# Vibration Analysis of Slender Sinking EDM Electrodes for the Precision Manufacturing of High Aspect Ratio Cavities

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**Abstract**

Process forces in electro-discharge machining (EDM) are focus of the main research activities within the area of EDM at the Laboratory for Machine Tools and Production Engineering (WZL). Developments in the area of piezoelectric sensors, with higher sensitivity aiming for higher natural frequencies of sensors, have allowed a more precise measurement of forces being exerted at the working electrodes during sinking EDM manufacture. In this paper, lateral deformation measurements of high aspect ratio electrodes made for single and continuous discharges for sinking EDM have been examined. Different aspects of unwanted vibrations that take place during the machining process are discussed. The influence of different process parameters on the maximum lateral vibration, electrode vibration frequency among other variables, are investigated and analysed. This study shows the influence of tool electrode vibrations onto the final desired precision of the manufactured work piece.

## 1 Introduction

Improvements in HSC milling are competing with manufacturing process like sinking EDM in terms of maximum process performance. Machining of precise high aspect ratio cavities on hard materials is a machining application covered by electro discharge machining. Anyway, even those processes are causing challenges due to aspects like difficult flushing, unstable process behaviour and sometimes electrode failure. As seen in [1] for micro Sinking-EDM, if the forces transmitted by the working media are uncontrolled they can generate unwanted vibrations which damage the final desired precision of the manufactured work piece. Lateral forces can also generate a deflection that destabilises the process, due to successive unwanted discharges or short circuits on the cavity’s wall. A better understanding of the process parameters that induce those critical effects will be analysed within the following experimentation.

## 2 Experimentation and Results

For this work, basic tests as well as practical examples are presented using the measurements of a high precision laser interferometer both for single discharges and for continuous sinking EDM process. In order to measure the electrode's lateral deviations, a mechanically robust cantilever was installed in the experimental setup, allowing the positioning of a laser interferometer to measure the lateral deviation of the electrodes just above the machining point during single and continuous discharges. The measurement device was fixed on an electrically isolated brass mounting connected to the quill of a Charmilles Roboform 41 Sinking EDM machine. A specially designed device, connected to the generator, allowed the machine to discharge only one spark per experiment. In order to better explain how this lateral deflection affects macro high aspect ratio electrodes, the tests were conducted on 1 x 30 x 100 mm fine grained graphite tool electrodes (Reference R8650 from SGL Carbon from Germany). Stainless steel sharp needles were used as work piece, to ensure that the force was always applied perpendicular and at the same spot of the tools electrode. A diagram showing the setup and some results of lateral electrode deviation for different single discharge parameters is shown in Figure 1.

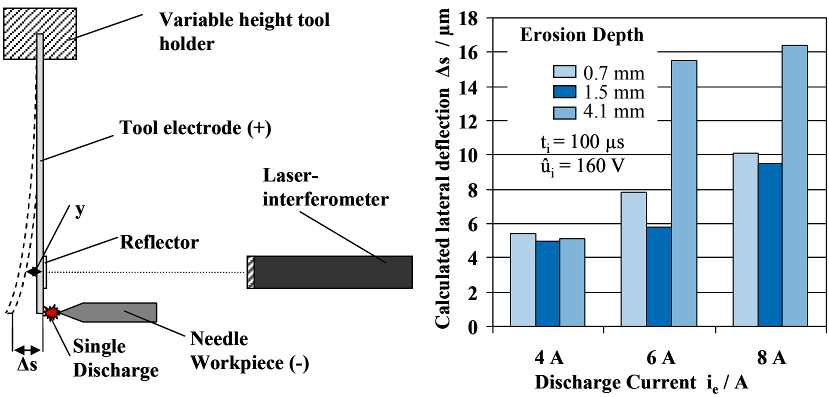


Figure 1: Testing device for the measurement of lateral deviation on high aspect ratio graphite electrodes during Sinking-EDM

It has been confirmed that higher discharge current achieves higher process forces, thus producing bigger lateral deflections on the tool electrode. It is also shown that the deeper the eroded cavity, the larger the lateral deviation of the electrodes. In order to achieve realistic results in terms of machining precision, a set of experiments was conducted, measuring the deviations of the electrodes during continuous sinking process for different discharge pause durations $t_o$, see Figure 2.

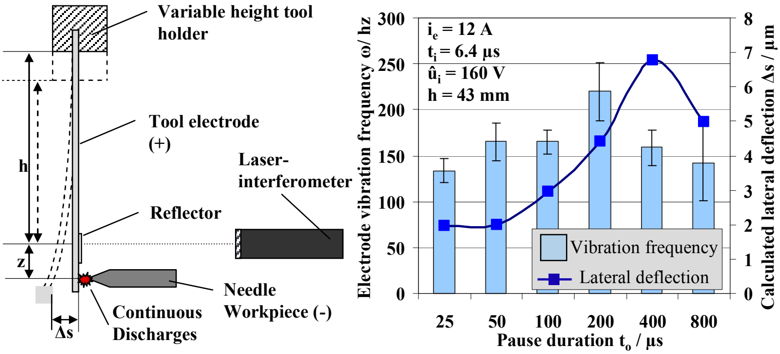


Figure 2: Measurement of lateral deviation and electrode vibration frequency on high aspect ratio graphite electrodes during a real continuous sinking-EDM process.

Figure 2 shows that even for a constant tool fixing height h, different electrode lateral deflection values, as well as different electrode vibration modes can be achieved when varying the pause duration between discharges. Using the findings of [1 - 3] it can be explained that after the initial discharge force that pushes both electrodes apart, which is created by the excess of thermal energy in the working gap, a negative force occurs that pulls the electrodes back together, possibly related to the over-expansion of the generated gas. This can create a driving oscillating force over the electrodes, which in turn, depending on their mechanical properties, can induce high vibrations that translate into process instabilities and loss of manufacturing precision. If this oscillating driving force is known and understood, scenarios like the one seen in Figure 2, where a pause duration $t_o$ between 25 and 100 µs can achieve 4 times less lateral deflection and a 25% lower vibration frequency than a $t_o$ of 200 - 400 µs, will be possible.

Figure 3 shows a diagram with real width measurements of manufactured 3 mm deep cavities w, using a 0.3 mm thick graphite electrode with different tool holding heights h. Inconel 718 was used as work piece material. It can be seen that a loss of precision of about 12% can be achieved by changing the holding length between 3.5 mm and 61 mm, but more importantly, there are significant differences between the studied values, allowing to believe that it is possible to create models that predict loss of precision for a given set of manufacturing parameters.

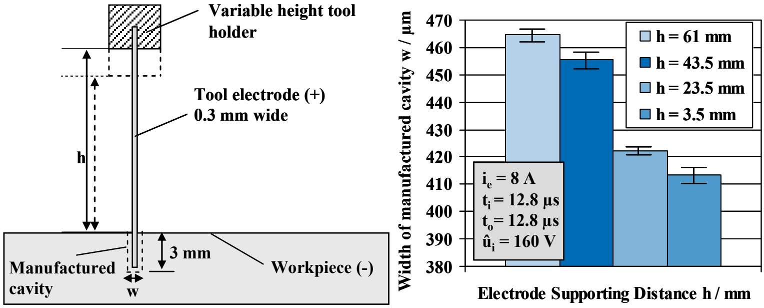


Figure 3: Width of manufactured cavities for constant erosion parameters, changing the holding tool height.

## 3 Conclusions

It has been shown how EDM process forces generate lateral deviations also on high aspect macro sinking tool electrodes. These deviations are high enough to damage the precision of the desired manufactured geometries. Dependencies were seen between the energy of the discharge, the tool holding length as well as the frequency of the discharges with the amount of the electrode deflection. It should be possible to generate machining technology tables that include the maximum working parameters and expected geometrical deviations for selected electrode shapes and configurations.

**References:**

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