The Latest Trend of EDM Machine Tools and Machining Technology
- Review of 24th JIMTOP (Japan International Machine Tool Fair) -

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Abstract
This paper briefs the status and latest trend of EDM machine tools and machining technology nowadays, based on the author’s investigation at the Japan International Machine Tool Fair (JIMTOF) 2008, which was held during October 30 to November 4 in Tokyo, Japan this year. It is found that the status and trend in EDM technology can be expressed with the following keywords: micro-machining with graphite electrode, ultra-precision machining, high-speed machining, applications to parts machining. Also, a lot of efforts on saving energy, reducing the tool consumption, lightening the burden on the environment were found.

1. Introduction
To embody the consistent theme of JIMTOF2008—“Mono-zukuri innovation - in favor of the earth and the future”, EDM machine tool manufacturers as well as manufacturers of other machine tools are all making effort to fabricate products to be energy-efficient, high-speed, high-accuracy and environment-friendly. In the JIMTOF2008, a large number of efforts were found to be made to improve the machining accuracy and efficiency, shorting the machining time, reducing the tool consumption, saving the energy, controlling the exhausted CO₂ and lightening the burden on the environment. Various kinds of new technical invention and innovation were displayed.

This review mainly focuses on the author’s impression of the EDM machine tools and machining technology during visiting and investigating JIMTOF2008.

2. Trend of Die-sinking EDM machine tool and machining technology
2.1 Micro-machining with graphite electrode
In JIMTOF2008, one of the trends in the die sinking EDM is the EDM micro-machining using graphite electrode. Generally, compared with the copper electrode, the graphite electrode possesses good electrical discharge property and good surface roughness of the workpiece. Because stiffness of copper materials is low, it is hard to use copper to fabricate the tool electrode with micro-shapes by cutting. Furthermore, influenced by the unbalanced heat generated from the uneven electrical discharges during the machining, the copper is easy to get deformed. Therefore, copper is not good at machining micro-shapes. On the other hand, compared with the copper electrode, the graphite electrode has good cutting property. Especially, in recent years, with the improvement of graphite materials, high-density graphite is now sold in the market. It becomes possible to fabricate the micro graphite electrode of high accuracy in a short time. In addition, since the material price of copper is increasing, graphite electrode is gradually getting popular. Therefore, die sinking EDM machine tool manufacturers are focusing on the invention of micro-machining technologies using the graphite electrode.

Among those technologies, there are many examples of machining pin gates and ribs in injection molds. The length of the pin gate of the mold is generally dozens of times of the diameter, and the requirement for the accuracy of the diameter is high. Makino Milling Machine Co.’s “Super Spark Graphite” is a kind of machining technology specialized in the machining of high-depth products using the graphite electrode with its original machining power supply and control system. It is now possible to obtain the accuracy of ±0.22μm when machining a φ0.2mm hole at the tip. Figure 1 is an example of the pin gate whose tip hole is φ0.6mm, length is 95mm and surface roughness is 3μm Rz. Since a special cooling system for the ball screw and the bearing is adopted, the temperature is not going to rise and the feeding accuracy in the z direction is greatly improved. Therefore, the variation of the hole diameter is reduced and the high machining accuracy of the high aspect ratio products is realized.

Mitsubishi Electric Corporation’s high performance, compact size, and high accuracy die sinking EDM machine tool “EA8PV Advance” (Figure 2), is aimed at fabricating dies and molds for micro-workpiece such as connectors and so on. This machine is equipped with the NP2 circuit suitable for...
micro-machining, the function used for compensating the thermal displacement, and the stone machine platen, so it can guarantee the machining accuracy of ±3μm. Furthermore, by using the three-side elevating machining tank, the setup operation becomes easier. The machining example of thin-rib products by using the graphite electrode is shown in Figure 3.

2.2 Minimization of tool wear

Sodick Co. exhibited its 5th generation super-precision die-sinking EDM machine tool “AP3L” (Figure 4), an ultra precise machine driven by the linear-motor. Since a brand new discharge stabilizing system “SGF II”, which greatly reduces the occurrence of arcing and the tool wear, is adopted, this machine not only has the advantageous machining performance for the graphite electrode during high-speed machining, but also leads to a 0.006% wear ratio, nearly zero-wear. This system is applicable to the machining using copper electrode as well as using graphite electrode. Because the electrode wear is approaching zero, the graphite electrode used in the rough machining can continue to be used until the machining is completed and there is no need for changing the electrode. Thus, the setup time is shortened and the cost of fabricating the electrode is also reduced. Furthermore, as the occurrence of arcing and the unevenness of electrical discharge are prevented, even by using the copper electrode, the extremely deep pin gate in 100mm-length can also be machined without changing the machining conditions. There is no need for jetting, rotating and orbiting. In addition, the machining process becomes more stable, since

![Figure 2: High accuracy die-sinking EDM machine tool “EA8PV advance” (Mitsubishi Electric Co.)](image)

![Figure 3: Samples of thin-rib machining (Mitsubishi Electric Co.)](image)

<table>
<thead>
<tr>
<th>Tool electrode: TTK-5</th>
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<tr>
<td>Workpiece: STAVAX</td>
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<td>Machining depth: 6.0mm</td>
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<td>Machining time: 1h36min</td>
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<td>Surface roughness: 6μmRz, 1μmRa</td>
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Fig.1 Pin-gate machining with graphite electrode (Makino Milling Machine Co.)

Finishing diameter φ0.617mm

Fig.1 Pin-gate machining with graphite electrode (Makino Milling Machine Co.)

Tool electrode: TTK-5
Workpiece: STAVAX
Machining time: 9h30min (without pilot hole)
Surface roughness: 3μmRz

Fig.3 Samples of thin-rib machining (Mitsubishi Electric Co.)
various adaptive control systems and circuits, as well as the high-speed driven device by linear-motor are equipped. Furthermore, as the result of being equipped with the new power supply which generates the optimal sparks and the linear-motor with high response property, it is realized to machine the 70μm-pitch connector (Figure 5).

3. Wire EDM equipment

3.1 Efforts to reduce energy consumption and environmental burden

How to control the electricity consumption and the electrode consumption is becoming one of the goals in the environmental issues during manufacturing EDM machine tools. Many manufacturers carry on the technical innovation on the basis of cutting down the CO₂ exhaustion whenever in the time of manufacturing or operating the EDM machine tools.

Mitsubishi Electrical Co.'s NA series WEDM machine tools merge a lot of new technologies pursuing the thorough efficiency. Especially compared with the conventional machine tools, the electricity consumption is cut down by 55% at the maximum. Furthermore, by using the “wake-up mode” function which is capable of reducing the standby electricity consumption sharply, it is realized to cut down the electricity consumption by 69% at the maximum.

Makino Milling Machine Co. is giving high priority to reducing the environmental burden and the wire consumption. For example, in the case of WEDM equipments “DUO43” and “DUO64” (Figure 6), since the electrical discharge power is increased by using the φ0.3mm wire electrode in stead of the conventional φ0.25mm one, the machining efficiency is enhanced by 30%. In addition, since the tension of the wire is increased by 25%, not only the machining accuracy is maintained but also the stable machining process is obtained. With the slowing down of the wire-electrode feeding rate, the wire consumption is reduced by 33%. DUO series machine tools also provide two kinds of guide selected according to the thickness of the workpiece, which meet a wide range of needs. In other words, the open-close V type guide is used in the situation of machining thick workpiece, while the round guide is chosen when machining the small-sized workpiece.

3.2 Pursuing high machining accuracy

Seibu Electric and Machinery Co. focuses on maintaining the accuracy of the machine tool over a
long period, based on the consideration that the absolute accuracy of the machine tool is indispensable. The exhibited “SupperMM series” (Figure 7) can keep the high machining accuracy even after a long-time use, since the machining accuracy is guaranteed by the static accuracy of the machine itself instead of the software compensation. Seibu Electric and Machinery Co. is in the pursuit of the limitation of high accuracy and high stiffness, through the “scraper” operation of the skilled workers. Since the pitching, the yawing accuracy and the absolute accuracy of machinery are getting higher, a 2μm pitch machining accuracy is steadily obtained. Figure 8 shows an example of the results of pitch machining accuracy by SuperMM.

On the other hand, since the technology of sensors has been advanced and the processing speed of the hardware has been enhanced, the information of machining status is instantaneously collected and processed. Therefore, the machining condition matched with the machining status can be set at a high speed, and it is easier to achieve the high accuracy machining.

“NA1200P” and “NA2400P” (Figure 9) exhibited by Mitsubishi Electric Co. are the superior high-accuracy guaranteed machines and the high-rank models of “NA1200” and “NA2400”. The ±1μm pitch and shape accuracy is achieved by the improvement of the drive system, the structure capable of controlling the heat deformation and the water-cooling system for the machine body. Furthermore, by adopting the shape control power supply, electrical discharges take place evenly on the upper, central and lower part of the workpiece in the direction of the thickness, thus the 1μm straightness in the situation of workpiece with 50mm thickness is realized. In addition, the roundness reaches 0.8μm and the machining accuracy is greatly enhanced by using the original drive method called “opt-driven system” which realizes the high speed control by means of the fiber communication. And the surface roughness of 0.4μmRz is obtained for the tungsten carbide machining by using the super finishing power supply and the water dielectric. With the improvement of the control system and the wire running system, the ratio of surface roughness in the transversal and longitudinal direction is remarkably improved. In addition, by the application of the digital control power supply “Digital V power supply”, the machining time is shortened by 30% and the wire consumption is reduced by 44% in the maximum compared with the previous machine tools.

Sodick’s “AG400L” and “AG600G” (Figure 10) are high-speed wire electrical discharge machines

![Fig.7 High accuracy WEDM machine tool “SuperMM500S” (Seibu Electric and Machinery Co.)](image)

![Fig.8 Pitch machining accuracy by SuperMM (Seibu Electric and Machinery Co.)](image)
driven by linear-motor, whose setup efficiency is improved by using the square work stand. Equipped with the new technology called “DSM (Dynamic Shape Master)”, the machining performance for workpiece with different thickness is improved. Generally, when machining the workpiece with partly different thickness, it is difficult to maintain the jetting pressure and the machining accuracy, and the wire breaking occurs often. DSM is composed of the following technologies: 1.DSPC (Dynamic Shape Preview Control) with which the workpiece shape is preliminarily recognized and the machining code is generated by Intelligent Q^vic EDW; 2.TC2 (Thinking Circuit 2) with which the machining conditions for the different-thickness machining is automatically controlled with the thickness detecting device; 3.AFC (Active Flow Control) with which the most proper flushing pressure from the upper and lower nozzles and the most appropriate nozzle shape are decided. With these advanced technologies, stabilization of the machining process, avoidance of the wire breaking in the machining of blind holes and the hollow parts, realization of high speed machining in the floating machining, and improvement of the shape accuracy and surface roughness in the different thickness machining, are achieved. Furthermore, the TC2 equipped in the DSM is capable of automatically activating the control function to avoid the machining line marks on the surface caused by the change of the thickness of the workpiece. The improvement of the machining efficiency by 40% in the maximum is realized by the application of DSM.

3.3 Enhancing the quality of machining surface

When performing wire electrical discharge in the water, the surface state of the workpiece worsens due to the corrosion. For conventional anti-electrolysis power supply, the average electric voltage between the electrodes was controlled to be zero. However, from the microscopic view, the average voltage is not adjusted to zero. For different kind of material, the corrosion potential also varies. In order to prevent the corrosion of the workpiece, the anti-corrosion system was invented by Sodick Co. to prevent corrosion and coloring by applying both the electrical anti-corrosion technology and the chemical anti-corrosion technology.

Tool electrode: HQW φ0.20mm
Workpiece: NAK55
Workpiece thickness: 25mm
Machining time: 3h
Surface roughness: 20μmRz
Dielectric: Water 50,000Ω·cm

Fig.11 Machining sample with anti-corrosion technology (Sodick Co.)
technology. The system can automatically set the parameters matched with the material property of the workpiece from the CAM data and obtain the workpiece surface without corrosion (Figure 11).

4. Other technology trends

4.1 Applications to parts machining

With the improvement of the machining efficiency and the increase in demand for parts with complex shape, the EDM machine tools, which are mainly used to fabricate the die and mold conventionally, are now being applied to fabricate the parts in a wide range. As an example, WEDM machine tools are able to process parts with complex shapes by adding a rotating axis.

The rotating axis used in the conventional WEDM equipment generally does not rotate during machining and not synchronize with the NC instrument. Nowadays demands for machining complex parts like spiral-shaped components which are hard to cut are increasing. In order to meet the demands, System 3R Co. has developed a stainless B axis which is linked to the NC device (Figure 12). By using this equipment, the axis can rotate synchronized with other drive axes during the machining. Thus, it becomes possible to fabricate the complex parts and tools, especially the special medical instruments (Figure 13). In addition, in Hoden Seimitsu Kako Kenkyusho Co., which has a lot of EDM knowhow and specializes in the business of entrusted electrical discharge machining, the machining of complex screws is realized by using the self-invented rotating instrument (Figure 14).

In JIMTOF 2008, Fanuc Co. exhibited the high-accuracy, large-tapered machining samples, and other complex parts machined by WEDM machine tool with its own machining technology and the clamping apparatus instead of exhibiting new machine tool. When the WEDM machine tool is used in the large-tapered machining, the consequently caused bending of the wire will make the real machining angle differ from the theoretical one. The bending amount also changes according to the tilting direction, so various compensations are indispensable. Moreover, the error in taper machining changes with the discharge energy and the material of the wire electrode. So it is difficult to find out the theoretically correct bending amount of the wire. Therefore, a sample machining is carried out beforehand and the machining angle error is obtained by measuring the processed workpiece. Then the tilting angle of the wire electrode is compensated automatically according to the results of sample machining. Figure 15 shows the example of high-accuracy tapered machining by using [ROBOCUT α-1ID].
4.2 High-speed and automation of micro-hole drilling
Since there is more and more demand for drilling the micro-holes represented by the fuel-jetting nozzle of the engine, the micro-hole EDM drilling machine manufacturers are now giving high priority to the technology development in the automation and the high-speed of the micro-hole drilling. Micro-hole EDM drilling machines from home like Elenix Co., Astech Co., Mitsubishi Electric Co. and Sodick Co. and abroad such as the Korean makers were exhibited in JIMTOF2008.

Elenix Co. targets at the mass manufacturing of micro holes from \( \phi 0.03 \text{mm} \) to \( \phi 3 \text{mm} \) by using commercial electrodes. Micro-hole EDM drilling system “ST300U+Robot” suitable for part machining was exhibited in JIMTOF2008 (Figure 16). Composed of the general-use and high accuracy micro-hole drilling machine ST300U and the multi-joint robot, ST300U+R can automatically perform the whole process, that is workpiece supply by parts feeder, positioning, hole drilling, inspection, and electrode exchange.

Astec Co. exhibited the conventional high-speed micro-hole drilling machine and the CNC high-speed micro-hole drilling machine. As shown in Figure 17, the CNC high-speed micro hole drilling machine possesses the extremely high stiffness because of introducing the casting metal as the fundamental machine bed. The machine has sophisticated functionality and high positioning accuracy, and thus it has a wide range of applications such as the continual machining of the inclination-changing holes and the diameter-changing holes. And by using the automatic electrode-exchange device and guide-exchange device, the continuous machining of micro holes in different diameters is made possible.

4.3 Pursuit of the performance-price ratio
Integrating the technologies of GF Agie Charmilles, the first WEDM machine tool with the GF Agie Charmilles’ brand, “CUT30” was displayed in JIMTOF2008 (Figure 18 shows [CUT20]). Based on the development concept of simplicity and high performance, CUT30 is low-priced WEDM machine tool with a high performance-price ratio which is suitable for the machining of dies /molds and parts.

4.4 Improvement of manufacturing-supporting system
Besides the enhancement of the processing performance like machining accuracy and efficiency mentioned above, the EDM machine tool manufacturers are also pursuing the easy use of the machinery and building the manufacturing-supporting system which will make the operation of the machine simple even for the first-time users by the application of navigators, touch panels and so on. For example, many exhibited machine tools are capable of automatically searching and choosing the most suitable machining conditions in the way of dialogue. There are also machine tools capable of automatically extracting the EDM machining surface from the CAD data of the
workpiece, generating the NC data used in machining and checking the interference. Furthermore, many manufacturers are providing the detailed after-service such as the version update of the software and the provision of the latest machining conditions on the website.

5. Summary and foresight

JIMTOF2008 attracted a large number of visitors from home and abroad and closed grandly and successfully. The home visitors increased by 10%, while the visitors from abroad increased by 20% compared with the JIMTOF 2006. However, because of the financial crisis of the United States and the influence of the economic recession, the order of machine tools is decreasing and the economic environment of the machine tool industry is getting more and more serious. In order to maintain the competitiveness in the manufacturing industry, the machine tools, as the foundations of the production, are indispensable and those with advantages come to be requested more strongly in future. To support the manufacturing in Japan and the world, it is necessary to continue the research and the innovation in developing the high efficiency, high quality, energy-saving, environmental-friendly machine tools. Especially, the treatment of the environmental problem of manufacturing will become one of the important evaluation items in the process of manufacturing, operating and disposing the machine tool including the EDM machines.

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