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# Application of Laser Scanning as a Pre-machining metrology technique in Jet-ECM

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**Abstract**

In Electrochemical Machining (ECM), where the material removal takes place based on the anodic dissolution of the workpiece material, the working distance is one of the most important parameters. Especially in Jet Electrochemical Machining (Jet-ECM), where a micro nozzle is moved over the initial surface of the workpiece in order to apply an electrolytic free jet to produce the desired shapes, the distance between the nozzle and the workpiece becomes even more important. On the one hand a small working distance is aspired to achieve high current densities resulting in a high efficiency of the process. On the other hand the working distance needs to be large enough to avoid damages on the micro nozzle caused by electrical discharges or mechanical contact. Hence, the adjustment of the working gap is essential to realize a precise, effective and secure Jet-ECM process.

The control of the gap size is done based on the data gathered before machining by surface measurement. Until now, the initial surface has been detected by electrostatic probing through moving the nozzle stepwise to the work piece surface and detect the voltage drop between the nozzle and the work piece. With this strategy, only a limited number of points can be detected within adequate time. Hence, in most cases only three points of the initial surface are detected in order to adjust the working distance according to the planar inclination of the workpiece. The coordinates of the three detected points are used to calculate the normal vector of the initial surface. In recent studies, another strategy was analysed, which is realized by dividing the surface into smaller areas and respectively calculating the normal vector of each area in order to obtain more accurate data of the initial surface. A further strategy is to use probing along the machining path of the tool and to gather the coordinates of a number of points along the path.

The above mentioned methods usually do not ensure the precise control of the gap size especially for the surfaces with complex geometry with locally confined convex and concave shapes and are highly affected by the size of the probe. In this study, the application of a laser scanner is investigated for the measurement of the workpiece surface before machining to gather the required data for the adjustment of the working distance during Jet-EC machining of complicated surfaces.

Keywords: Jet-ECM, Working Distance Adjustment, Surface Measurement, Laser Scanning

## 1. Introduction

Jet-ECM like other electrochemical machining processes is based on anodic dissolution of the workpiece material. The electrolyte is ejected perpendicularly towards the workpiece surface from micro nozzle. Due to the high velocity, a closed free jet is formed surrounded by atmospheric air. Microstructures are machined by controlled movements of the nozzle and the creation of microstructures is controlled by switching the applied voltage. The scheme of the process can be seen in Figure 1 [1].

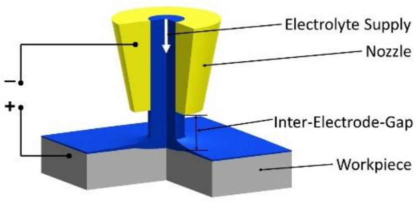


**Figure 1.** Scheme of Jet-ECM [1]

The initial working gap, which is the distance between the nozzle's front surface and the workpiece surface significantly influences the resulting current density in Jet-ECM. Hence, the working gap needs to be adjusted during machining in order to realize a high current density and a high removal rate and to prevent damages on the micro nozzle caused by electrical discharges or mechanical contact. The gap size is usually adjusted to the size equal to the internal diameter of the jet nozzle. For precise machining, a maximal gap size deviation of 10% should be considered. Any novel measuring method, should provide the accuracy higher than the mentioned value.

For measuring the working gap, the workpiece surface should be detected before machining. Until now, this has been done by applying one of the following four strategies [2, 3]. AN – adjusting by normal vector, based on touching three points of the sample surface by electrostatic probing and calculating the normal vector of the surface. AG – adjusting by grid, which is like AN, however, more points are touched. The normal vectors of the corresponding areas can be calculated from the determined values. The working gap is adjusted during the process by using a plurality of normal vectors. AR – adjusting by reference points, where a number of points along the removal geometry are detected. The working gap is then calculated according to the results and precisely controlled during the process. The most recent technology is Control Dynamical (CD) where the gap is measured and controlled during the process using measurement signals, e.g. electrical and mechanical. CD is precise, however, in order to prevent collisions, it should be combined with one of the previous methods.

In all of the above mentioned methods, machining is done based on the limited number of detections and may lead to wrong working distances due to convex and concave shapes which have not been detected. Besides, the accuracy of the measurement is highly dependent on the diameter of the jet nozzle.

In this study, a laser triangulation system is implemented into a Jet-ECM setup in order to be used for initial dimensional measurement of the workpiece surfaces.

## 2. Design of Experiments

A Jet-ECM prototype setup (Figure 2) developed at Technische Universität Chemnitz, was used in this study. The setup is controlled by a custom control software based on LabVIEW from National Instruments GmbH, Germany.

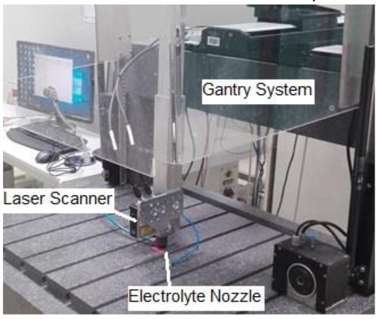


**Figure 2.** Jet-ECM prototype setup

A 3-axis system with linear stages from Physik Instrumente GmbH, Germany, is used to realize the movements of the nozzle. Two linear stages M-531.PD are used for the movements in X- and Y-direction and one M-521.PD is used for the direction of Z. The accuracy of the stages is 1 µm.

A Micro-Epsilon scanCONTROL 2900-25 laser scanning system with the measuring range of 25 mm was mounted on the aluminium tool holder with rectangular profile. The scanning data can be exported in STL, ASC and CSV formats where the last two contain the coordination of each point and can be read by the machine control software. The linearity of the scanner in Z-direction is ± 25 µm. In the direction of X linear scans with 1280 points per profile are carried out, which results in a resolution of 18 µm to 20 µm depending on the distance between the scanner and the object.

## 3. Experimental Results

Scanning experiments were done on the surface of a 20 Euro-Cent coin which has convex and concave shapes in micro scale. The specimen was fixed in X/Y-plane and the scanner was moved in Y-direction with a speed of 1.5 mm/s. The exposure time was considered 0.50 ms. During the scan of the coin, the measured data were exported to the 3D visualisation software Micro Epsilon ScanCONTROL where one of the measurement results is represented in Figure 3.

The image consists of 1,777,920 scanned points. The coordinates of the points along the removal geometry are used for gap adjustment. This method is similar to AR which was introduced in introduction.

However, certain deviations can be recognized, as there are some points scanned above the surface of the coin, due to varying reflectivity and some data are missing due to blocking effects on the vertical flanks. For that reason, the measured data need to be filtered and aligned before they are applied for the nozzle adjustment.

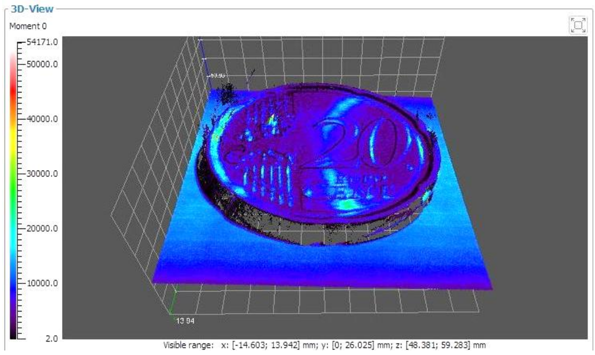


**Figure 3.** 3D-scan of the complex surface of a 20 Euro-Cent coin carried out with the Jet-ECM prototype setup

## 4. Discussion

Since the linearity of the applied scanner is ± 25 µm, the results of the scanning results will be satisfactory, if nozzles with a diameter of 500 µm or more are applied. In this case, the accuracy of the measurement is within 10% of the desired gap size. For smaller gap sizes, which are required for smaller nozzle diameters, Laser Scanners with higher accuracy should be applied. Since the linearity, and therefore also the accuracy, are linearly dependent on the measuring range, laser scanners with smaller measuring range should be used for smaller gap sizes.

In contrast to the existing measurement strategies using electrical probing by help of the electrolyte nozzle, the precision of these measurements does not depend on the nozzle dimension and the machine parts as well as the workpiece are not affected by mechanical or electrical impact.

## 5. Conclusion

In this paper, Laser scanning as a surface measurement technique for adjusting the working gap in Jet-ECM is investigated. Compared to existing adjustment strategies, Laser scanning was applied as a faster measuring technique using the 3-axis motion system of the existing prototype setup. As an example, the surface of a 20 Euro-Cent coin was captured and imported to the control software. The gathered data are adequate to be used for working distance adjustment in Jet-ECM. For that purpose, the captured data need to be filtered and aligned in order to remove existing deviations caused by varying reflectivity and blocking effects.

## 6. Acknowledgement

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#### References

[1] Hackert-Oschätzchen M, Meichsner G, Zinecker M, Martin A and Schubert A 2012 Micro machining with continuous electrolytic free jet *J. Precision Engineering* B 36 612-619

[2] Hackert-Oschätzchen M, Meichsner G, Martin A and Schubert A 2014 Evaluation of Gap Control Strategies in Jet-ECM on Defined Shape Deviations *Proceedings of INSECT2014* 23-35

[3] Hackert-Oschätzchen M, Meichsner G, Martin A and Schubert A 2014 Analysis of strategies for gap control in jet electrochemical machining *Proceedings of the 14th euspen International Conference. 439-442*