Article reprint from

Commercial Micro Manufacturing International

PEM Technologies LLC
Natrona Heights, PA
412-736-7961
drisko@pemtechnologies.com

PRECISION Electrolytic Machining

DON RISKO,
PEM TECHNOLOGIES LLC

<< **Figure 1: The PEM400 machine.** >>

Theory

The Precision Electrolytic Machining (PEM) process is based on subtracting or removing material from the surface of a conductive metal by electrolytic dissolution. That machining process is based on Faraday's Law of electrolytic action which is the same principle used in electroplating and electropolishing. When an electric field is established between two metal objects by a direct current voltage and the metal surfaces are separated by a distance filled with an electrolyte, electrons will flow between them while ions are released from the positive surface.

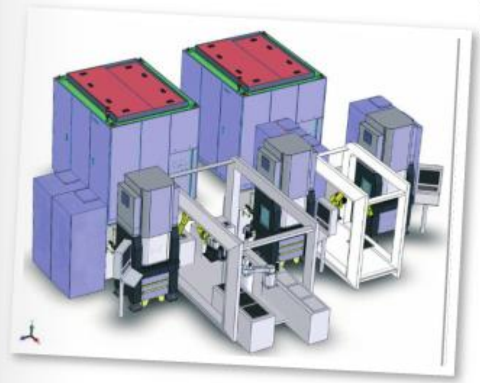
PEM Process

A preformed metal electrode acts as a machining tool that never touches the surface of the workpiece and never draws a spark. A D.C. pulse from the electrode is used to ionize and release surface atoms from the workpiece in the presence of an electrolyte solution. A precision reciprocating action of the electrode positions the electrode within 10 microns of the surface (termed the 'gap'), then retracts up to 400 microns. Typical reciprocation rate is 30 to 70 times per second while electrolyte is continuously pumped between the tool and workpiece and flushes the ions removed from the surface during the retracted time. The typical electrolyte solution is a mixture of sodium nitrate and deionized water. The D.C. pulse is programmed to coincide with the electrode proximity to the workpiece surface, hence allowing high-current pulses of short duration that precisely remove surface atoms without boiling the electrolyte in the gap.

Typical machining parameters for the PEM process are:

Feed rate: 0.1— 0.8 mm/min
Current density: 100 A/ cm²
Machining voltage: 1—20 Volts
Tool oscillation: 0—90 Hz
Electrolyte (typical): 6% sodium nitrate
Electrolyte flow: 0.1—40 L/min
Electrolyte temperature: 20—30 °C
Electrolyte pH: 6.5—8

NEW TECHNOLOGIES | ARTICLE



<< **Figure 2: Three-machine automated system.** >>

PEM Machining Systems

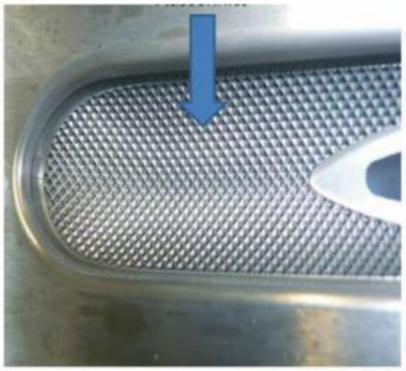
The PEM machining system is comprised of the following four components:

1. **PEM Mechanic**
   The PEM machine is a granite structure with Z-axis programmable feed and oscillation. Standard machine configurations include provisions for automation and multi-axis (including rotary axis) versions. The PEM400 is shown in figure 1.
2. **PEM Control**
   A completely programmable graphic-based Human Interface provides ease of use, intuitive status displays, data logging and out-of-limits conditions. I/O for tool monitoring and automation are standard.
3. **PEM Power Supply**
   Precise constant current pulses are supplied to the electrode(s) that can be adjusted in duration, frequency and phase relationship to the reciprocating electrode.
4. **Aqua System**
   Provides conditioned electrolyte to the machining gap so that electrolyte continuously flows at the desired rate.

A range of fully automated systems consisting of one or many machines is available. An example of a system consisting of three PEM operations on a part is shown in figure 2. In this example, the first machine is creating external features; the second machine is performing a turning operation by rotating the part; and the third machine is machining slots through a 0.5 mm thick workpiece.

>> **Continued on page 42**

>> Continued from page 41



<< **Figure 3:** **PEMed mould.** >>

Examples and Applications
Applications exist in essentially every manufacturing market. Some typical examples are fuel injection components in diesel-automotive; artificial heart valves in medical; turbine blade features in aerospace, rotary shaver heads in consumer products; sensor components in energy; and punch and dies in tooling.

The following are specific examples of the PEM capabilities. Machining surface features from tens to hundreds of microns have been accomplished with the PEM process. For example, the mould in figure 3 was machined in 9 minutes using a stainless steel electrode. Surface finish is 0.01 micron Ra with a feature depth of approximately 0.5 mm. Similar results have been obtained machining a texturing die consisting of pyramid geometry. Similarly, a surface micro structure consisting of 70 micron diameter pins, 250 microns high with a center spacing of 200 microns is machined into stainless steel in 12 minutes. The surface finish obtained by PEM machining is primarily determined by the material. A homogenous material with tight grain structure generally produces the best surface finish. If there are voids or eutectics such as carbides, these will affect the surface finish results.

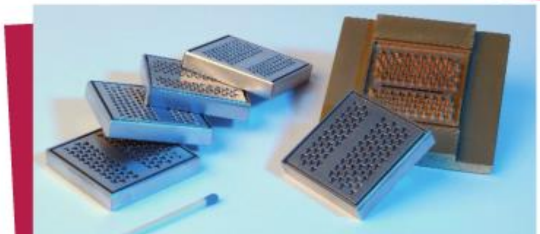
Manufacturing dies and punches with the PEM process has resulted in significant time and cost savings. Punched for small screw heads such as those used in cell phones are machined in the hardened condition using a multi-position tool. The head diameter of these punches is 0.8 mm with an appropriate taper and edge radius. Likewise, the miniature driver for these screws can be machined with a 48 position tool at a machining rate of less than 4 seconds per part.

The coin die features shapes, size and surface textures which have different requirements across the face of the die. The matching conditions need to be machined into the electrode with a typical machining gap allowance of 10 microns. A precise electrolyte flow pattern is provided by the tool design to allow the required feature and surface to be machined. The medallion die of figure 4 illustrates the range of detail produced by PEM. A variety of these dies have been produced including one with a hologram feature. The machining time for a die ranges from 8 to 25 minutes depending on size and detail.

<< **Figure 4:** **Coin die.** >>

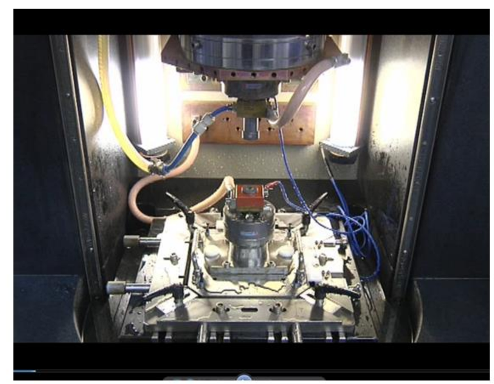
The mould insert of figure 5 is PEMed using the electrode shown. In order to produce the mould features of this configuration, electrolyte is provided to the machining gap through the electrode. Electrolyte flow through the electrode is used when the flow path required for PEM cannot be achieved with a cross-flow configuration. In a similar fashion, the 100 cavity mould of figure 6 is machined in one operation with a surface finish less than 0.1 micron Ra. The cavities in this mould are approximately 2.5 mm deep. Cavity depth and geometry are important because the PEM tool must be able to flush electrolyte over all surfaces in a uniform manner.

<< **Figure 5:** **Mould insert and PEM electrode.** >>



<< **Figure 6:** **100-cavity mould and PEM electrode.** >>

>> Continued on page 44



<< Figure 7: Turbine wheel. >>

<< Figure 8: Typical PEM machining. >>

<< Figure 9: Nitinol medical implant component. >>

The turbine wheel of figure 7 is PEMed from a solid disk. There are 30 airfoils in the outer ring and 14 in the inner ring of the 34 mm diameter wheel. Six turbine wheels are machined in one fixture in an 18-minute cycle. The electrode is made from a 0.75 mm thick stainless steel disk with the airfoil shapes wire EDM cut with the required machining gap allowance. The disk is mounted in a holder that allows electrolyte to flow through each airfoil shape as it plunges into the workpiece. A typical machining operation is shown in figure 8 where electrolyte is seen flowing radially outward from the tool as it oscillates at 50 Hz. In similar fashion, the Nitinol part of figure 9 is machined to lengths up to 32 mm with a tolerance of 7 microns. 60 of these can be machined in one operation.

The diesel injector component of figure 10 has an internal oval-shaped connecting passage machined using the oval electrode on the end of an arm that extends into the component main bore. After positioning the electrode, electrolyte is flushed into the main bore to allow electrolyte flow between the electrode and workpiece. A radius is created at the oval hole entrance and exit by the machining current. Fixturing for this part consists of a nest for 48 parts that are machined simultaneously using 24 double-ended electrodes. Machining time for the 48 parts is 11 minutes or 14 seconds machining time per part.

<< Figure 10: Diesel injection component with electrode. >>

A variety of automotive components have features produced by the PEM process. Components similar to the one shown in figure 11 require several different feature shapes and good surface finish to be machined into a hardened blank.

The PEM process has limited ability to produce very sharp edges. However, there are exceptions based on material, part geometry and electrode design. Typically, edge radii are limited to approximately 0.05 mm. Some applications such as surgical components and rotary shaver heads are PEMed to sharp cutting heads.

Summary

The PEM process exhibits many machining advantages compared to other processes. Benefits of PEM include:

- Produces features that are difficult or impossible to attain by other means
- Extremely long tool life
- No burrs or material deformation
- No machining stresses
- Hardened metals can be machined
- Simultaneous machining of multiple features
- Excellent surface finish
- Simultaneous multi-part machining with no cycle time penalty

As a result of these features of the PEM process, typical post-processing of machined components such as deburring, edge radiusing, and polishing are not necessary. Because the PEM process allows machining of hardened components, concerns about feature dimensions after heat treating are eliminated. Since PEM is not a thermal process, features and surfaces do not exhibit thermal damage.

The PEM machining process is an advanced electrolytic metal removal technology capable of machining a variety of geometry features on or in metal workpieces. The relatively fast metal removal rate (typically eight to 20 times faster than EDM) and excellent surface finish (typically 0.02 to 0.2 microns Ra) makes PEM a manufacturing process of choice for many applications.

PEM Technologies LLC

<< Figure 11: PEMed automotive part. >>

Applications for Precision Electrolytic Machining

- Fluid Dynamic motors & actuators
- High precision gears
- Medical implants
- Diesel fuel system components
- Die and mold inserts and punches
- Surgical instruments
- Dynamic seals
- Compacting dies
- Jet engine fuel system components
- Aircraft hydraulic actuators
- Heat transfer surfaces

PEM Technologies LLC
Natrona Heights, PA
412-736-7961
drisko@pemtechnologies.com