Electrical discharge machining (EDM) - introductory workshop on CAD/CAM

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Introductory Workshop on CAD/CAM *****

Conducted by the CAD/CAM Centre of the Department of Mechanical Engineering, University of Moratuwa in association with the Agricultural Machinery Manufacturers Association of Sri Lanka Inc. (AgMMA)

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ELECTRICAL DISCHARGE MACHINING (EDM)

Electrical Discharge Machining, also known as spark erosion machining, is a method of non-conventional machining where the principle involved is removal of metal through the action of high-energy electric sparks directed on to the surface of the workpiece (Fig.2). The basic set up of equipment to achieve this is shown in Fig.1.

The tool and the workpiece are submerged in a dielectric fluid (ie. a non-conductive fluid but through which electricity can be caused to transmit in the form of a spark under a high voltage diference). A very small gap, usually of the order of 0.025 mm (0.001 inch), is maintained between the tool ('electrode') and the workpiece by means of a servo-system. A direct current at up to 300 V is applied to the system which includes a capacitor in parallel with the spark gap. As the voltage in the capacitor builds up, the fluid suffers dielectric breakdown and a spark appears through the gap generating very high temperature which causes fusion (melting) and vapourisation of minute amounts of **both the workpiece and tool materials.** Deionization of the dielectric reestablishes the insulating film, the spark extinguishes and the capacitor begins to charge again. This cycle is repeated thousands of times per second(0.2 - 100 kHz).

There are two distinctly different types of EDM processes : the solid electrode type (Fig.1) and the wire electrode type (Fig 3). In the former, a plain vertical eroding configuration ('sinking') is used and the cavity shape and dimensions are an exact inverse replica of the solid electrode used (Electrodes for this purpose are made by using methods such as copy milling).The latter resembles cutting through the metal with a band saw. The wire feeds continuously between a take-off spool and a take-up spool (with reversal of direction of travel when the end is reached) in order to compensate for its erosion. The wire electrode is numerically controlled and moves through the metal according to the set path (Fig.4). This arrangement permits cutting intricate openings and tight-radius 2-D contours. Machines for wire-cut EDM has the provision or executing 'u' and 'v' motions in addition to the usual X and Y movements defining the path of travel. These two movements independently control the position of one wire spool axis (the other being fixed) thereby enabling slight tapers ('draft angles') to be generated on the cut surface.

Examples of components produced by the two types of EDM processes are shown in Fig.5. Solid electrode EDM is capable of producing complex cavitiees such as those found in injection moulds or performing seemingly impossible tasks such as machining small diameter (less than 1 mm) very deep holes. Wire-cut process on the otherhand is ideal for making press tools (punch - die combinations), extrusion dies and also external shapes such as cam profiles. EDM machines, once set, can perform the task with minimum operator supervision. However, in view of the very low metal removal rates they are not economical for repetitive part production, except perhaps for very small batches.

Workpiece

EDM is applicable to all materials that are fairly good electrical conductors, thus including metals, alloys and most carbides. The process is insensitive to the hardness of the material; therefore it has found wide application for machining cavitiees and contours in already hardened die steel blocks, thus avoiding distortion that would be inevitable if the dies were first machined and then heat treated.

Tool ('Electrode')

The electrode material may be any good electrical conductor with suficiently high melting point to minimise rapid wear of tool. For solid electrodes, copper or graphite is commonly used. Polarizing of workpiece and tool depends on the combination of materials and is done in such a way that the largest volume is removed from the workpiece. Under optimum conditions the wear ratio (workpiece to tool) by volume is 3:1 with metallic electrodes and from 3:1 to 100:1 with graphite electrodes. Usually the use of roughing electrodes followed by a finishing electrode is required for dimensional accuracy. For wire electrodes, the diameters range from 0.03 to 0.3 mm and soft copper or other metals are used.

Dielectric Fluid

For solid electrode process a hydrocarbon oil such as kerosene or parafin is used, while for wire-cut process deionized (demineralized) water is recommended. Use of deionized water is advantageous as a dielectric medium in wire electrode processes because the wider spark gap improves flushing, debris is smaller and no arc is generated which would inevitably result in the wire breaking.

Metal Removal Rate & Surface Finish

The mechanism of metal removal in EDM is primarily by fusion but not all particles released are fused, particularly in the case of certain metals. It appears that highly localised thermal stresses also play a role in the metal-removal process. Metal removal rate is primarily a function of the current density; higher current densities create rougher surfaces and also extend deeper the heat-affected zone (typically 2 - 120 microns). Therefore it is customary to end the cut at a low current density.

A surface generated by EDM, especially in the roughing operations, has a certain high degree of roughness and a characteristic matt appearance. After the use of a finishing electrode it is possible to achieve roughness heights of the order of 1 micron or less. Such surfaces produced by EDM usually need simply a final polishing or no finishing at all. Fig.6 shows a typical EDM surface under high magnification. The surface is composed of extremely small craters.

With spark erosion, the structure of the surface is inevitably changed by heat. When hydrocarbons are used as the dielectric, the released carbon from the breakdown of dielectric diffuses into steel surfaces and produces very hard layers with carbide-orming elements. High residual tensile stresses are also possible in this surface layer and for workpiece materials that tend to be brittle at room temperature, the surface may also contain fine cracks. Consequently some other finishing process may be often needed subsequent to EDM to remove a thin surface layer.

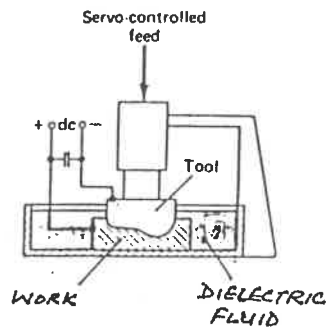

FIG.1 ELECTRICAL DISCHARGE MACHINING (EDM) (WITH SOLID ELECTRODE)

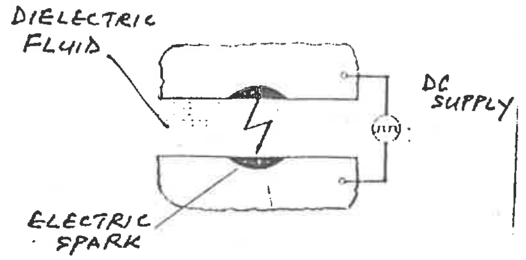

FIG 2. PRINCIPLE OF EDM

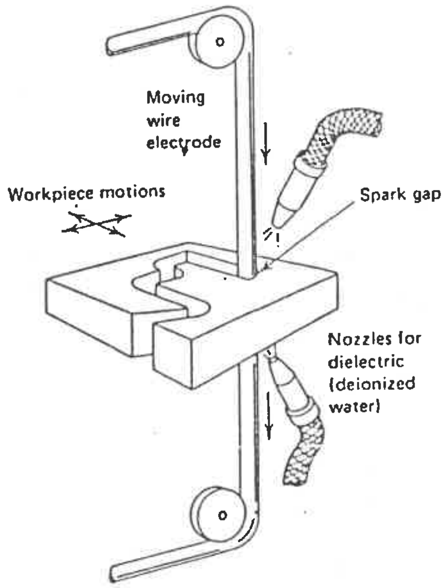

FIG.3 ELECTRICAL DISCHARGE MACHINING (EDM) (WITH WIRE ELECTRODE)

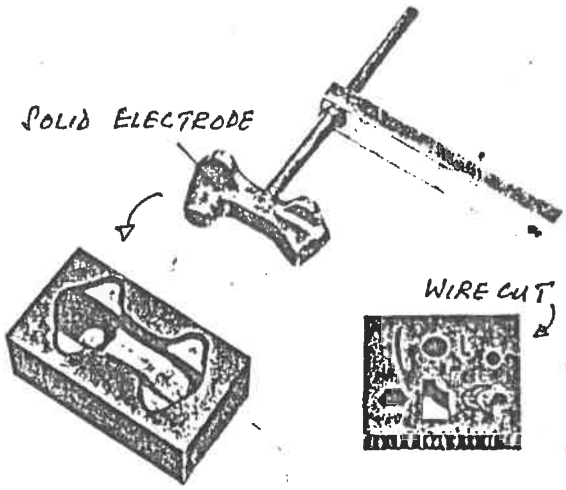

FIG.5 TYPICAL EDM MANUFATURED PARTS

FIG.6. SURFACE FORMED BY EDM

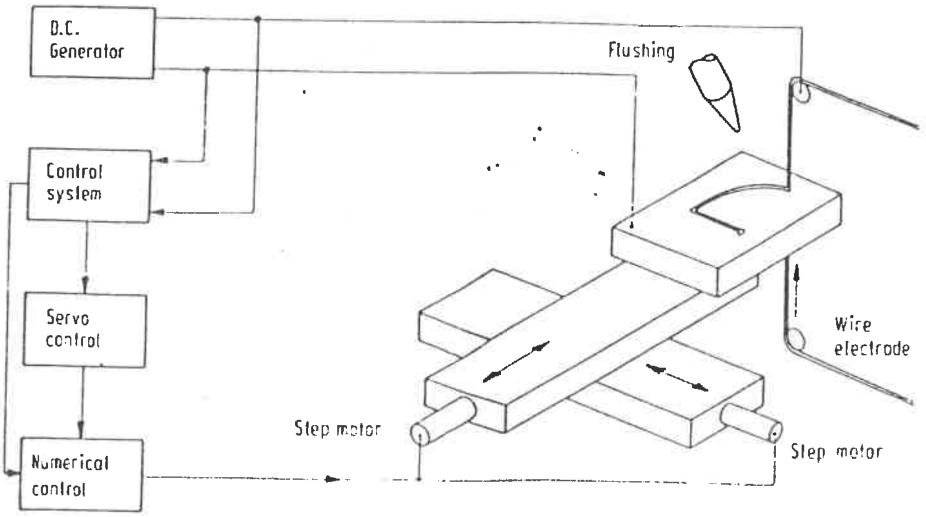

FIG.4 PRINCIPLE OF MACHINE CONTROL FOR EDM (WITH WIRE ELECTRODE)