were measured in the X- as well as in the Y-direction. The following plots respectively refer to the average of both of these values.

3.1 Lateral Dimensions

Figure 4 shows the calotte width *w* as a function of an increasing process time and a rising gap voltage.

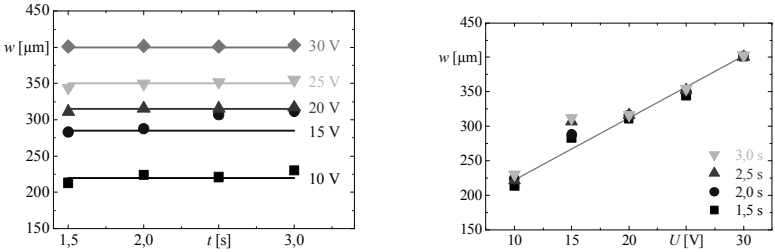

Figure 4: Calotte diameters as function of increasing process time (left) and rising gap voltage (right)

It can be assumed that the diameter of the dissolved calottes is nearly constant over the analysed machining duration for all the applied electric potentials. This

dependency is highlighted by the horizontal lines on the left graph of figure 4, displaying constant gap voltages.

With a rising potential, as shown on the right side, the calottes will ream up significantly. There is nearly a linear coherence between the analysed electric potential and the calotte diameter. Applying a voltage of 30 V causes a width of about 400 µm, which is about two times the width of the calottes machined with 10 V.

3.2 Vertical Dimensions

The relation between the height *h* of the Jet-EC machined calotte abrasions and the analysed process time as well as the applied gap voltage is shown in **figure 5**.

The left-hand graph displays the depth by an increase of the process time. As expected, the dissolved pits grow deeper the longer they are machined. After 3.0 s a maximum depth of 12 µm could be dissolved using gap voltages of 20 V to 25 V.

An ascending potential, as shown on the right graph, does not involve deeper abrasions categorically. There is a maximum in the range around 20 V, after which a further increase of the potential results in a decreasing calotte depth, which is highlighted by the interpolating spline curves.

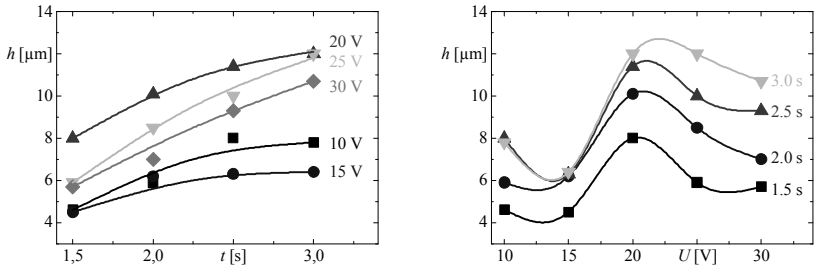

Figure 5: Calotte depths as function of increasing process time (left) and rising gap voltage (right)

At longer lasting process times nearly the same calotte depths are achieved by applying a voltage, which exceeds 20 V. Here, the influence of the rising working distance must be observed based on the deepening of the calottes. Therefore an adjustment of the electric potential could produce relief, whereat the concurrent widening of the machined area has to be regarded.

4 Summary

In the present work the electrochemical abrasion behaviour of tungsten carbide alloy CTE12A was investigated using a Jet-ECM prototype facility. Therefore micro

calottes were machined by varying the electric potential and increasing the process time. The resulting pit ablation were analysed via confocal microscopy capturing depth profiles of the dissolved calotte geometries.

The width of the calottes depends on the applied gap voltage whereat the diameter shows an approximately linear dependence from the used electric potential. Applying a voltage of 10 V causes an abrasion width of approximately 220 µm. A rising of the electric potential up to 30 V leads to an expansion of about 400 µm. For an increasing process time the calotte width remains nearly constant at similar gap voltages.

The machined calotte depth increases with an ascending process time. After 3.0 s a maximum depth of 12 µm was dissolved. But it exhibits a more complicated interrelationship to the analysed gap voltage. The maximum depths were reached applying 20 V for each analysed time step. With regard to short process times up to 2.5 s, a further increase of the potential leads to a decreasing calotte depth and to a widening of the dissolved area. With longer lasting ablation, along with an increasing working distance, this relation is reduced. At 3.0 s of processing time the same depth could be reached using an increased voltage of 25 V. From the present experiments it can be derived, that a systematic adjustment of the electric potential will be useful for electroshaping carbide metal materials, though this is not needed for machining of metal materials.

Acknowledgment

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