Ultrasonic-Assisted Micro-EDM of Deep Bores: Process and Discharge Analysis

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Abstract

Ultrasonic vibration has been found very beneficial for the micro electro discharge machining (µEDM) of deep microstructures with high aspect ratios. In this study, the discharge properties of µEDM aided with direct ultrasonic workpiece vibration are analysed and compared to conventional µEDM machining. It can be shown that not only the number of discharges per second is significantly improved, but also the typical height of the discharge current is differently distributed. The investigation shows that the amount of open circuit states in µEDM can be noticeably reduced by using ultrasonic vibration assistance.

1 Introduction

Micro Electro Discharge Machining (µEDM) is a well known means for the machining of precise high aspect ratio structures such as micro bores. Due to its noncontact nature and its process principle of ablating material by melting and evaporating caused by electric discharges, it is independent of material hardness, brittleness or toughness. This makes the µEDM suitable for micro mould- and die making – using hardened steels – as well as for the machining of materials such as cemented carbides or ceramics. Recently, also nonconductive ceramic materials have been successfully machined using µEDM [1].

To increase the achievable aspect ratio without diminishing accuracy is one of the main goals of development, hence process stability is crucial. Flushing conditions and the state of the discharge gap have been identified as main influences; optimisation using improved flushing strategies and optimised discharge gap control circuits has lead to great improvements. Especially the use of ultrasonic vibration enables the process to achieve aspect ratios of up to 40 in bore diameter ranges of less than 150µm. At Chemnitz University of Technology and the Fraunhofer IWU, tests have been conducted to achieve very deep micro bores using ultrasonically assisted µEDM with the vibration being applied directly to the workpiece (figure 1) [2].

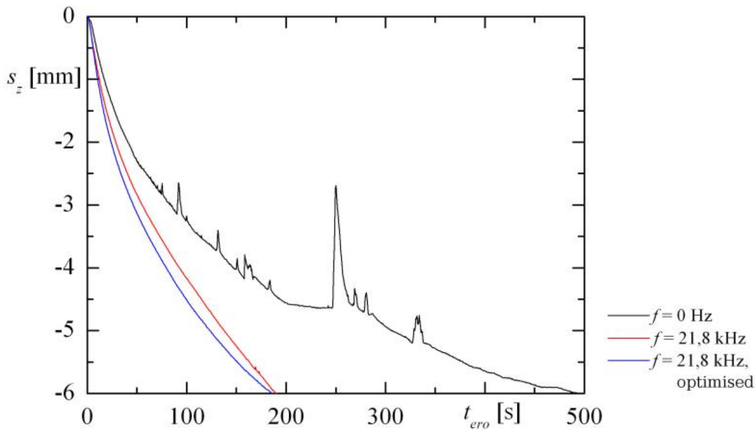

Figure 1: Tool feed in conventional and ultrasonic assisted deep bore µEDM process

2 Experiment

2.1 Objectives

The influence of ultrasonic vibration on the discharge duration (cutting off of long arc discharges) was examined in previous studies [3], but now it can be shown that the ultrasonic assisted process not only significantly improves the total number of discharges per second, but also influences the discharge current i_e and the volume ablated per discharge. With these findings, a stabilisation of the process using ultrasonic assistance could be proven. Furthermore, strategies for optimising µEDM parameters such as gap width, discharge voltage and discharge energy can be developed, compared and verified based directly on the discharges and the real process. This not only enables an optimisation of process speed, form accuracy and precision but also contributes to understanding the nature of the µEDM process itself and how it is affected by ultrasonic vibration.

2.2 Experimental setup

Using state of the art measurement technologies for the recording and analysis of current and voltage in the discharge gap, conventional µEDM and US-assisted µEDM have been compared by means of discharge current height, total number of discharges per second and total number of discharges per volume. The process was analysed when machining an 18CrNi8 steel using Tungsten Carbide tool electrodes (diameter 85µm) and deionised water as dielectric. The µEDM machine tool (RC-type generator) was set to 160V open circuit voltage and minimum energy settings, leading to pulse durations of approx. 100ns. Tool electrode rotation of 1000/min was applied. When using ultrasonic vibration, a direct workpiece excitation of 3µm peak-peak amplitude (in feed direction) at 21.8 kHz frequency is set. The frontal gap regulation strategy (voltage based) was optimised for maximum machining speed.

3 Experimental results and discussion

From examining the discharges per second, it can be seen that ultrasonic vibration clearly raises this number (figure 2) over nearly the complete current range. Two phenomena are to be noted: The large increase in very low current pulses due to discharges being cut-off by the change of distance between the electrodes; the number here is in the range of the vibration frequency. Secondly the smaller number of highest-current discharges when applying ultrasonic, which can be explained by fewer states of open circuit during the process. Those discharges can only take place when the capacitor is fully loaded and the gap breakdown strength is maximal, hence after a relatively long period of time without discharge. From observation this happens mostly after a long short circuit, when gap width control reacts with a retraction movement of the tool electrode, overshooting into open circuit state. The smaller number of those discharges can therefore be interpreted as a sign for a more stable process.

Summarising, in the used setup the direct ultrasonic vibration allows the µEDM process to generate over 34000 discharges of $i_e \geq 3{,}0$A (efficient for ablation) per second more than the conventional process in the same process stage and geometry.

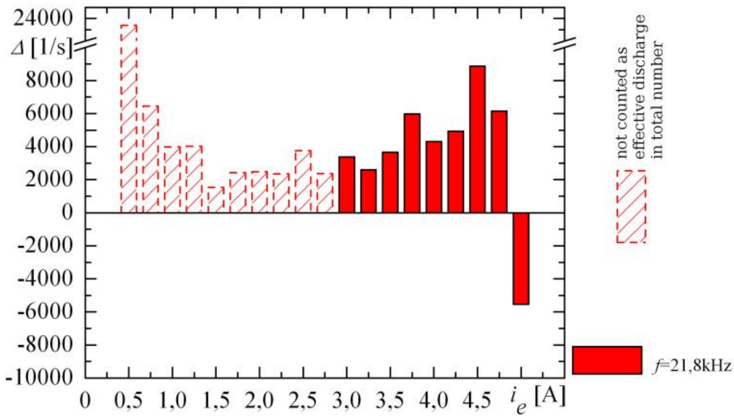

Figure 2: Discharge number comparison between conventional and ultrasonic assisted µEDM

4 Summary and future work

As shown, ultrasonic vibration significantly improves the µEDM process of machining micro bores with high aspect ratio. Analysis of the pulse distribution shows an increase in total numbers per second and a decrease in high-current discharges resulting from open circuit stages. Future work must be targeted at analysing pulse distribution over machining depth to investigate the geometric influences of the to-be machined structure and the flushing onto the µEDM process, thus providing generic parameter settings for ultrasonically improved micro machining.

References:

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