ADVANCES IN ULTRASONIC AIDED EDM VARIANTS AND NEW IMPROVEMENTS OF EDM PROCESS

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ABSTRACT: EDM techniques have developed in many areas. Trends on activities carried out by researchers depend on the interest of the market and the availability of the technology. Some future trends activities in EDM are presented in the state of the art of the field: machining of advanced materials, mirror surface finish using powder additives, ultrasonic assisted EDM, dry EDM and EDM in water. The review presented in this paper deals with the novel techniques employed, the efforts carried out by the researchers towards validating and predicting EDM performance using adequate modelling techniques.

KEY WORDS: EDM, modelling, UEDM, Dry EDM, UWEDM.

1. INTRODUCTION

Introduction of ultrasonic vibration to the electrode is one of the methods used to expand the application of EDM and to improve the machining performance on difficult to machine materials.

The study of the effects on ultrasonic vibration of the electrode on EDM has been undertaken since mid 1980’s. The higher efficiency obtained by ultrasonic vibration is mainly attributed to the improvement in dielectric flushing which helps the debris removal and the creation of a large pressure variation in working gap, as an enhancement of molten metal ejection (Guo et al., 1997).

2. ENHANCEMENTS OVERVIEW

Figure 1 shows the progress of method in combining ultrasonic vibration with EDM:

Zhang et al. proposed EDM aided by ultrasonic frequency using a DC (direct current) power supply instead of the usual pulse power deliver. The pulse discharge is produced by the relative motion between the tool and the workpiece simplifying the equipment and reducing its cost (Zhang et al., 1997).

2.1. Wire EDM-ultrasonic aided

Guo et al. studied the machining mechanism of wire EDM with ultrasonic vibration of the wire and found that the combined technology UWEDM (Ultrasonic Aided Wire EDM) facilitates the form of multiple channel discharge and raise the utilization ratio of the energy that leads to the improvement in cutting rate, surface roughness and reduces the probability of wire rupture (Guo et al., 1997). They also concluded that with ultrasonic aid, the cutting efficiency of WEDM (Wire EDM) can be increased by 30% and obtain a better roughness of the machined surface.

2.2. Dry EDM-ultrasonic aided

The main advantages mentioned by Kunieda about this technique are (Kunieda, 2004):
- tool electrode wear is negligible for any pulse duration;
- the residual stress is small since the melting resolidification layer is thin;
- working gap is smaller than in conventional EDM;
- it is possible to change supplying gas according to different applications;
- the machine structure is more compact since no working basin, fluid tank and fluid circulation system is needed.

Ultrasonic vibration electrical discharge machining in gas (UEDM in gas) was first
mentioned by Q. Zhang et al. The experimental results have shown that the increase of open voltage, pulse duration, amplitude of ultrasonic vibration can increase the MRR (Material Remove Rate). They also concluded that oxygen gas produced greater MRR than air. Zhang et al. introduced the theories of ultrasonic vibration in increasing MRR (Zhang et al., 2004).

On further investigations, Q. Zhang et al. found that MRR at UEDM in gas is twice greater than at EDM in gas but lower than at conventional EDM with the same surface roughness (Q. Zhang et al., 2005).

Since the MRR is inferior compared to conventional machining, the developments of the technique were focused more on MRR increase.

Figure 2 illustrates the proportion of research studies conducted in this area. It can be seen that dry EDM can be applied to EDM, UEDM, WEDM, EDM milling and variants. About 24% of the papers deal with UEDM techniques.

Figure 2. Research studies conducted in dry EDM (Abbas et al., 2007)

- **Dry EDM milling**
  
  The dry EDM technique is improved by Kunieda et al. when they introduced the high speed 3D milling by dry EDM (Kunieda et al., 2003). The MRR increased when the discharge power density on the working surface exceeds a certain threshold due to thermally activated chemical reaction between the gas and workpiece material. An improvement of dry EDM characteristics was achieved using piezoelectric actuator to help in controlling the gap length. To elucidate the effects of the piezoelectric, an EDM performance simulator was developed to evaluate the machining stability and the process MRR (Kunieda et al., 2004).

- **Dry WEDM**

  Furudate and Kunieda concluded that the process reaction force is very small, the vibration of the wire electrode is minute, and the gap distance in dry WEDM is narrower than in conventional WEDM using dielectric liquid which enables the method to realize high accuracy finish cut (Furudate & Kunieda, 2001).

  Travelling tool electrode can improve the debris removal from the working gap even in atmosphere and immersed machining. Thus the straightness obtained along the workpiece thickness direction is better than that obtained at EDM in water.

  Some drawbacks of dry WEDM were emphasized which include lower MRR compared to conventional WEDM and difference in machined surface quality recorded at high precision finish cutting. The weaknesses can be resolved by increasing the wire winding speed and decreasing the actual depth of the cut.

3. **OTHER POSSIBLE VARIANTS**

3.1. **Powder additives**

  The hybrid material removal process is called powder mixed EDM. It works steadily at low pulse energy significantly affecting the performance of EDM process. Electrically conductive powder reduces the insulating strength of the dielectric fluid and increases the spark gap.

  EDM process becomes more stable and improves machining efficiency, MRR and surface quality. The characteristics of the powder like size, type and concentration have an effect on the dielectric performance (Pecas & Henriques, 2003).

3.2. **EDM in water**

  Water as dielectric is an alternative to hydrocarbon oil. The method is used to promote a better health and safe environment in EDM working. This is because hydrocarbon oil such as kerosene decomposes and releases harmful vapour as mentioned in (Q. Zhang et al., 2005).

  - **EDM in pure water**

    The first mention about usage of water as dielectric fluid is made by Jeswani. He concluded that machining in pure water produces higher MRR and a lower wear ratio when a high pulse energy range was used (Jeswani, 1981).

    Konig and Siebers explained the influence of the working medium on the removal process. The machining in water-based media produces higher thermal stability and consequently higher power input can be used especially under critical conditions. This leads to greater increases in the removal rate (Konig & Siebers, 1993).

  - **Water with additives**

    A highly concentrated aqueous glycerine solution was reported to have an advantage comparing to hydrocarbon dielectrics when
working with long pulse durations and positive polarity tool electrode (Koening and Joerres, 1987). Organic compounds such as ethylene glycol, polyethylene glycol, dextrose and sucrose were also used to improve the performance of deionized water (Leao & Pashby, 2004).

In conclusion water-based dielectric can replace hydrocarbon oils since it is environmentally safe. When comparing the performance of water-based dielectric with hydrocarbon oil it shows that surface finished in distilled water is better compared with kerosene. Further investigations should be made to evaluate the performance in machining advanced materials such as composites.

4. AUTHORS RESEARCHES

Although an enormous amount of research efforts has been put into representing the UEDM process by various methods, a more elaborate general model, based on thermal–mechanical approaches, has not yet been reported.

We propose a general model of the removal mechanism at microgeometric level by computer aided finite element method (FEM) of ultrasonic aided electrodischarge machining (UEDM) – for steel based workpieces (Ghiculescu et al., 2009).

4.1. FEM modeling of UEDM

The electrodischarge machining aided by ultrasonic longitudinal oscillations of electrode-tool (UEDM) is based on a very intricate mechanism of material removal. Cavitation phenomena, ultrasonically induced within the working gap play an important part.

At classic EDM finishing, the process presents high instability mainly due to very narrow working gap.

At UEDM finishing, the main output technological parameters are remarkably improved: machining rate \( V_W \) up to 500%, surface roughness (Ra) and volumetric relative wear up to 50% (Ghiculescu et al., 2010).

Basically, these are the results of the cumulative microjets (cumulative implosion of gas bubbles from working gap developing pressure of MPa order) action produced at final of each ultrasonic oscillation period. They are parallel to machined surface and remove much more material in liquid state (melted by electrical discharges) and solid state (the microgeometry peaks with lower shear resistance). The collective implosion of gas bubbles occurs only after dielectric liquid stretching semiperiod, which must be produced shortly after the pulse end.

In order to evaluate this time interval between pulse end and ultrasonic implosion, Comsol Multiphysics, Transient Heat Transfer Module was used for thermal phenomena modelling, specific to EDM. Several temperature distributions were achieved in order to simulate the critical moments of discharges against the bubbles collective implosion ultrasonically induced.

4.2. FEM model simulation

The removal mechanism through commanded pulses was approached, obtaining temperature distribution after pulse end, after bubble collapse and at cumulative microjets stage (figure 3).

Figure 3. Variation of hydrostatic pressure in the frontal gap.

The extension of gas bubble of 0.2 mm diameter formed around plasma channel was defined by PT1 and PT2 points, placed on the superior surface of the workpiece - see figure 2.

Figure 4. 2D geometry model parameters

The EDM spot was put at 3500 °K taking into account the assumption that during the pulse time the melted material is overheated above boiling temperature (around 3300 °K for steel) with 500 °K due to increased pressure produced by plasma channel. The adjacent zones to EDM spot, bordered by PT1 and PT2 were considered as insulated due to gas bubble influence. The rest of boundaries belonging to workpiece were set at dielectric liquid temperature, which generally is nearby 310 °K. The FEM first results highlight that a very small part of the workpiece (of mm order) is thermally affected by a 25 µs discharge.
From experimental, data confirmed by FEM modelling, it results that working with longer pulse time (25 µs) can achieve greater performance in MRR and surface quality.

The UEDM method can be used when the fabrication volume is large enough to justify the corresponding additional expenses and longer manufacturing preparation.

Further researches will be focused on synchronizing the EDM and ultrasonic generators and to improve flexibility of UEDM technology.

We also intend to use a Computer Integrated Machining system to achieve fast manufacturing elements of acoustic chain in order to decrease the response time related to new workpieces manufacturing preparation.

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6. SELECTIVE REFERENCES


