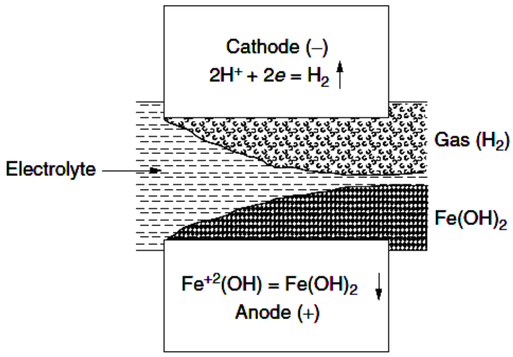
Chemistry involved in ECM process and explain the processparameters.

Theory of ECM- chemistry involved

- ECM uses a direct current at a high density of 0.5 to 5 A/mm2 and a low voltage of 10 to 30 V. The machining current passes through the electrolytic solution that fills the gap between an anodic workpiece and a preshaped cathodic tool.
- The electrolyte is forced to flow through the interelectrode gap at high velocity, usually more than 5 m/s, to intensify the mass and charge transfer through the sublayer near the anode.
- The electrolyte removes the dissolution products, such as metal hydroxides, heat, and gas bubbles, generated in the interelectrode gap. McGeough (1988) claimed that when a potential difference is applied across the electrodes, several possible reactions occur at the anode and the cathode.
- Figure illustrates the dissolution reaction of iron in sodium chloride (NaCl) water solution as an electrolyte. The result of electrolyte dissociation and NaCl dissolution leads to

$$H_2O \rightarrow H^+ + OH^-$$
$$NaCl \rightarrow Na^+ + Cl^-$$



Electrochemical reactions during ECM of iron.

The negatively charged anions OH− and Cl− move toward the anode, and the positively charged cations of H+ and Na+ are directed to the cathode.
At the anode, Fe changes to Fe++ by losing two electrons.

$$\mathbf{Fe \rightarrow Fe^{++} + 2e}$$

At the cathode, the reaction involves the generation of hydrogen gas and the hydroxyl ions.

$$\mathbf{2H_2O + 2e \rightarrow H_2 + 2(OH)^-}$$

The outcome of these electrochemical reactions is that iron ions combine with other ones to precipitate out as iron hydroxide, Fe(OH)2.

$$Fe + 2H_2O \rightarrow Fe(OH)_2 + H_2$$

The ferrous hydroxide may react further with water and oxygen to form ferric hydroxide, Fe(OH)3.

$$4Fe(OH)_2 + 2H_2O + O_2 \rightarrow 4Fe(OH)_3$$

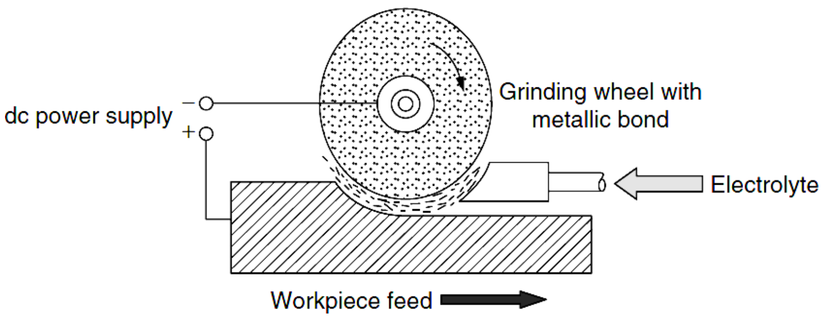
With this metal-electrolyte combination, electrolysis has involved the dissolution of iron, from the anode, and the generation of hydrogen, at the cathode.

PROCESS PARAMETERS:

Power Supply Type direct current
Voltage 2 to 35 V
Current 50 to 40,000 A
Current density 0.1 A/mm2 to 5 A/mm2
Electrolyte Material NaCl and NaNO3
Temperature 20oC – 50oC
Flow rate 20 lpm per 100 A current
Pressure 0.5 to 20 bar
Dilution 100 g/l to 500 g/l
Working gap 0.1 mm to 2 mm
Overcut 0.2 mm to 3 mm
Feed rate 0.5 mm/min to 15 mm/min
Electrode material copper, brass, bronze
Surface roughness, Ra 0.2 to 1.5 µm

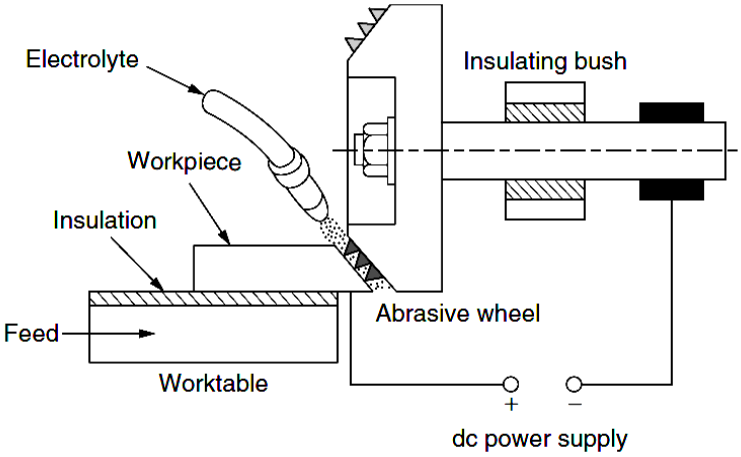
Principle of ECG with sketch. list out the advantage of ECG.Also mention the product application of ECG.

- Electrochemical grinding is a process that removes electrically conductive material by grinding with a negatively charged abrasive grinding wheel, an electrolyte fluid, and a positively charged workpiece.
- Materials removed from the workpiece stay in the electrolyte fluid. Electrochemical grinding is similar to electrochemical machining but uses a wheel instead of a tool shaped like the contour of the workpiece.
- Electrochemical grinding (ECG) utilizes a negatively charged abrasive grinding wheel, electrolyte solution, and a positively charged workpiece, as shown in Fig.The process is, therefore, similar to ECM except that the cathode is a specially constructed grinding wheel instead of a cathodic shaped tool like the contour to be machined by ECM.
- The insulating abrasive material (diamond or aluminum oxide) of the grinding wheel is set in a conductive bonding material. In ECG, the nonconducting abrasive particles act as a spacer between the wheel conductive bond and the anodic workpiece.
- Depending on the grain size of these particles, a constant inter electrode gap (0.025 mm or less) through which the electrolyte is flushed can be maintained.



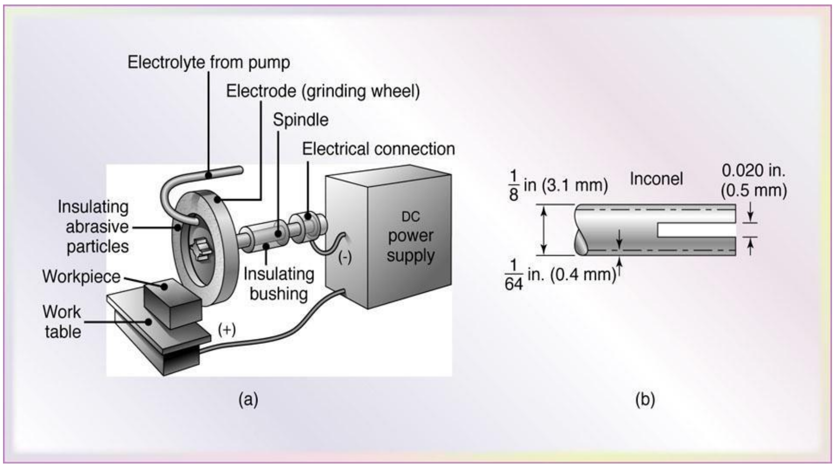
- ➢ The abrasives continuously remove the machining products from the working area. In the machining system shown in Fig., the wheel is a rotating cathodic tool with abrasive particles (60-320 grit number) on its periphery.
- ➢ Electrolyte flow, usually $NaNO_3$, is provided for ECD.The wheel rotates at a surface speed of 20 to 35 m/s, while current ratings are from 50 to 300 A.

ECG SYSTEM:



Material removal rate:

- ➢ When a gap voltage of 4 to 40 V is applied between the cathodic grinding wheel and the anodic workpiece, a current density of about 120 to 240 A/cm^2 is created. The current density depends on the material being, the gap width, and the applied voltage.
- ➢ Material is mainly removed by ECD, while the MA of the abrasive grits accounts for an additional 5 to 10 percent of the total material removal.



- ➢ Removal rates by ECG are 4 times faster than by conventional grinding, and ECG always produces burr-free parts that are unstressed. The volumetric removal rate (VRR) is typically 1600 mm^3/min.
- ➢ McGeough (1988) and Brown (1998) claimed that to obtain the maximum removal rate, the grinding area should be as large as possible to draw greater machining current, which affects the ECD phase.

- The volumetric removal rate (mm3/min) in ECG can be calculated using the following equation:

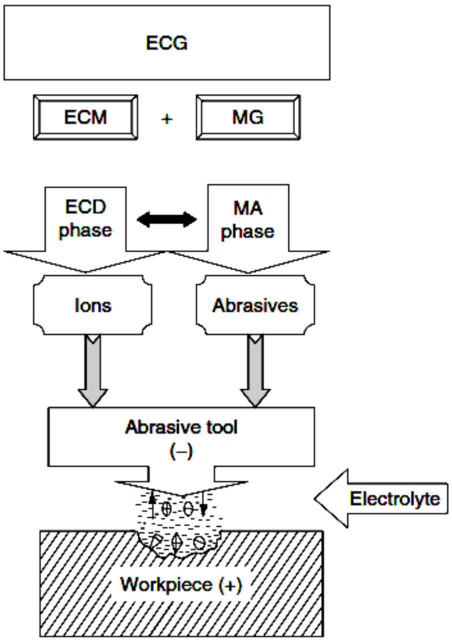
$$\text{VRR} = \frac{\varepsilon I}{\rho F}$$

where e = equivalent weight, g
I = machining current, A
r = density of work piece material, g/mm3
F = Faraday‟s constant, C

Process characteristics

- The wheels and work piece are electrically conductive.
- Wheels used last for many grindings - typically 90% of the metal are by electrolysis and 10% from the abrasive grinding wheel. Capable of producing smooth edges without the burrs caused by mechanical grinding.
- Does not produce appreciable heat that would distort work piece.
- Decomposes the work
- piece and deposits them into the electrolyte solution. The most common electrolytes are sodium chloride and sodium nitrate at concentrations of 2 lbs per gallon.
- It uses a rotating cathode embedded with abrasive particles for applications comparable to milling, grinding and sawing.
- Most of the metal removal is done by the electrolyte, resulting in very low tool wear.

<u>ECG PROCESS COMPONENTS:</u>



- ECG is a hybrid machining process that combines MA(Mechanical Abrasion) and ECD(Electro Chemical Deposition). The machining rate, therefore, increases many times; surface layer properties are improved, while tool wear and energy consumption are reduced.

- While Faraday‟s laws govern the ECD phase, the action of the abrasivegrains depends on conditions existing in the gap, such as the electric field, transport of electrolyte, and hydrodynamic effects on layers near the anode.
- The contribution of either of these two machining phases in the material removal process and in surface layer formation depends on the process parameters. Figure shows the basic components of the ECG process.
- The contribution of each machining phase to the material removal from the workpiece has resulted in a considerable increase in the total removal rate QECG, in relation to the sum of the removal rate of the electrochemical process and the grinding processes QECD and QMA, when keeping the same values of respective parameters as during the ECG process.

APPLICATIONS:

The ECG process is particularly effective for
1. Machining parts made from difficult-to-cut materials, such as sintered carbides, creep-resisting (Inconel, Nimonic) alloys, titanium alloys, and metallic composites.
2. Applications similar to milling, grinding, cutting off, sawing, and tool and cutter sharpening.
3. Production of tungsten carbide cutting tools, fragile parts, and thin walled tubes.
4. Removal of fatigue cracks from steel structures under seawater. In such an application holes about 25 mm in diameter, in steel 12 to 25 mm thick, have been produced by ECG at the ends of fatigue cracks to stop further development of the cracks and to enable the removal of specimens for metallurgical inspection.
5. Producing specimens for metal fatigue and tensile tests.
6. Machining of carbides and a variety of high-strength alloys.

ADVANTAGES

- Absence of work hardening
- Elimination of grinding burrs
- Absence of distortion of thin fragile or thermo sensitive parts
- Good surface quality
- Production of narrow tolerances
- Longer grinding wheel life

DISADVANTAGES

- Higher capital cost than conventional machines
- Process limited to electrically conductive materials

Electrochemical honing process and application in detail.

- Electrochemical honing (ECH) combines the high removal characteristics of ECD and MA of conventional honing. The process has much higher removal rates than either conventional honing or internal cylindrical grinding.
- In ECH the cathodic tool is similar to the conventional honing tool, withseveral rows of small holes to enable the electrolyte to be introduced directly to the inter electrode gap. The electrolyte provides electrons through the ionization process, acts as a coolant, and flushes away chips that are sheared off by MA

and metal sludge that results from ECD action.

- The majority of material is removed by the ECD phase, while the abrading stones remove enough metal to generate a round, straight, geometrically true cylinder. During machining, the MA removes the surface oxides that areformed on the work surface by the dissolution process.
- The removal of such oxides enhances further the ECD phase as it presents a fresh surface for further electrolytic dissolution. Sodium nitrate solution (240 g/L) is used instead of the more corrosive sodium chloride (120g/L) or acid electrolytes.
- An electrolyte temperature of 38°C, pressure of 1000 kPa, and flow rate of 95 L/min can be used. ECH employs dc current at a gap voltage of 6 to 30 V, which ensures a current density of 465 A/cm2. Improper electrolyte distribution in the machining gap may lead to geometrical errors in the produced bore.

Process characteristics

- The machining system shown in Fig. employs a reciprocating abrasive stone (with metallic bond) carried on a spindle, which is made cathodic and separated from the work piece by a rapidly flowing electrolyte.

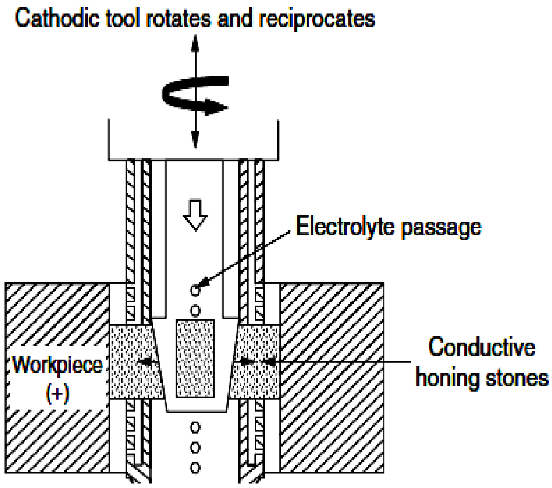
- In such an arrangement, the abrasive stones are used to maintain the gap size of 0.076 to 0.250 mm and, moreover, depassivate the machining surfacedue to the ECD phase occurring through the bond. A different tooling system (Fig.) can be used where the cathodic tool carries nonconductive honingsticks that are responsible for the MA.

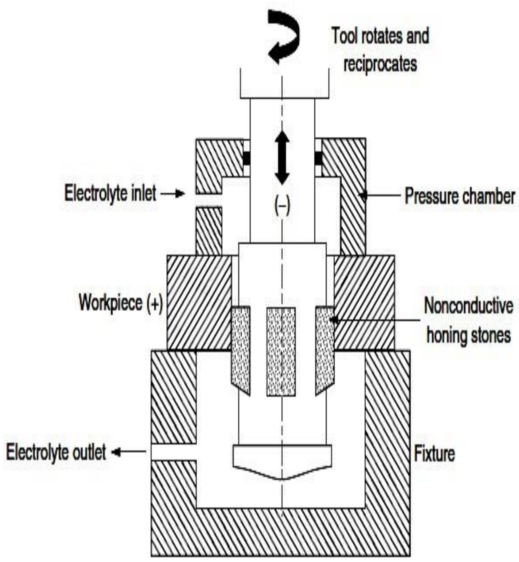
- The machine spindle that rotates and reciprocates is responsible for the ECD process. The material removal rate for ECH is 3 to 5 times faster than that of conventional honing and 4 times faster than that of internal cylindrical grinding. Tolerances in the range of ±0.003 mm are achievable, while surface roughnesses in the range of 0.2 to 0.8 μm Ra are possible.

- To control the surface roughness, MA is allowed to continue for a few seconds after the current has been turned off. Such a method leaves a light compressive residual stress in the surface.

- The surface finish generated by the ECH process is the conventional cross-hatched cut surface that is accepted and used for sealing and load-bearing surfaces. However, for stress-free surfaces and geometrically accurate bores, the last few seconds of MA action should be allowed for the pure ECD process.

ECH SCHEMATIC DIAGRAM: **ECH MACHINING SYSTEM COMPONENTS:**



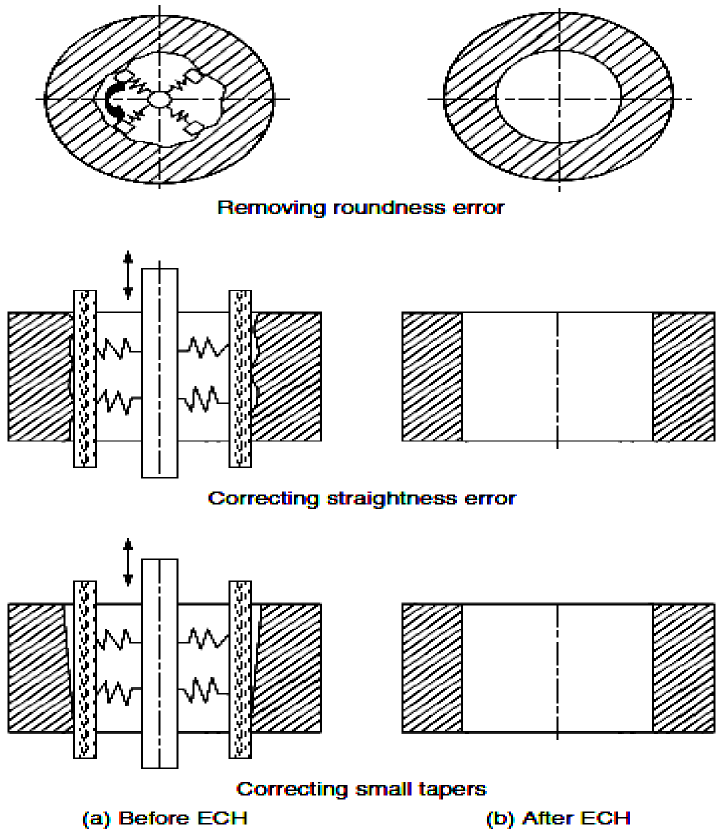


APPLICATIONS:

- As a result of the rotating and reciprocating honing motions, the process markedly reduces the errors in roundness through the rotary motion. Moreover, through tool reciprocation both taper and waviness errors are also reduced as shown in Fig.

- Because of the light stone pressure used, heat distortion is avoided. The presence of the ECD phase introduces no stresses and automatically deburrs the part.
- ECH can be used for hard and conductive materials that are susceptible to heat and distortion. The process can tackle pinion gears of high-alloy steel as well as holes in cast tool steel components.

ECH EFFECTS ON BORE ERRORS:



- Hone forming (HF) is an application that combines the honing and electro deposition processes. It is used to simultaneously abrade the work surface and deposit metal.
- In some of its basic principles the method is the reversal of ECH. This method is used in case of salvaging parts that became out-of-tolerance and reconditioning worn surfaces by metal deposition and abrasion of the new deposited layers.