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LAWRENCE LIVERMORE LABORATORY

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MASTER

FEASIBILITY OF ELECTROCHEMICAL MACHINING
FACILITY AT LLL

A Committee Report

Compiled by:

William L. Randall

October 1974

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FEASIBILITY OF ELECTROCHEMICAL MACHINING FACILITY AT LLL

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During the past decade or so, the question of an electrochemical machining (ECM) facility at LLL has been raised. Inquiries about these methods have not been in great numbers, but have come up when it appears that ECM methods could be the solution for the machining, shaping, drilling, trepanning, grinding, or milling of a particular type of material or for a particularly intricate shape or shapes.

There are advantages and disadvantages to be considered, and these criteria should be the deciding factors for ECM facilities.

Advantages of ECM:

1. Can machine metallic materials of very high hardness (as can grinding and electrodischarge machining).
2. Surfaces produced are free of stress and/or damage (in contrast to grinding on EDM).
3. Can produce curved surfaces, complex and intricate shapes as quickly as simple shapes (once ECM tooling has been developed).
4. Can be combined with standard machining practices.
5. Production rates on complex parts can be on an order of magnitude faster than direct machining (once ECM tooling has been developed), even on readily machinable materials.
6. Surface finishes as good as $0.1 \mu\text{m}$ (4AA) can be obtained.
7. There is no wear on the tooling if certain precautions are observed in its use.
8. "In house capability" would be available.

General Discussion:

It is useful to understand a few details of ECM in order to appreciate some of the difficulties. Basically, it depends upon dissolution of the anodic electrode (workpiece) during electrolysis by passing current through an electrolyte, flowing in the gap between the anode and the cathode (shaped tooling); this anode-cathode gap can be as small as 0.004" (1000 mm). High amperage 100-1000 A/in² (15-150 A/cm²) is used to provide a suitable removal rate. These conditions lead to rapid generation of hydroxide solids, gas bubbles and heat, which are kept at tolerable levels by high flow velocity of the electrolyte ~100-200 ft/sec (3³-6³cms/sec). This in turn requires substantial pressure drops 50-400 psi (3-28 MPa) and can involve high flow rates on the order of hundreds of gpm (M³/s). The gap is maintained during the machining cycle by feeding the cathode, usually along a single axis. The electrolyte must be cleaned of solids before recirculation to maintain the removal rate and to avoid arcing. The tooling ordinarily operates without wear, but a single arc can destroy the tooling. Modern ECM power supplies have elaborate anti-arcing features, to at least limit the damage if an arc occurs. Besides worrying about arcing, the tooling designer must contend with the spatial variations in gap thickness, fluid flow, velocity, electrolyte dilution and electrolyte temperatures, all of which are interconnected. Fluid cavitation must be avoided, which may require an exhaust backpressure, which in turn can cause sealing problems and pumping capacity problems. Electrolyte splash onto adjacent part surfaces can cause unwanted etching.

Disadvantages:

1. A massive machine structure is required for ordinary-sized parts, because of the high pressure loads and because extreme rigidity is needed to avoid water-hammer instability.
2. The electrolyte handling system (pumps, centrifuges, settling tanks, etc.) is also massive. For example, the Lockheed Sunnyvale system has two million gallon (757⁴/L) settling tanks, and is limited to the two electrolytes in those tanks.
3. The corrosive nature of the electrolyte presents a continued maintenance problem for equipment in the ECM area.

4. The complexity of the processes within the machining gap make the tooling design a combination of science and black art. This in turn means:
 - a. Tool designers must have a thorough engineering understanding plus a lot of experience.
 - b. Tooling lead times of several months are typical, since several iterations may be required.
5. Part geometry is limited (in commercially available machines) to that compatible with a one dimensional die-sinking form, e.g., re-entrant shapes cannot be handled. Also, asymmetric shapes, such as sinking details on a semi-circular shape, may cause unbalanced pressure forces that cause great difficulty.
6. Because of factors of force, temperature, distortion, and variations in electrolyte properties, the repeatability of the process is limited. The difficulties of tooling design limit the basic accuracy. Tolerances on the order of ± 0.005 " (0.1250 mm) are normal, except that ± 0.001 " (0.025 mm) can be held on specific features such as hole depth.

Summary:

ECM is most suitable in the following types of applications:

- a) Large production quantities are required in a difficult to machine shape or material which is suitable for ECM.
- b) The material hardness and/or surface requirements make the job impossible or at least very unattractive to do by any method except ECM.

Thus far, LLL has not been faced with problems that fall into either of the above categories. Such problems may arise in the future; one possibility is the production of turbine blades or buckets for our geothermal work. Since the going-in costs for a viable ECM facility would be in the order of a million dollars for equipment, several years from decision to first part, and several heads for support (including hiring of at least one experienced expert), the establishing of an ECM facility at LLL is not recommended without a clear need. The use of ECM facilities at Y-12, Lockheed Sunnyvale and the United Air Lines repair facility at San Francisco, is not recommended unless the ECM applications can be justified by economics and/or manufacturing necessity.

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