# A holistic approach for µEDM milling on SLMed steel

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## Abstract

Maraging steel mould insert blanks have been produced selective laser melting (SLM) and then they are further processed by micro electrical discharge machining (µEDM) to generate the desired features. In order to reach high efficiency manufacturing of micro features, a holistic approach with this micro-sparking technique is pursued at University of Leuven. Accordingly various upgrading has been carried out on a commercial SARIX® machine, including monitoring and controlling of the stability of the sparking process (gap variation and energy distribution etc.), wear compensation of the tool-electrode, and on-machine metrology. Preliminary experiments have been carried out with promising results in terms of production time and shape accuracy.

## 1. Introduction

Maraging Steel is a pre-alloyed ultra-high strength steel. Its composition corresponds to US classification 18% Ni Maraging 300, European 1.2709 and German X3NiCoMoTi 18-9-5. This steel is characterized with very good mechanical properties and it is applied in industry as an ideal tool material for injection molding. With the recent development of thermal management in micro injection moulding [1], additive manufacturing (AM) technologies have been recently introduced into the production of mould inserts for this process. While verious manufacturing technolgies can be applied to carry our post processing after AM, this research focuses on the micro-EDM milling process.

Defects in micro-EDM in a broad definition include both undesired change of surface integrity and geometrical deviation compared to the technical specifications on the workpiece. The fundamentals of the EDM process imply that material removal is inevitable on the tool electrode. Although it is possible to quantitatively reduce the tool-wear by applying negative polarity on the tool and with very short pulses, accurate tool-wear compensation is still not available in cases such as changes of feature geometry, tools of different dimensions, tool path variation or extended machining duration. KU Leuven has a long tradition in EDM research and recently a holistic approach has emerged for zero-defect micro-EDM processing. This includes on-machine sparking monitoring, special wear compensation mechanism and upgrade of machine tool accuracy.

## 2. In-situ sparking monitoring and discrimination

In order to reduce the dimensional and shape errors caused by wear on the tool electrode and process uncertainty, the applied energy in micro milling EDM is substantially low to the order of a few µJ, even in case of roughing process. A common approach for tool-wear compensation is through slot test machining. Although usually 5 test slots are machined to average out the random deviations, this approach still cannot represent the various sparking conditions, especially under unstable machining situations such as at corners and deep cavities with small electrode.

An in-situ sparking monitoring and pulse discrimination method has been developed at KU Leuven. The approach primarily aims at establishing the relationship between sparking conditions and the wear on the tool electrode, whereby the variable for wear compensation in the machine's servo controller can be in-situ updated periodically. Fig. 2 depicts the scheme of the sparking monitoring and a typical histogram of discharge energy with high energy settings (e206) and the constructed linear relationship between the mean discharge energy of each pulse pattern and the tool-wear per discharge. This implementation has been carried out on a SARIX® SX-100 machine, using high-speed data acquisition in LabVIEW® environment and data analysis in MatLab®. This complies with the conclusion on tool-wear prediction stated in [3], which is based on pulse population as a whole regardless of the difference in pulse patterns.

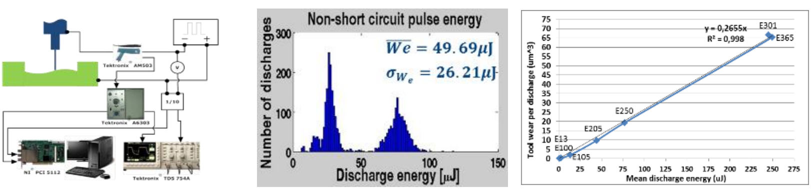


**Fig. 2** Experimental setup for pulse monitoring and discrimination

## 3. Wire-EDM micro-Milling

The second component in this holistic approach is a method of tool-wear compensation through continuous feeding of fresh electrode material, which is realized by wire-EDM milling. As illustrated on the left in Fig. 6, a small diameter (ø100µm) wire moves around a small tool tip during the process and the part of the wire under this tip is engaged in micro-sparking. The first prototype of this experimental mechanism is depicted in the middle of Fig.3. One pulley drives the ø100µm wire to feed around a small groove on the tool tip (ø1mm) made of Ruby which is shown on the left of Fig.3. On the right a pocket of 60µm in depth produced through 16 line-by-line scanning (100µm pitch) is depicted. The surface flatness is about 2µm.

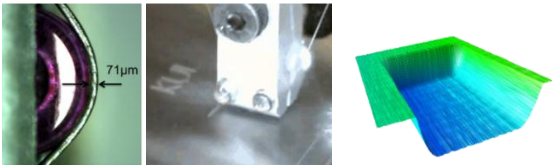


**Fig. 3** Wire-EDM milling tool tip and produced cavity

## 4. Improvement of on-machine metrology

The third component of the holistic approach is the upgrading of the on-machine measurement hardware. In order to improve the absolute dimensional accuracy on machined components, the positioning uncertainty of the tool electrode should be as well. Therefore, there have been two upgrades carried out on the SARIX® micro-EDM machine. First, a HEIDENHAIN® linear scale has been installed along the Z-axis. With the installation of the linear scale, both the backlash errors and long-stroke measurement uncertainty are improved, especially in the case of short stroke movement. **Table 1.1** Comparison of errors in Z-axis movement

| Original | Z | Z | Z |
|---|---|---|---|
| Travel range (mm) | 90 | 10 | 2.4 |
| Step movement (mm) | 5 | 1 | 0.3 |
| Runs | 1 | 1 | 1 |
| Absolute accuracy (µm) | 7.4 | 3.9 | 3.5 |
| Repeatability (µm) | 1.6 | 1.4 | 1.5 |
| Repeatability + (µm) | | | |
| Repeatability - (µm) | | | |
| Backlash (µm) | 1.2 | 1.2 | 1.2 |
| Mean bidir. Pos. dev (µm) | 6.6 | 2.7 | 2.2 |

| With linear scale | Z | Z | Z | Z | Z |
|---|---|---|---|---|---|
| Travel range (mm) | 140 | 10 | 1 | 0.1 | 0.01 |
| Step movement (mm) | 5 | 1 | 0.1 | 0.01 | 0.001 |
| Runs | 5 | 5 | 5 | 5 | 1 |
| Absolute accuracy (µm) | 7.0 | 2.3 | 1.3 | 1.4 | |
| Repeatability (µm) | | | | | |
| Repeatability + (µm) | 0.83 | 1.3 | 0.4 | 0.22 | |
| Repeatability - (µm) | 0.8 | 0.61 | 0.57 | 0.22 | |
| Backlash (µm) | 0.64 | 1.5 | 0.78 | 1.2 | 0.5 |
| Mean bidir. Pos. dev (µm) | 6.15 | 0.57 | 0.35 | 0.24 | 0.36 |

A comparison of the measured machine movement errors is given in Table 1. In addition to the linear scale, a BLUM® sensor has also been installed on the machine to measure the tool electrode diameter and length in a more efficient way. The measurement repeatability can be better than 0.5µm, but the dielectric remained on the electrode tip appears to be problematic. Meanwhile comparison of the on-machine electrode length measurement with the BLUM® sensor or through electrical touch has been carried out. Preliminary experiments show that the measurement repeatability of 3 tests lies within 0.5µm for both methods.

## 5. Conclusions

To realize zero-defect micro-sparking machining, a holistic approach has been pursued to improve the performance of this process. Some key components in this approach have been introduced (e.g. in-situ process monitoring, electrode wear compensation through continuous wire-feeding and upgrade of on-machine metrology). Future research will also include the improvement of the run-our accuracy of the spindle and the repeatability accuracy of the electrode length measurement. Preliminary experiments with promising results (2-3µm radial deviation for small corner features of 0.6mm in radius and 3mm in depth) have been carried out and further system integration and application on industrial demonstrators are in progress.

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