euspen's 24th International Conference & Exhibition, Dublin, IE, June 2024
www.euspen.eu

Investigation of acoustic emission behaviors and their synchronization with discharge pulse signals in micro electrical discharge machining

Long Ye[1,2], Jun Qian[1,2], and Dominiek Reynaerts[1,2,*]

[1]*Manufacturing Processes and Systems (MaPS), Department of Mechanical Engineering, KU Leuven, Leuven, Belgium.*
[2]*Members Flanders Make, Leuven, Belgium*

Corresponding author: dominiek.reynaerts@kuleuven.be

Abstract

Process monitoring is a key-enabling technology to offer an indirect insight into the intricate spatio-temproal discharge phenomena and, consequently, the removal mechanism in micro electrical discharge machining. Recent research has explored the monitoring of acoustic emission (AE), showcasing its potential to complement the breadth of process knowledge. This paper delves into an investigation of AE behaviors synchronized with electrical pulse signals, grounded in empirical understanding. The synchronization, examined in both single discharge and consecutive discharges, facilitates a fundamental interpretation of the AE mechanism and its correlation with the removal mechanism.

Electrical discharge machining, acoustic emission, process monitoring

1. Introduction

Micro electrical discharge machining (µEDM) is an established non-contact machining technique for processing difficult-to-cut materials such as superalloy, metal matrix composites and technical ceramics. Despite its established status, the intricacies of the removal mechanism in µEDM remain elusive primarily due to its complex spatial-tempral phenonmena. This knowledge gap poses constraints on further advancements and applications in precision engineering. To address this challenge, process monitoring emerges as a viable approach to providing an indirect insight into the real-time process dynamics and therefore receives industrial applications for process diagnosis, process control and quality control.

Traditional µEDM process monitoring mainly focuses on electrical signals because of their interpretable association with the removal mechanism and widespread accessibility through electrical sensors. However, these signals are susceptible process noise and can be insensitive to the discharge positions. Acoustic emission (AE) signals present a compelling alternative for high-quality monitoring, being immune to low-frequency electrical noise. Craig and Smith [1] applied two AE sensors for locating the discharge spots in the context of successive discharges. Goodlet and Koshy [2] validated the feasibility of applying AE for monitoring in real time the gap flushing and found its efficacy for indicating material removal at each individual discharge. A fundamental study of AE phenomena was conducted by Klink et al. [3] through synchronization of discharge forces and gas bubbles. They attributed the main variation of AE bursts to the dynamic pressures caused by bubble collapse and provided an alternate explanation to the effects of electrical parameters on material removal.

Despite these valuable insights, a significant gap persists in understanding the association between AE and discharge phenomena. This research aims to bridge this gap by conducting an in-depth investigation into AE fundamentals, employing a synchronization study with discharge pulse signals.

2. Experimental setup

The monitoring experiments were conducted on a desktop µEDM machine (SARIX® SX-100-HPM). The workpiece material was Titanium alloy (Ti-6Al-4V) and the electrode with diameter of 0.5 mm was made of tungsten carbide (WC). HEDMA® hydrocarbon oil was used as dielectric fluid. Electrical discharge and AE signals were acquired in real time by external sensors, as illustrated in Figure 1. Particularly, the structure-borne piezoelectric AE sensor (Kistler® 8152C, sensitive frequency band 100 ~ 900 kHz) was located around 15 mm away from the discharge spots. Silicon grease was applied as a coupling medium between the sensor and the workpiece surface, whose connection was secured by screwing. All signals were recorded simulatanously by different channels of an oscilloscope.

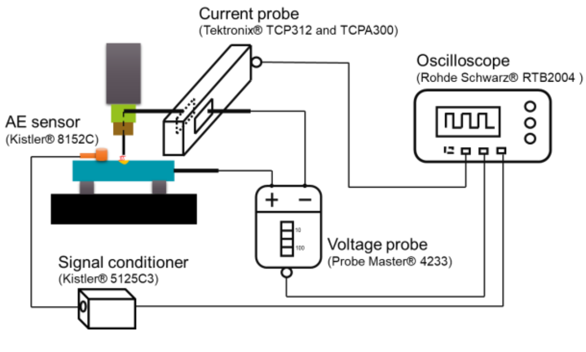

Figure 1. Expriemental setup for monitoring both electrical and acoustic emission signals. The sampling rate is 100 MHz and 20 MHz for single discharge test and consecutive discharges test, respectively.

3. Results and discussion

3.1. Single discharge test

A single discharge experiment was performed to investigate the AE phenomena and material removal mechanism. As shown in Fig. 2 (a) and (b), an AE burst consisting of consecutive imbricate transient hits with time-varying strengths is generated, lagging a certain time behind the ignition of the electrical discharge. The time lag, caused by the AE signal transmission, depends on the distance between the AE sensor location and actual discharge spot. Different from the momentary discharge phenomena, the AE phenomena can maintain for a much longer period of time. This is attributed to the AE mechanism where the gas bubble continually exerts a dynamical pressure on the workpiece surface. Klink et al. [3] have confirmed the cycle of the bubble dynamics up to around 200 times as long. In particular, several peaks, which are registered by the recurring cycles of bubble collapse and rebound, can be noticed on the AE burst. This aligns with the observations in [3]. In addition, the AE burst energy can provide complemtary information to the removal mechanism, as indicated by Fig. 2(c). As shown in Fig. 2(d), it is not uncommon that higher electrical discharge energy can contribute to more removal of materials. However, this removal process can approach to a limitation after a high current index. This limitation can be implicated by the increasing AE energy that can affect the portion of energy partitioned to the electrodes.

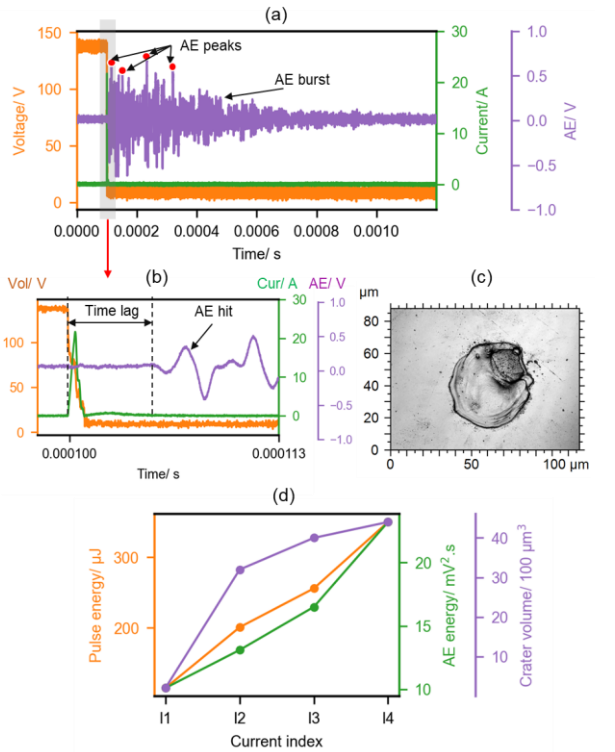

Figure 2. Single discharge and AE monitoring: (a) synchronization of AE with electrical signals; (b) zoom-in details of discharge moment; (c) single crater resulted from the single discharge and (d) correlation of AE energy, discharge energy and crater volume.

3.2. Consecutive discharges test

The synchronization of AE signals with electrical discharge signals are presented in Fig. 3 where consecutive discharges were produced for a constant time of 12 ms. In general, the AE bursts are temproally correlated with discharge clusters that consist of a train of effective discharges. This finding suggests the generation of consecutive discharges within the same bubble cycle. It is empirically acknowledged that the collapse of bubbles can facilitate the removal of molten materials. Therefore, this facilitation can only be provided for very limited discharges according to this finding. Comparing to the single discharge test, the average AE energies are much lower in the consecutive discharges because of cumulative effects caused by the generated debris and bubbles. This can be further evidenced by a comparison between Fig. 3 (a) and (b), where the former typically yields a more contaminated gap condition by the intensively produced discharges and correspondingly by-products. In this case, the AE decaying stage is hardly found and AE bursts can not be easily differentiated from each other because of overlapped bubble cycles. While for the sparsely distributed discharges, AE bursts are discernible with typical registration of peaks and intervals. The particular AE energy, however, indicates an inefficient removal process in this situation. It is worth noting that there is no AE activity when a train of short-circuits appear as illustrated in Fig. 3 (c). This can be useful for identifying the unique process condition.

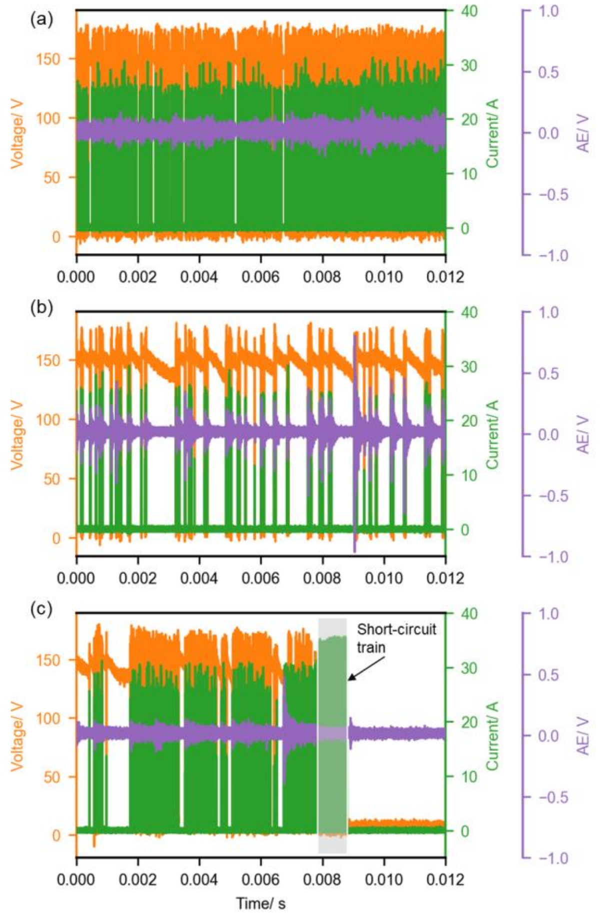

Figure 3. Correlation of AE signals with discharge signals under different discharge process conditions: (a) intensive discharge train; (b) sparse discharge train and (c) aggressive discharge train.

4. Conclusion

The paper investigates the synchronization between acoustic emission (AE) signals and electrical pulse signals in both single discharge and consecutive discharges tests. The AE energy is proven to provide complementary information for the material removal. Notably, the observed variations in AE signal characteristics with respect to discharge clusters underscore the efficacy of AE features in discerning unique discharge conditions.

References

[1] Smith C, Koshy P 2013 Jan. Applications of acoustic mapping in electrical discharge machining. *CIRP Annals*. 62(1):171-4.

[2] Goodlet A, Koshy P 2015 Jan. Real-time evaluation of gap flushing in electrical discharge machining. *CIRP Annals*. 64(1):241-4.

[3] Klink A, Holsten M, Schneider S, Koshy P 2016 J. Acoustic emission signatures of electrical discharge machining. *CIRP Annals*. 65(1):229-32.