Electrical Discharge Machining of Microholes Using Carbon Fibre Tool Electrodes

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Abstract

The paper presents results of investigation into the μEDM process performed with carbon fibres working as tool electrodes. Carbon fibre electrodes selected properties are considered. The discussion of the errors of microholes machined during μEDM process with such electrodes is presented. Special attention is paid to the unbounded length of carbon fibre and possible errors related to this parameter are shown.

1 Introduction

In micro electrical discharge machining where the case of wear concerns very strongly also the tool electrode novel materials are tested to reduce this unwanted process [1]. Sometimes different methods to produce microelectrodes are considered [2, 3]. In some cases, even though the diameters of tool electrode are of desired submicron scale the length of such electrodes is also very small [3], limiting by the fact itself the performance of undertaken micromanufacturing process. Thus, the use of carbon fibre tool electrode which length can be adapted for certain purposes by trimming to adequate size is highly desired. The first positive results of machining with short electrodes were reported in work [4]. Drawn conclusions led to further analysis and experiments with longer carbon fibres.

2 Carbon fibre electrodes

Carbon fibres have suitable properties for microelectrodes in EDM process. The diameters are between 5 to 10 μm. The electrical resistivity is very low even comparing to other materials commonly used as electrode materials. For example for tungsten it is 5.60×10^{-8} Ωm, for tungsten carbide $1.7...2.2\times10^{-7}$ Ωm and for carbon fibres should be even 0.18×10^{-8} Ωm [4]. However, measurements of resistance for

polyacrylonitrile (PAN) derived carbon fibre, used in experiments, revealed higher values ($0.15x10^{-5}$ Ωm) than those given in literature. The values of this important parameter are strongly influenced by the fibre origin and technological process of fabrication. This property is one of the most important in EDM process because conductive materials for electrodes are applied.

Other important properties as well as fabrication procedure of short carbon fibre electrodes were mentioned in [4]. Longer electrodes with length exceeding 1 mm are similar to short ones but the working part (carbon fibre itself) can be of desirable length – Figure 1. The fibre is placed in guide-eye to support the unbounded end of it. Sliding it out for the appropriated length can change the unconstrained length of fibre. This solution should remarkably reduce the problem of machining errors caused by transverse movement during sudden process phenomena.

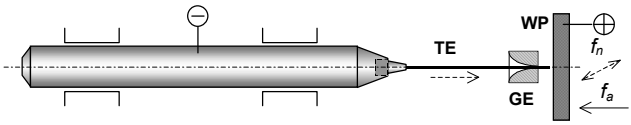

Figure 1: Machining idea of microholes with long fibre electrode: TE - tool electrode, WP – workpiece, GE – guide-eye

3 Discussion of the errors of microholes generated during μEDM process

The entrance diameter of cavities or microholes obtained by μEDM with the carbon fibre electrodes depends strongly on the unbounded length of the carbon fibre. It is natural consequence of a high slenderness of the fibre by relation of its length (one to few mm) to its diameter (7 μm). The series of microholes machined with gradually shortened fibre confirmed such dependence – Figures 2 and 3.

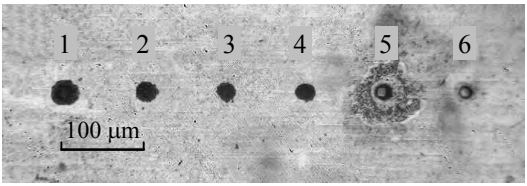

Figure 2: Series of 6 microholes in beryllium bronze foil with thickness of 4 μm

The radial oversize of the microholes changes from 12.5 μm for the first hole to 5.5 μm for the last one. The oversize is the result of presence of machining side gap and

of fibre vibrations. Because electrical process parameters were constant (U=120 V; R=23.8 kΩ; C=22 pF), the machining gap should be similar in all trials. Therefore, changeable bending by vibrations of the fibre causes changes of the diameter oversize. Similar results have been obtained by microsinking in hardened stainless steel. The theoretical calculations done for various lengths of the fibre and for selected bending forces shown that during machining on the fibre acts force larger than 0.1 μN – Figure 4.

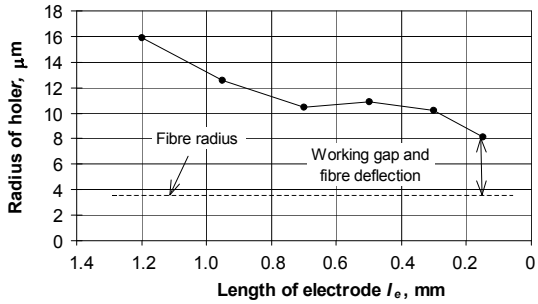

Figure 3: Radius of machined micro-hole versus unbounded length of carbon fibre

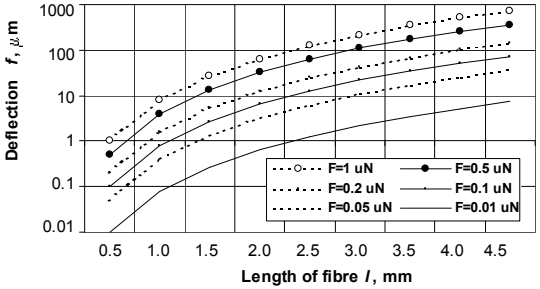

Figure 4: Calculated deflections of 7 μm carbon fibre versus its length for selected values of bending force

As expected the length of electrode gets shorter the transverse movements of the working tool caused by sudden phenomena of EDM process are smaller. Also the diameter of the affected zone is smaller. For through microholes, machined in beryllium bronze foil with the thickness of 4 μm, SEM observations shown relatively large shape irregularities caused by fibre vibrations – Figure 5. Another machining

method was tested with inclined fibre. The results were shaped through holes with expected ovality – Figure 6.

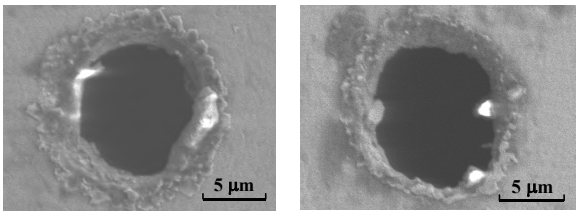

Figure 5: Shapes of through microholes machined with carbon fibre electrode

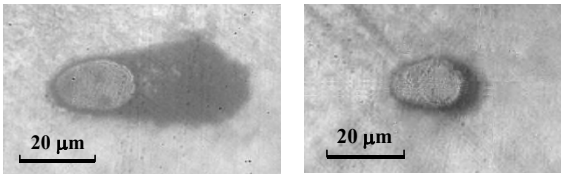

Figure 6: Examples of oval-shaped through microholes machined with inclined electrode

4 Conclusions

It may seem that better performance can be obtained with short carbon fibre electrodes and there is no need to apply the longer ones. However due to high wear ratio of electrode it is difficult to machine the deep cavity or even a through hole. That is way the analysis of errors with the use of longer electrodes was needed and so the solution to minimise them is necessary.

References:

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