Electro-Chemical Machining (Non-Conventional or Non-Traditional Machining Processes)

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Abstract— Electro-chemical machining is a non-traditional process used mainly to machine hard or difficult to cut metal such as composites, stainless steels etc. During experiments three parameters are changed electrolyte flow rate, feed rate, voltage. Conventional processes is responsible for the development of non-traditional processes because it is difficult to machining super alloys and other hard materials. Present paper show that the high material rate is obtained at high feed rate, high voltage and minimum electrolyte flow rate. The feed rate is concern to main parameter which affect material removal rate.

Keywords: Electro-Chemical Machining

Purpose: the purpose of this research paper is to know what is the working requirements and its efficiency and all the areas where it can use efficiently.

I. INTRODUCTION

The process of metal abstraction by electro chemical dissolution was kenned as long back as 1780 AD but it is only over the last couple of decenniums that this method has been used to advantage. It is withal kenned as contactless electrochemical composing process. The eminent feature of electrolysis is that electrical energy is utilized to engender a chemical reaction, consequently, the machining process predicated on this principle is kenned as Electrochemical machining (ECM). This process works on the principle of Faraday's laws of electrolysis.

Michael Faraday discovered that if the two electrodes are placed in a bath containing a conductive liquid and DC potential (5-25V) is applied across them, metal can be depleted from the anode and plated on the cathode. This principle was in utilization for long time. ECM is the inversion of the electroplating.

ECM can be thought of a controlled anodic dissolution at atomic level of the work piece that is electrically conductive by a shaped implement due to flow of high current at relatively low potential difference through an electrolyte which is quite often dihydrogen monoxide predicated neutral salt solution. In ECM, Electrolyte is so culled that there is no plating on implement and shape of implement remains unchanged. If the close gap (0.1 to 0.2mm) is maintained between implement and work, the machined surface takes the replica of implement shape.

II. CHEMISTRY OF ALL PROCESSES

During ECM, there will be reactions occurring at the electrodes i.e. at the anode or work piece and at the cathode or the implement along with within the electrolyte.

Let us take an example of machining of low carbon steel which is primarily a ferrous alloy mainly containing iron. For electrochemical machining of steel, generally a neutral salt solution of sodium chloride (NaCl) is taken as the electrolyte. The electrolyte and dihydrogen monoxide undergoes ionic dissociation as shown below as potential difference is applied

$$NaCl \leftrightarrow Na+ + ClH2O \leftrightarrow H+ + (OH)-$$

As the potential difference is applied between the work piece (anode) and the implement (cathode), the positive ions move towards the implement and negative ions move towards the work piece. Thus the hydrogen ions will take away electrons from the cathode (implement) and from hydrogen gas as:

$$2H+ + 2e- = H2 \uparrow \text{ at cathode}$$

Similarly, the iron atoms will emerge from the anode (work piece) as:

$$Fe = Fe+ + + 2e$$

Within the electrolyte iron ions would amalgamate with chloride ions to compose iron chloride and similarly sodium ions would amalgamate with hydroxyl ions to compose sodium hydroxide

$$Na+ + OH- = NaOH$$

In practice FeCl2 and Fe(OH)2 would compose and get precipitated in the form of sludge. In this manner it can be noted that the work piece gets gradually machined and gets precipitated as the sludge. Moreover there is not coating on the implement, only hydrogen gas evolves at the implement or cathode. Fig. 2 depicts the electro-chemical reactions schematically. As the material abstraction takes place due to atomic level dissociation, the machined surface is of excellent surface finish and stress free.

III. METAL CUTTING RATE OR METAL ABSTRACTION RATE CALCULATIONS

During ECM, metal from the anode (or work piece) is abstracted atom by atom by abstracting negative electrical charges that bind the surface atoms to their neighbors. The ionized atoms are then positively charged and can be magnetized away from the work piece by an electric field. In an electrolytic cell (ECM cell) material abstraction rate is governed by Faraday's law of electrolysis. The amount of chemical change engendered by an electric current (or the amount of substance deposited or dissolved) is proportional to the quantity of electric charges passed through electrolyte.
W Q

The amount of different substances deposited or dissolved by the same quantity of electricity are proportional to their Electrochemical equipollent weights.(ECE)
W ECE

$$ECE= M/v$$

Where M is the atomic weight and v is the valency. These laws can be expressed in mathematical form as follows:
MRR

$$W=1/F(ECE).Q$$

$$MRR =1/F(M/v)I\ t$$

Where F is the faraday's constant=96500 coulombs =26.8amp-hr, Q is the charge (0coloumb), I the current (ampere) and t is the dissolution period. This equation is predicated on number of simplified postulation and does not account for the effect of some of consequential process variables, namely, transmutations in valency of electrochemical EC dissolution during some operation, gas evolution due to machining and bubble formation this can be also due to electrolyte conductivity and temperature variation along the electrolyte flow path, over potential m presence of passivation film etc. Passivity arises as a result of chemical and electro chemical deportment of metals which results in the formation of protective film on their surfaces. Further, dissolution of iron in Nacl solution, depending upon the machining conditions, may be either in the form of ferrous hydroxide or ferric hydroxide. Mode of dissolution during machining if alloys, is still more arduous to ken. The preferential valency mode of dissolution has been found to depend upon the electrolyte flow rate, IEG and length of electrolyte flow path.

IV. ECONOMICS OF ECM PROCESS

Fine-tuned costs of ECM installations are quite high compared to its operating costs. Overhead costs are same as for other conventional machining methods. Some costs are quite unique, such as those of high potency, electrode tooling and electrolyte. ECM needs power of high current capacity. In localities where power is amply frugal, this factor can be overlooked. Electrode or tooling cost is a fine-tuned cost because there is a little wear of the ECM implement. There occurs, however, a negligible abrasion wear of electrode due to electrolyte flow across the gap, with regard to authentic tooling cost, it is not very different from conventional machine tooling. Electrolyte is not as costly as one might cerebrate it to be. The most widely used electrolyte is Sodium chloride (salt) and it is quite frugal. The mundane price of salt seldom exceeds Rs 10 per kg, when purchased in sizably voluminous quantities.

Cost of the work piece fixtures are not very high. The cost per piece will however depends on work piece material and number of component. On the shop floor, ECM installation need not be operated by very adept engineers and operation of machinery can be learnt facilely. The economic prosperity of ECM, in fact depends largely on cull of applications, if an operation is simple or if the material can be facilely machined by other methods, high cost of ECM plant cannot be justified.

V. MECHANICAL PROPERTIES OF PARTS PRODUCED IN ECM

Mechanical properties of components engendered by ECM process It is paramount to ken the effect of ECM on the mechanical properties of electrochemically machined components. This will greatly affect the acceptability of the process in different industries. Scarcely any evidence is available about the hydrogen embrittlement of the ECM components. The fundamental reason being that hydrogen is evolved at cathode while metal abstraction is taking place due to anodic dissolution at the anode. It has been reported that there is no effect of ECM on ductility, yield vigor, ultimate vigor, and micro hardness of the machined component.

Surface layers damaged during conventional machining or by some other processes, may be abstracted by ECM and this may result in amelioration in the properties of the work material. However, such abstraction of layers from the work surface reduces fatigue vigor of a conventionally machined components. The conventionally machined surfaces have compressive residual stresses responsible for higher fatigue vigor. This fact has been verified experimentally. However, the required fatigue vigor can be recuperated by further opportune post mechanical culminating treatment. These subsequent mechanical treatment impart compressive stresses to the surface, so that the resulting work piece can exhibit fatigue properties commensurable to or better that those of mechanically culminated components. The surface finish engendered by ECM may withal be source of reduction in fatigue properties. The surface engendered by ECM generally has better wear friction and corrosion resistance properties than those engendered by mechanical designates. Following Table gives effect of type of finish on fatigue vigor. Micro examination of specimen has revealed that fatigue cracks customarily originate from pits. Due to flowing electrolyte, these defects are more rigorous than those found in electro polishing. However, reduction in fatigue life is low and depth of inter granular attack quantified is about hundredth of a millimeter or even less. Abstraction of compressive stress layer seems to be the main reason, and inter granular attack and other defects induced during ECM appears to be secondary reasons for reduction in fatigue vigor. Infelicitous coalescence of work and electrolyte or infelicitous cull of operating conditions may result in non uniform dissolution of metals and alloys. It would lead to selective etching, intergranular attack or pitting. But such defects can be minimized by employing opportune heat treatment procedure and additionally by developing an opportune electrolyte and culling opportune operating conditions.

VI. DYNAMICS OF ECM PROCESS

In last section, we have derived an expression for MRR in ECM. Now the question arises whether one should sanction machining without any victual or give an aliment. To solve this, let us consider and electrolyte permeating a parallel gap "h" between implement and work piece. If the constant voltage (V) is applied across the gap, one should ascertain how gap changes take place.

A. Equipment

The electrochemical machining system has the following modules:

- Power supply
- Electrolyte supply and cleaning system
- Implement and implement victual system
- Work piece and Work holding system.

1) Power supply:

During ECM, a high value of direct current (may be as high as 40000 A) and a low value of electric potential (in range of 5-25 V) across IEG(Interelectrode gap) is desirable. The highest current density achieved so far is around 20,000 A/cm2. Hence, with the avail of a rectifier and a transformer, three phase AC is converted to a low voltage, high current

DC. Silicon controlled rectifier (SCRs) are utilized both for rectification as well as for voltage regulation because of their rapid replication to the vicissitudes in the process load and their compactness. Voltage regulation of ± 1% is adequate for most of the precision ECM works. However, lack of process control, equipment failure, operator's error, and homogeneous other reasons may result in sparking between implement and work. The electrical circuitry detects these events and power is cut off (utilizing the contrivance like SCRs) within 10 micro seconds to obviate the rigorous damage to the implement and work. In case of precision works even a minuscule damage to an electrode is not acceptable. It may be minimized by utilizing a bank of SCRs placed across the DC input to ECM machine.

2) Electrolyte Supply and Cleaning System:

The electrolyte supply and cleaning system consisting of a pump, filter, pipings, control valves, heating or cooling coils, pressure gauges, and a storage tank (or reservoir). Electrolyte supply ports may be made in the implement, work or fixture, depending upon the requisite of the mode of electrolyte flow. Diminutive inter electrode gap, customarily more minuscule than 1mm, should be maintained for achieving High MRR and high precision. For this purport, smooth flow of electrolyte should be maintained and any blockade of such a diminutive gap by particles carried by electrolyte, should be eschewed. Hence, electrolyte cleanliness is imperative. It is customarily done with the avail of filters composed of SS steel, Monel or any other anticorrosive material. It should be ascertained that the piping system does not introduce any peregrine material like corroded particles, scale or pieces of broken seal material. Piping system is consequently composed of SS steel, Glass fibre reinforced plastic (GFRP), plastic lined MS or kindred other anti-corrosive material. The required minimum capacity of electrolyte tank is 500 gallons for each 10000 A of current. ECM is supposed to machine different metals and alloys at optimum machining conditions and with varying requisites of precision, surface texture, etc. Under such situations, a single tank system is not recommended because of loss of time and wastage of electrolyte during drilling cleaning, commixing or filling of incipient electrolyte in the tank. It results in higher cost and poor precision of electro chemically machined surface and withal poor control of operating conditions. More than one tank consequently, can be used and their number would depend upon the range of electrolytes needed to meet the work load.

3) Implement and Implement Aliment System:

Utilization of anti-corrosive material for implements and fixtures is consequential because they are required for a long period of time to operate in the corrosive environment of electrolyte. High thermal conductivity and high thermal conductivity are main requisites. Facile machining of implement material is equipollently consequential because dimensional precision and surface finish of the implement directly affect the work piece precision and surface finish. Aluminum, Brass, Bronze, copper, carbon, stainless steel and monel are a few of the material utilized for this purport. Further, those areas on the implement where ECM action is not required, should be insulated.

For example, lack of insulation on the sides of die sinking implement causes unwanted machining of work and results in a loss of precision of the machined work piece. Utilization of non – corrosive and electrically non conducting material for making fixtures is recommended. Additionally, the fixtures and implements should be rigid enough to eschew vibration or deflection under the high hydraulic forces to which they are subjected.

4) Work piece and work holding system:

Only electrically conductive material can be machined by this process, the chemical properties of anode (work) material largely govern the material abstraction rate (MRR). Work holding contrivances are composed of electrically nonconductive materials having good thermal stability, and low moisture absorption properties, For Example, graphite fibres , reinforced plastics, plastics, Perspex ,etc., are the materials utilized for fabricating the work holding contrivance.

B. Applications

1) ECM can be habituated to make disc for turbine rotor blades composed of HSTR alloys
2) ECM can be utilized for slotting very thin walled collets
3) ECM can be utilized for facsimileing of internal and external surfaces, cutting of curvilinear slots, machining of intricate patterns, engenderment of long curved profiles, machining of gears and chain sprockets, engenderment of integrally bladed nozzle for use in diesel locomotives, engenderment of satellite rings and connecting rods, machining of thin immensely colossal diameter diaphragms.
4) ECM principle has be employed for performing a number of machining operations namely, turning, treplaning, broaching, grinding, fine aperture drilling, die sinking, perforating, deburring,plunge cutting etc.
5) ECM can additionally be acclimated to engender internal profile of internal cams.

C. Advantages

ECM offers impressive and perdurable advantages.

1) ECM can machine highly perplexed and curved surfaces in a single pass.
2) A single implement can be acclimated to machine a sizably voluminous number of pieces without any loss in its shape and size. Theoretically implement life is high
3) Machinability of the work material is independent of its physical and mechanical properties. The process is capable of machining metals and alloys irrespective of their vigor and hardness.
4) Machined surfaces are stress and burr free having good surface finish
5) It yields low scrap, virtually automatic operation, low overall machining time, and reduced inventory expenses.
6) There is no thermal damage and burr free surface can be engendered.

D. Disadvantages

1) High capital cost of equipment
2) Design and tooling system is intricate
3) Hydrogen libration at the implement surface may cause hydrogen embrittlement of the surface.

4) Spark damage may become sometimes problematic
5) Fatigue properties of the machined surface may reduce as compared to conventional techniques (by 20%)
6) Nonconductive material cannot be machined.
7) Blind apertures cannot be machined in solid block in one stage
8) Corrosion and rust of ECM machine can be hazard
9) Space and floor area requisite are withal higher than for conventional machining methods. Some supplemental quandaries cognate to machine implement requisites such as power supply, electrolyte handling and implement aliment servo systems.