Die-sink Electric Discharge (ED) Machining

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Die-sink electric discharge (ED) machining is a machining method with which it is possible

1. To produce relatively sharp internal corners and deep narrow shapes with drafted walls.


For a long time ED machining was the only possible method for hardened steels. High speed technologies have improved the potentials of a milling method, but the shape depth still sets certain limits: The deeper the shape, the larger cutter diameter must be selected because of the cutting force and vibrations caused by the rotating movement. Die-sink ED machining technology does not set this kind of limit, because there are no notable mechanical stresses on the cutting tool.

The basic elements in the die-sink ED machining method are: electrode, dielectric medium and workpiece. The ED machine moves electrode and/or workpiece three dimensionally and in some machine types rotationally. (See images) The three dimensional axes are named as X, Y and Z and the rotational axis as C.

Basic elements

Image 1. The simplest configuration. The electrode moves with a slow downward movement. The aim is to produce deep small radius holes and grooves to the workpiece. Workpiece is in a fixed position.

Image 2. More complicated configuration. Either the electrode or the workpiece moves 2-dimensionally. 2-axes machining.

Image 3. If the bottom of the slots in the image 2 is contoured in up-and-down directions, it would require an additional programmable axis in the machine for 3-dimensional movement.
The electric discharge machining process is rather simple. The ED machine produces rapid and regular changes in electric potential between the electrode and the workpiece. Depending on the electrode and the workpiece materials either one can be set as positive pole. The change in potential causes the liquid medium to change from an insulator to a conductor and a spark occurs between the electrode and the workpiece at the moment the electrode is near enough to the workpiece. The spark causes the workpiece surface to melt in a very small round area. The workpiece surface will become pitted. (See image.) There is a servo system in the electric discharge machine, which prevents the electrode to touch the workpiece. Touching would short circuit the system and no machining would take place. Between the sparks the workpiece surface cools down. The melted workpiece material forms a round chip, which is flushed away with the dielectric fluid.

Removing the chips from the sparking gap is very important. The chips can cause difficulties in different ways:

- Chips conduct electricity and enlarge the sparking gap. The machining result in the workpiece will then be larger than estimated.
- Chips can build up and insulate workpiece surface. Portion of the sparking energy is lost in re-machining the chips instead of the workpiece.
- Moving chips cause variations in the voltage between the workpiece and the electrode. ED machine adjusts its servos by taking measures from the machining voltage. Inequality in the voltage disturbs servo actions.

There are different techniques in chip removal. These techniques include pressurising the dielectric fluid through the workpiece or through the electrode, using vacuum, using external fluid flow mechanisms and/or mechanically moving the electrode. These techniques are described in more detail under the title ‘Electrode Manufacturing’.
The ED machine system has three important adjustable parameters:

- electric current
- electric potential
- polarity

The machine manufacturers give advice about the suitable values for different workpiece materials. The higher the current and potential the rougher and more pitted the machined surface, but also the higher machining speed. Usually there are two phases: rough machining and finishing machining. During the rough machining phase the ED machine is adjusted to remove material quickly and efficiently. During the finishing phase the material removal rate is smaller and the aim is to produce as accurate dimensions as possible.

ED machining electrode is a negative of the machining result. If the machined shape is to be a drafted hole, the electrode is a drafted boss – but smaller. The electrode is sparking gap width smaller than the wished cavity. Equally much smaller in all dimensions. The electrode dimensions are calculated from the material specific charts that come with the ED machines. See separated training material about electrode manufacturing.

Electrodes wear during the process. Corners wear more than flat surfaces, because there is more intense sparking in the corners and more material is removed than from the flat surfaces. With certain combinations of electrode and workpiece materials and ED machine adjusting parameters there is a possibility for condition called ‘no-wear machining’. Generally this condition occurs with copper or graphite electrodes machining steel.

The most common electrode materials are:

- graphite
- brass and other copper alloys
- pure tungsten and tungsten alloys
- copper graphite

80 – 90% of the electrodes that are prepared for machining steels are graphite. There are four reasons:

- graphite is relatively cheap material
- it is easy to machine
- it does not conduct heat very well
- its melting point is very high, over 3000 °C

Graphite electrodes are usually used for high melting point materials and other metallic electrode for machining low temperature materials. One of the exceptions is tungsten-carbide for which the graphite electrodes are not recommended. Electric discharge machining is basically machining by melting the workpiece with electric shocks. If the melting point of the electrode material is similar compared to the workpiece melting point, a rapid wear occurs. Among the metallic materials tungsten has an equally high melting point as graphite, but tungsten is very difficult to machine. Metallic materials are usually very good heat conductors. Metallic electrodes warm up during the machining process and part of the machining energy is lost in heating the electrode. Graphite electrodes are more efficient, because they do not conduct heat and warm during the process.
There are different graphite grades starting from astrofine to rough machining grades. The particle size and the surface quality in graphite electrodes have a significant impact on the machined surface quality. The finer the graphite granules and the better the electrode surface quality the better is the result in the machined surface.

The dielectric fluids are either some petroleum product (hydrocarbon fluid) or deionised water. Hydrocarbon fluids are more common in die-sink applications and deionised water in wire-cut ED machining applications. The fluids cool the workpiece and melted workpiece material remove machined chips and act as a medium for the electric sparks. The electrical properties of the fluids are well known.

High speed machining methods have replaced ED machining in many applications, including machining of hardened steel and small radius internal corners. The high speed machining cutters can be very small. Despite of these there is still a need for the die-sink ED machining method. Drafted deep and very narrow slots, drafted small diameter holes and difficult materials are typical examples of applications where there is no good option for ED machine. The material hardness is not a restriction, but the material must conduct electricity. Moulds for parts which are designed with strengthening and cooling ribs are typical examples of die-sink ED machining applications. (See image.)

Injection moulded parts are sometimes designed to have decorative rough surfaces. Appropriately ED machined mould cavity produces nice decorative surfaces to the moulded plastic part. Usually the ED machined pitted surface is removed with manual tools and handwork, but sometimes the ED surface is wanted. High speed machining methods have decreased the need for mould cavity finishing operations. If there is a need to polish mould surface, the ED machined surface must be totally removed with manual tooling. It can take a very long time, especially if the shapes are deep and narrow.

On the case of pressure die casting moulds the ED worked surface must always be totally removed. The pressure die casting mould surface is a little rough, never polished. The ED machined pitted surface is a potential starting point for fatigue cracking. The pressure die casting mould surface will eventually crack, but cracking will occur sooner if there is roughness after ED operations.
References

ED machine manufacturer www-pages:

- Brother, http://www.brother.com
- Charmilles, http://www.charmilles.com
- Sodick, http://www.sodick.com