International Journal of Mechanical Engineering and Robotics Research

ISSN 2278 – 0149 www.ijmerr.com
Vol. 1, No. 2, July 2012

Research Paper

ADVANCEMENT IN MICRO-MANUFACTURING USING MEDM AND ITS APPLICATIONS

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In this growing world of technology, design and manufacturing at the nano and micro level we need the things (product, service, design, technology) more accurate and defect free and on the same guidelines this paper revolve around the same concept of advanced and precision manufacturing. Micro Electro Discharge Machining is a market growing processing technology due to the industrial interest and the increasing number of applications. Micro Electric Discharge Machining appears to be very promising as a future micro-machining technique, since in many areas of applications it offers several advantages, which include higher machining rate, better precision and control, and a wide range of materials that can be machined. This requires advancement of micro manufacturing processes; hence industrial research on micro-machining has become considerably important and widespread. Manufacturing of micro holes by using Micro Electric Discharge Machining (Micro-EDM) is one of the topics towards developing micro manufacturing technology. Consequently, disastrous range of parameters which lead to defect formation inside the hole are found to be due to long pulse duration (>500 ns) together with higher gain (>15). In addition, entrance and exit diameters of through micro-holes are also measured and experimental data are discussed. Conclusively over-travel of tool electrode or secondary machining with a new electrode is recommended to obtain straighter walls and fine surface in micro-holes. Aspect ratios above 15 are obtained easily by using tool electrode with a diameter equal to or less than 75 μm in blind holes. The topic is investigated experimentally and extensively in this work.

Keywords: Discharge machining, Micromachining, Micro-tool, Micro-hole, Material removal rate

INTRODUCTION

In recent years, Micro Electric Discharge Machining (MEDM) has been modeled to obtain a better understanding of the process. Micro-electric discharge machining is one of the advanced and precision manufacturing

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technology which deals with the micro manufacturing. It is used in products of aerospace, automobile and biomedical science industries. It can produce very accurate shapes with very small burrs much smaller than those produced by drilling and energy-beam processing. These parts do not need after-treatment processing such as deburring. It is essential for materials used in fuel nozzles, micro sensors, micro capsules, micro motors micro surgical instruments, micro robots, micro turbine and micro-moulds to resist wear, high temperature and high pressure micro manufacturing parts are widely used in the field of high performance micro machining technology. It can easily work on the hardest known substances with great ease and accuracy. With the increasing demand for micro parts and structures in many industries, and also with rapid developments in Micro-Electro-Mechanical Systems (MEMS), micro manufacturing techniques for producing these parts become increasingly important. Micro structures including micro holes, micro slots, micro shafts, and micro gears are mostly used micro products needed in industry. Currently micro holes are formed by different manufacturing methods including micro Electrical Discharge Machining (micro-EDM), Electron Beam Machining (EBM), laser machining, etching, Electro Chemical Machining (ECM), Micro-Ultrasonic Machining (MUSM). The selection of appropriate micromachining technique mainly depends on the type of material, size and shape of feature, aspect ratios (in the case of micro hole), cost of process, etc.

Micro Electrical discharge machining is a non-traditional concept of machining which has been widely used to produce dies and moulds. It is also used for finishing parts for aerospace and automotive industry and surgical components. Micro EDM is a thermal process, it utilizes spark to erode a conductive material. As there is no contact between tool and work piece, there is no force acting between them. Therefore the process works efficiently, particularly in machining of difficult-to-cut materials. The micro-EDM operates on the same principle as that of EDM. Micro EDM has wide area of applications like in aerospace, nuclear, industrial, automobile, MEMS etc. In Electrical Discharge Machining the electrode is moved downward toward the work material until the spark gap (the nearest distance between both electrodes) small enough so that the impressed voltage is great enough to ionize the dielectric. Micro Electro Discharge Machining is a market growing processing technology due to the industrial interest and the increasing number of applications. The process concept is not very different to conventional EDM. This fact makes easier to understand the features that can be machined. In spite of this, the process similarities, the process and the applied systems present some important differences with respect to conventional EDM.

NEED OF ADVANCED MICRO-HOLE EDM TECHNOLOGY

Precision micro-holes with smaller diameter, larger depth and accurate geometry are required for next generation fuel injector spray holes due to requirements of stringent EPA standards on future diesel engine emissions. Advanced EDM drilling technology is needed for next generation injector spray holes. This goal can be achieved by developing advanced EDM process controllers and precision tool servos, e.g., piezoelectric stages, to reduce the EDM drilling cycle time and improve dimensional consistency of drilled micro-holes.

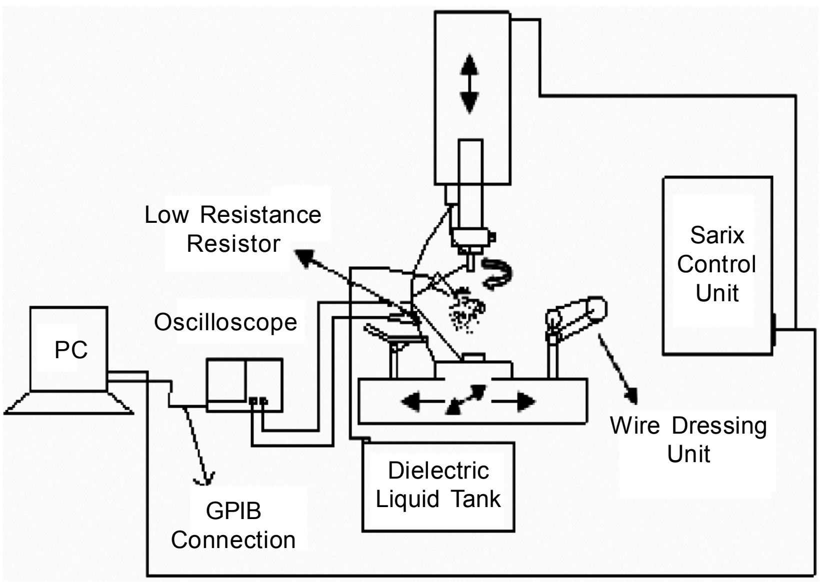
EXPERIMENTAL SETUPS AND PROCEDURES

In this Paper, experimental set-up and tools are described by giving their specifications and functions. Throughout the paper, experimental procedures explained with all details for micro hole machining by using micro-EDM technique. Schematic view of the micro-EDM set-up is shown in Figure 1.

Process Monitoring of MEDM

Process monitoring plays an important role in the MEDM process. It provides the real time machining status, which can be analyzed for the optimization of MEDM process parameters. By monitoring the MEDM process, the pulse types can be classified and information regarding the MEDM machining condition can then be acquired. There are two methods for the MEDM pulse classification. The most common method is to monitor the variation of MEDM pulse parameters, such as gap voltage and gap current. The other method is to analyze the of emitted radio frequency (RF) signals of MEDM pulses. For the spark pulse, the RF emitted from the MEDM region was higher than that of the arc pulse. As a result, the frequency level of RF signals was used to classify the MEDM pulses. MEDM has slow material removal rate (MRR) and needs to be improved for better machining cycle time. This improvement is particularly important to micro-hole MEDM because its MRR is further limited due to the narrower gap between electrode and work piece, which makes debris flushing difficult. MEDM process monitoring can further investigate effects of MEDM parameters for better process stability and efficiency, through analyzing waveforms of gap voltage and

Figure 1: Schematic Drawing of Micro-EDM System

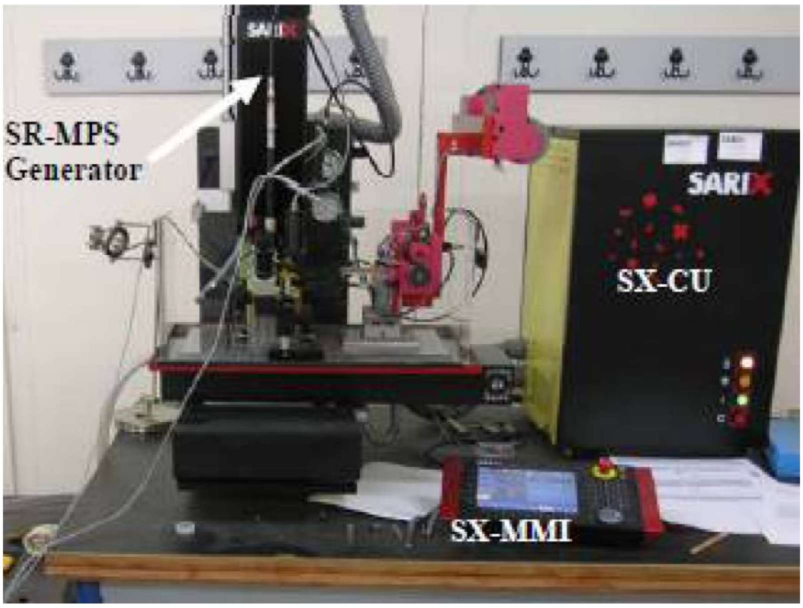


current to characterize the stochastic generation of MEDM discharges. This is the major advantage of MEDM process monitoring and can thus contribute to higher MRR for more efficient MEDM drilling.

EDM Process Controllers

The pulse generation in the EDM process is highly stochastic and complicated, which increases the difficulty of controller design and development. Several controllers have been investigated for the EDM process control for years and will be discussed in this section (Figure 2). The proportional-integral-derivative (PID) controller is commonly used for EDM process control. The PID controller utilizes a predefined mathematical model to dynamically adjust the servo movement according to sensor feedback. The difficulty of using a mathematical model to precisely describes the EDM process renders the PID controller less competitive in preventing the undesired arc and short circuit pulses. Research on advanced control strategy for micro-hole EDM is needed to develop more capable controllers for the nonlinear, stochastic EDM process. Competent EDM process controllers should be able to distinguish the rapid changing EDM status to generate correct servo commands for the minimization of undesired pulses and faster drilling cycle time.

Figure 2: Micro-EDM Machine



Material Used for Micro-Hole Machining

Plastic mold steel is used as a wok piece material. Tungsten carbide electrodes with standard diameters are used as a tool electrode.

Use of Microscope and Dimensional Measurement

Machined micro-holes and their cross-sectioned geometry are examined by using Nikon ECLIPSE LV150 optical microscope It has five objectives with a

Table 1: Material Properties

S. No.	Tungsten Properties	
1.	Density and phase	15.8 g·cm–3, solid
2.	Solubility in water	Insoluble
3.	Melting point	2870 °C
4.	Boiling point	6000 °C
5.	Thermal conductivity	84.02 W·m–1·K–1
6.	Tensile strength	0.3448 GPa

magnification of 50x, 100x, 200x, 500x, 1000x. A 'Nikon digital camera coolpix 8400' installed on the top of microscope is also used to take the pictures of cross-sectional view of micro-holes. The hole pictures taken by camera is sent to the computer and by means of the Clemex image analysis software dimensional measurement will be done (Figures 3, 4 and 5).

Figure 3: Photograph of Defective Hole from Top View

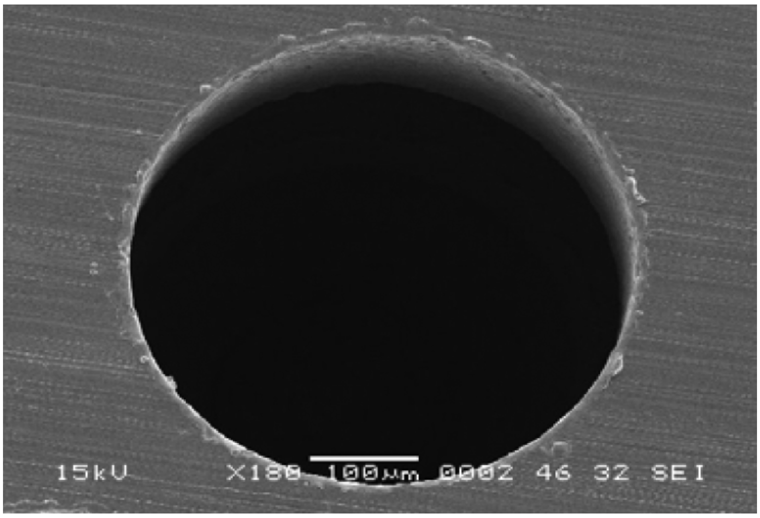
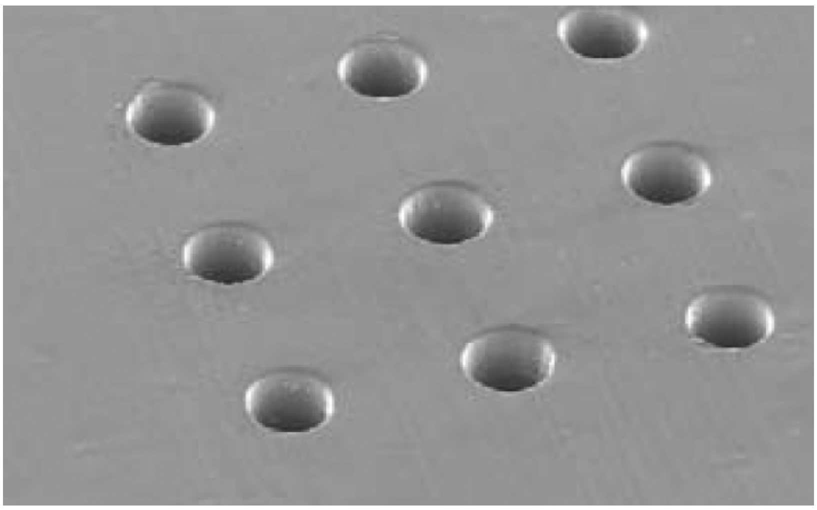


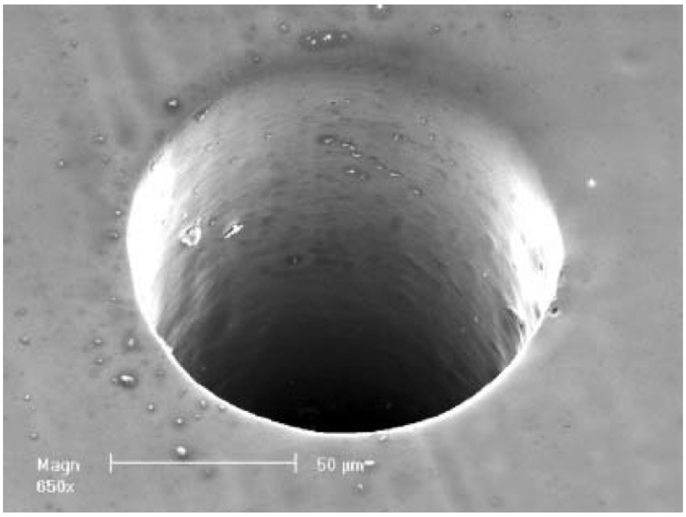
Figure 4: Different Holes Drill by Micro-EDM



MICRO-MANUFACTURING IS AN IMPORTANT NEW TECHNOLOGY

- It is an enabling technology for the widespread exploitation of nanoscience and nanotechnology, Developments—it bridges the gap between the nano- and macro-worlds.
- It is a disruptive technology that will completely change our thinking as to how, when, and where products will be manufactured—e.g., on-site, on-demand in the hospital operating room.
- It is a transforming technology that will redistribute manufacturing capability from the hands of a few to the hands of many—micro manufacturing becomes a cottage industry.
- It is a strategic technology that will enhance the competitive advantage of the US—reduced capital investment, reduced space and energy costs, increased portability, increased productivity.

Figure 5: Top View of Micro Holes



APPLICATION OF MICRO-EDM

- Machining capability of micro-EDM, in conductive materials with high precision regardless of material hardness.
- Create a wide range of application area with the increasing demand for miniaturized parts and components such as holes, nozzles, and gears.
- Produced micro parts by micro-EDM are widely used in Micro-Electro-Mechanical Systems (MEMS), biomedical applications, automotive industry, and defense industry.

ADVANTAGES

Some of the advantages of EDM include machining of:

- Complex shapes that would otherwise be difficult to produce with conventional cutting tools.
- Extremely hard material to very close tolerances.

- Very small work pieces where conventional cutting tools may damage the part from excess cutting tool pressure.
- A good surface finish can be obtained.
- Very fine holes can be easily drilled.

CONCLUSION

Micro-electrical discharge machining process is a widely used micro fabrication technique to produce micro-parts and components needed in the micro-mechatronic systems and industrial applications. Micro-hole fabrication is a primary task for this paper because micro-hole is the most simple and widely used micro products that can be manufactured by using micro-EDM.

- The MRR of tungsten carbide increased with the peak current increasing the electrical discharge energy density increase MRR when the pulse duration was short.
- The surface roughness increased with the peak current.
- More surplus material was removed from the machined surface so larger and deeper craters were formed on the machined surface.
- The machined surface of the tungsten carbide exhibited obvious micro-cracks. When the electrical energy was set high.
- EDM can prevent micro-crack on the machine surface to ensure the high quality machining characteristics.

ACKNOWLEDGMENT

The present research is running thanks to the support provided by the Department of Mechanical Engineering, Samrat Ashok Technological Institute, Vidisha (MP) India 2011-2012.Thanks also the members of the Bharat Heavy Electrical Limited Bhopal India.

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