

# ELECTROCHEMICAL HONING OF CYLINDRICAL PARTS- AN OVERVIEW

<sup>1</sup>Sumitra Sahoo and <sup>2</sup>Jain PK

<sup>1</sup>M.Tech student, <sup>2</sup>Professor and Head,  
Department of Mechanical & Industrial Engineering, IIT, Roorkee

---

**Abstract:** *Electrochemical Honing (ECH) is one of the most potentially emerging unconventional machining processes. This is a hybrid machining process combining the capabilities of electrochemical machining (ECM) and conventional honing. Owing to its advantages of both the processes, ECH is capable of producing high surface finish, tolerance, controlled surface generation of cross-hatch lay pattern or completely stress free and correction of geometrical inaccuracies on cylindrical workpieces such as out-of roundness, cylindricity, axis distortion etc. with very high productivity as compared to conventional superfinishing processes. Surface finish of the order of  $0.05\mu\text{m}$  and tolerance within  $\pm 0.002$  can be obtained. This is well within the category of superfinishing. This paper presents a complete review of electrochemical honing of cylindrical parts including internal holes, internal and external surface of cylinders with the objective to highlight the capabilities of ECH process. The competence of ECH towards achieving superfinishing is mainly focused.*

**Keywords:** *Electrochemical Honing, ECM, Internal cylinder, Cylindrical holes, Superfinishing*

---

## 1. INTRODUCTION

Electrochemical machining has been combined with several other machining processes, known as hybrid electrochemical processes. These are essential to enable improved machining characteristics particularly in difficult-to-machine materials like superalloys, Ti-alloys, tool steels, carbides etc. The associated processes may be mechanical machining or thermal machining. The mechanical machining assisted electrochemical processes are abrasive electrochemical machining, electrochemical grinding, and electrochemical honing. Electrochemical honing (ECH) is a hybrid machining process combining the capabilities of electrochemical machining (ECM) and conventional honing. Nearly 90% of material is removed by electrolytic action and rest by mechanical honing [1]. Honing tool is mainly used to scrub the passivating electrolytic metal oxide microfilm from higher work-profile area to correct the surface geometrical inaccuracies. Cross-hatch lay pattern essential for lubrication oil retention on the cylinder can be obtained by simultaneous rotation and reciprocation of the honing tool. ECH needs 5-10

times less time for same material removal than conventional machining process proving its high productivity capability. Surface finish within the range of superfinishing can also be attained.

This paper presents a detailed review of the past research work done on ECH of cylindrical holes, internal cylinders and external surface of cylinders. The capability of ECH towards achieving superfinishing is mainly focused here.

## 2. ELECTROCHEMICAL HONING PROCESS (ECH) - BRIEF DESCRIPTION

The principle of electrochemical honing depends on the high material removal characteristics of electrochemical machining and controlled functional surface generating capabilities of mechanical honing. This provides a range of benefits to the machined surfaces that are not achievable by either of the processes applied individually. In ECH, the cathodic tool is similar to conventional honing tool. It has several rows of small holes for introduction of electrolyte in the inter electrode gap. The honing tool is given simultaneous rotary and reciprocatory motion. Honing sticks are

protrude out radially with equal pressure. The electrolyte helps in the ionization process, acts as a coolant and flushes away chips generated from mechanical abrasion and metal sludge from electrolytic action. During machining, the honing stick removes the surface oxides that are formed on workpiece surface from electrolytic dissolution. The removal of surface oxides provides a fresh surface for further dissolution, so achieving higher productivity and better surface characteristics. The capability of ECH in comparison with ECM and conventional honing is shown in table 1.

The equipment consists of power supply, 3-phase

**Table1: Comparison of ECM, Conventional Honing and ECH Processes**

Process	Surface finish $\mu\text{m}$	Tolerance mm	Reference
ECM	0.4	$\pm 0.02$	Rao [3]
Conventional Honing	0.25-0.4	$\pm 0.008$	Jain et al. [4]
ECH	0.05	$\pm 0.002$	Dubey et al. [1]

**Table 2: Process Parameters of ECH [4]**

Parameters and Ranges	
Power supply	-Operation mode (constant or pulsed DC), -Current (100-3000A), Voltage (6-30V) -Current density (12-47 A/cm <sup>2</sup> )
Electrolyte	-Composition & Concentration, pH -Pressure (0.5-1.0 MPa), Temperature < 38°C -Flow rate (up to 95 litres per min)
Honing	-Type of abrasive (Al <sub>2</sub> O <sub>3</sub> , SiC, CBN, diamond), -Abrasive particle size (70–1200mesh size), -Type of bond (vitrified, resinoid), -Rotary speed (100–800 rpm), and reciprocating speed (0–18 m/min)
Workpiece	Electrolytic properties, Size, Rotating speed
Inter electrode gap	0.075 to 0.25mm.

AC supply converted to low voltage and high current DC (3000-6000A), electrolyte supply and cleaning system, ECH tool and drive system and work holding system. The influential process parameters for surface quality and the ranges for ECH on cylindrical parts are described in Table 2.

Research on ECH has been undergoing consistently in Indian Institute of Technology, Roorkee on gears and cylinders. Recently Misra et al. [18-19] found that the surface quality of gear teeth profile improves with processing time, but the increment rate decreases in course of time. The optimum electrolyte solution found to be 70% NaCl+30% NaNO<sub>3</sub>, where 53.17% PIBr (percentage improvement in bearing ratio) observed. Singh [20] observed improvement of 79% in average surface roughness value and 84% in maximum surface roughness value during investigations on precision finishing of spur gears by pulse-electrochemical honing (PECH) process. Singh [21] proposed use of ECH to remanufacture components to improve dimensional accuracy and surface characteristics of deposited layer in a single action.

### 3. LITERATURE REVIEW ON ELECTROCHEMICAL HONING (ECH) OF CYLINDRICAL PARTS

The electrochemical honing process is favored in research community from the point of high productivity and stringent surface quality requirements of high speed rotating components. This review presents the ability of ECH to achieve superfinishing in cylindrical holes, internal cylinders and external surface of cylinders studied so far.

#### 3.1 ECH of Cylindrical Holes

Electrochemical Honing was initiated by Randlett and Ellis [6] in 1967. Study on conventional honing and electrochemical honing conducted. It is found that ECH is much faster than conventional honing.

After that Budzynski [7-9] published the details of ECH machine and presented optimization of ECH on cylindrical holes (which are deformed by heat treatment) using ammonium nitrate as electrolyte. He found that current density, honing pressure and machining time do not influence surface finish and shape deviations, but influences material removal rate. For better accuracy, the electrolytic reaction time is to be kept constant for every elemental work surface.

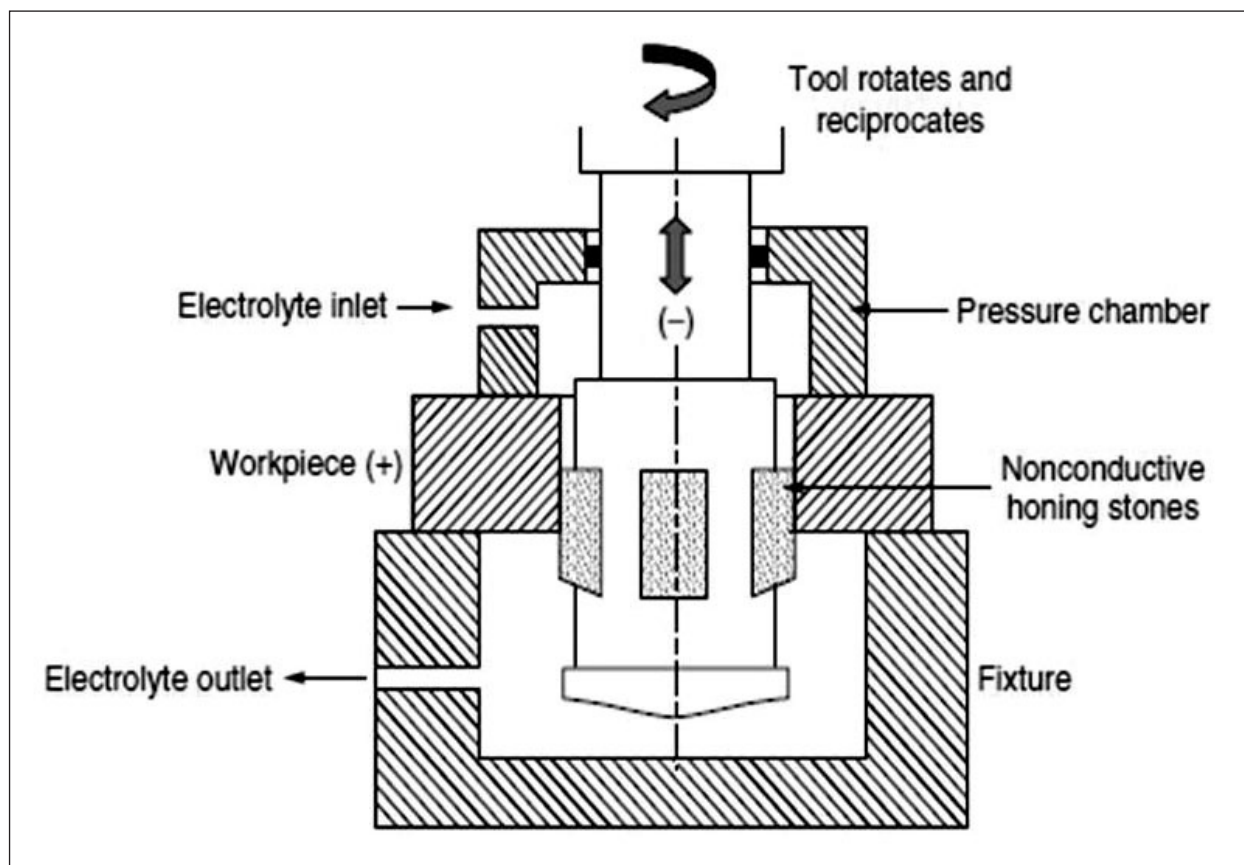


Fig 1. Schematic of ECH on Internal Cylinder [2]

Budzynski [10] also revealed that average surface roughness for longitudinal honing is always smaller than that of two directional honing (longitudinal with peripheral or rotational velocity) for electrochemically honed holes.

Kitaev [11] described the semiautomatic vertical honing machines to use for ECH of holes.

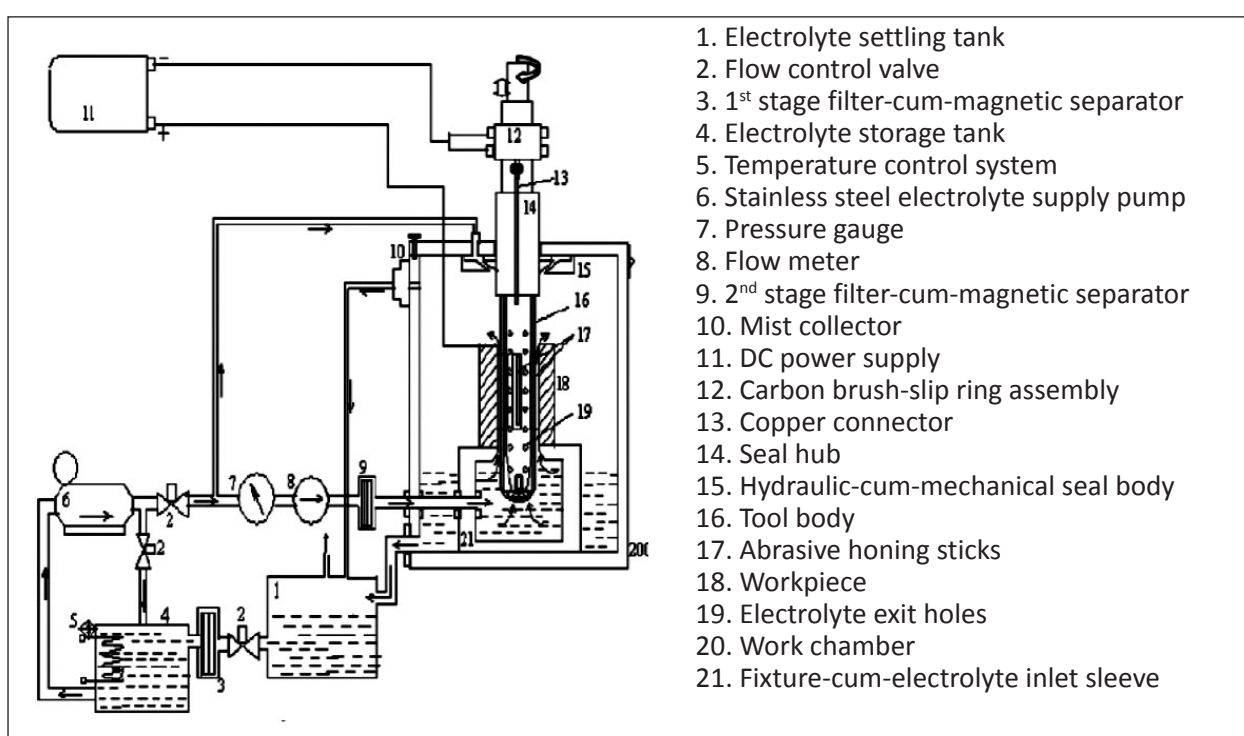
### 3.2 ECH of Internal Cylinders

Study on ECH of internal cylinders is carried out by Fasil [12] in IIT Roorkee. ECH parameters such as the effects of DC voltage, electrolyte pressure, electrolyte concentration and speed of rotation on the surface roughness are studied. It is found that electric voltage and electrolyte concentration have significant effects on the surface roughness.

Dubey [13] explored the influence of key ECH process parameters on Cast Iron ASTM35 work surface from micro and macro geometrical and material removal aspect (Fig. 2). The surface finish of the order of  $0.05\mu\text{m}$  and tolerance within  $\pm 0.002\text{mm}$  can be achieved. The electric voltage across the inter electrode gap, tool rotary and reciprocating speed are found to influence significantly the work

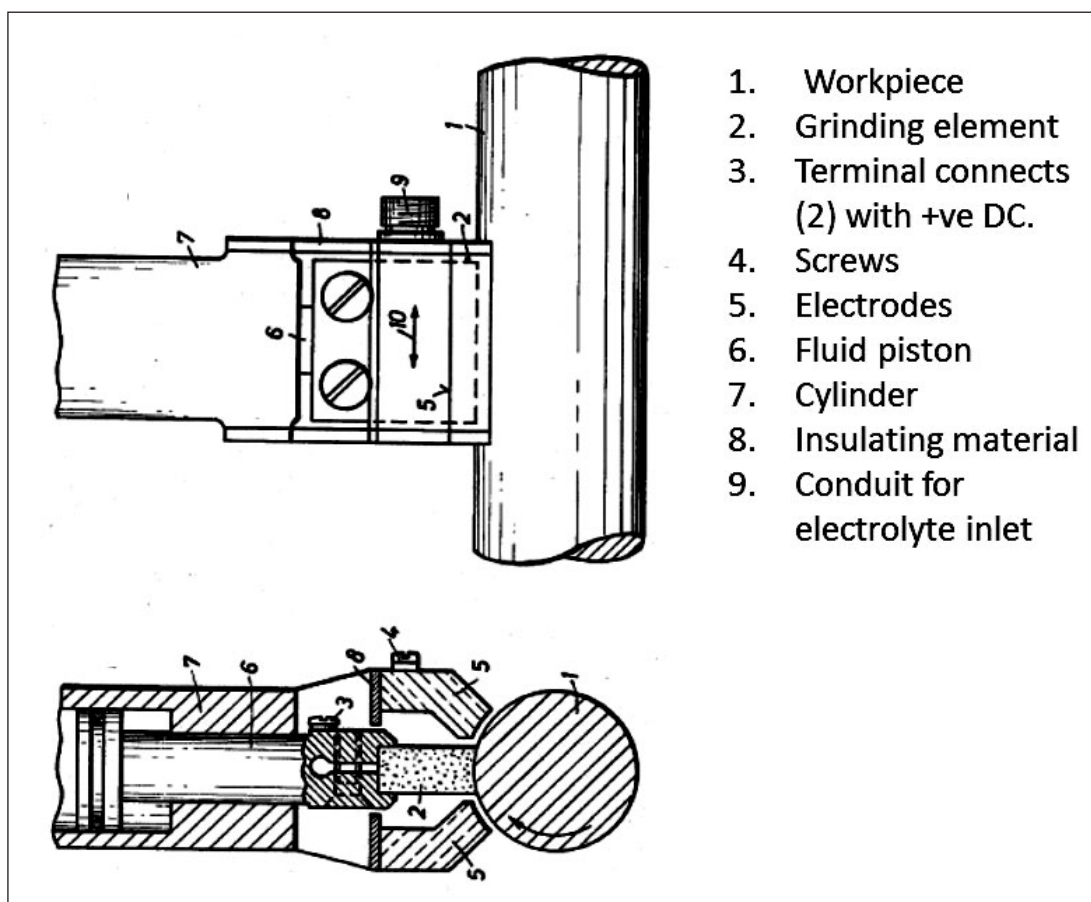
surface roughness improvement. Taguchi matrix robust design is applied for the experimental study of seven three level process input parameters and three prospective second order interactions. He concluded that with increasing current intensities, increased PIRa (Percentage improvement in surface roughness) observed. To achieve better PICyl (percentage improvement in cylindricity), a suitable speed ratio should be employed along with higher level of current and electrolyte concentration. The DIR (diametral increase rate) is higher at the higher level of the current intensity and speed ratio. Electrolyte flow rate is found to be quite insignificant. The effect of temperature is not so predominant in ECH. Increased stick out pressure provides an efficient scrubbing action. Coarser grits are more effective than fine grits.

Dubey et al. [1] analyzed the surface micro profile and correcting out of roundness in ECH of internal cylinder of ASTM-35 (C.I.) material. They found that individual effects of electrolytic parameters is less influential, while the mechanical honing related parameters and interactions are important for macro geometrical error correction. The rotary to reciprocating speed ratio, stick-



1. Electrolyte settling tank
2. Flow control valve
3. 1<sup>st</sup> stage filter-cum-magnetic separator
4. Electrolyte storage tank
5. Temperature control system
6. Stainless steel electrolyte supply pump
7. Pressure gauge
8. Flow meter
9. 2<sup>nd</sup> stage filter-cum-magnetic separator
10. Mist collector
11. DC power supply
12. Carbon brush-slip ring assembly
13. Copper connector
14. Seal hub
15. Hydraulic-cum-mechanical seal body
16. Tool body
17. Abrasive honing sticks
18. Workpiece
19. Electrolyte exit holes
20. Work chamber
21. Fixture-cum-electrolyte inlet sleeve

Fig 2. Electrochemical Honing set-up



1. Workpiece
2. Grinding element
3. Terminal connects (2) with +ve DC.
4. Screws
5. Electrodes
6. Fluid piston
7. Cylinder
8. Insulating material
9. Conduit for electrolyte inlet

Fig 3. Electrolytically Honing of cylinder Surface

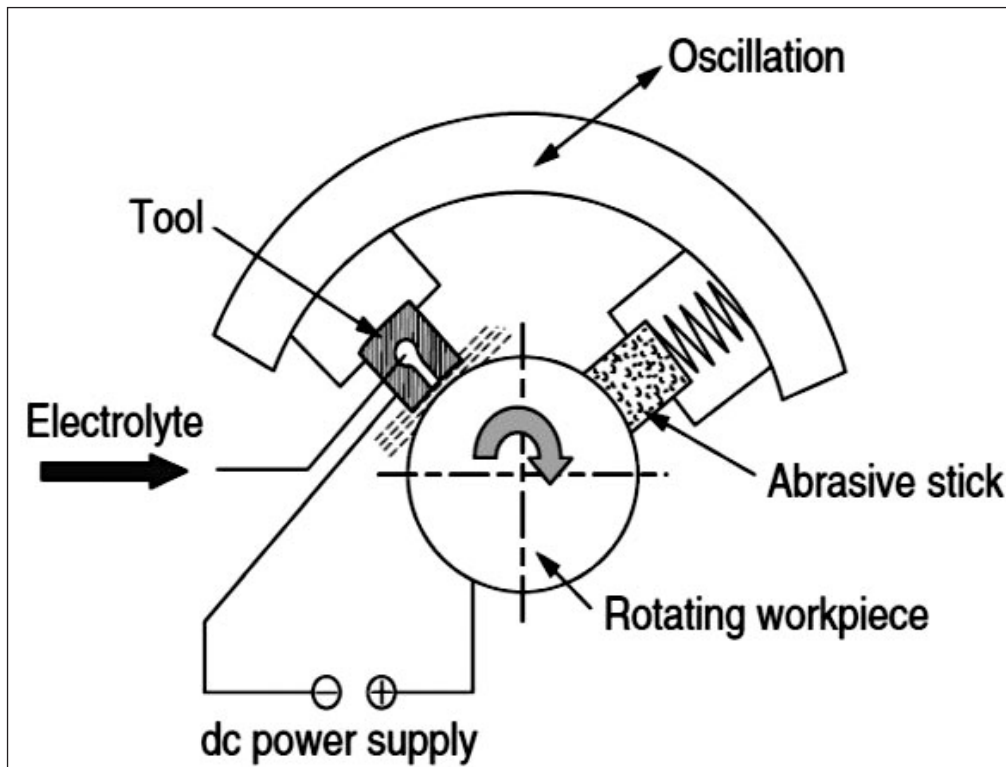


Fig 4

out pressure, grit size, interaction of current & electrolyte concentration, interaction of electrolyte concentration & speed ratio have significant influence on the percentage improvement in out-of-roundness. Electrolyte flow rate has less influence. Coarser grit size provides improved micro-process performance characteristics.

Dubey [14] mentioned three approaches: utility-based Taguchi approach, Taguchi-RBFNN-DF-GA (Radial basis function neural network-Desirability function-Genetic algorithm) strategy and GA-tuned fuzzy Taguchi inference application, which can be effectively employed for process modeling and multi-performance optimization. The utility-based Taguchi approach is easier to implement, provide user flexibility and accommodate the factorial interactions, but basically is an off-line technique. The Taguchi-RBFNN-GA and GA-tuned FIS (Fuzzy inference system) based strategies can be used as on-line multi-performance optimization and process control tools. However, these techniques are computationally demanding.

Radwan et al. [15] studied selective parameters influencing surface roughness and metal removal rate of internal cylinders produced by ECH. He found that  $\text{NaNO}_3$  gives improved result than  $\text{NaCl}$  for better surface roughness and material

removal rate for steel St37 workpiece. They also found increasing the electrolyte concentration, increases material removal rate. Increasing the tool rotational speed improves the average surface roughness. Increasing the applied current improves the average surface roughness.

### 3.3 ECH of External surface of cylinders

Wieck [16] patented an apparatus for electrolytically honing the exterior surface of a cylindrical workpiece. The apparatus has a set up for rotating and advancing the workpiece in axial direction through the apparatus. The working chamber consists of a counter electrode means and discharge channel. This reciprocates inside the apparatus parallel to the workpiece axis (Fig. 3) He described three designs of the apparatus.

Youssef [17] studied electrochemical dissolution with mechanical scrubbing. He used a separate cathodic tool electrode (Fig.4) to get higher stock removal rates. He also suggested a diamond abrasive stick with metallic bond (Fig.5) in his experiment on electrolytic superfinishing of sintered carbide.

Wei et al. [5] claimed that geometric inaccuracy of workpiece can be corrected by ECH by fully utilizing the protective ability of oxide film on the surface



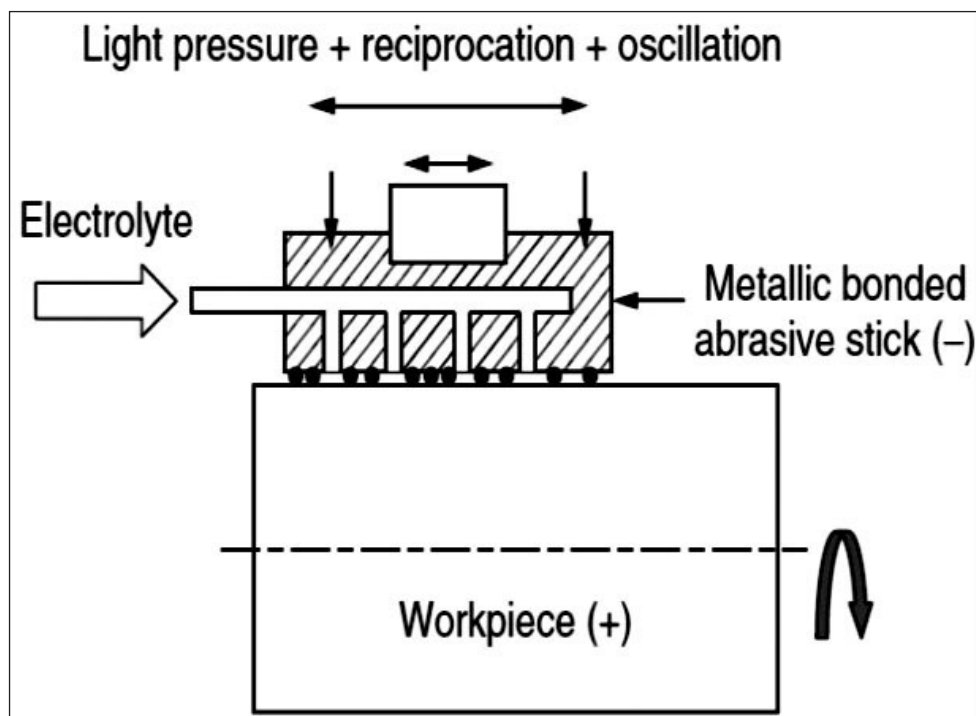


Fig 5

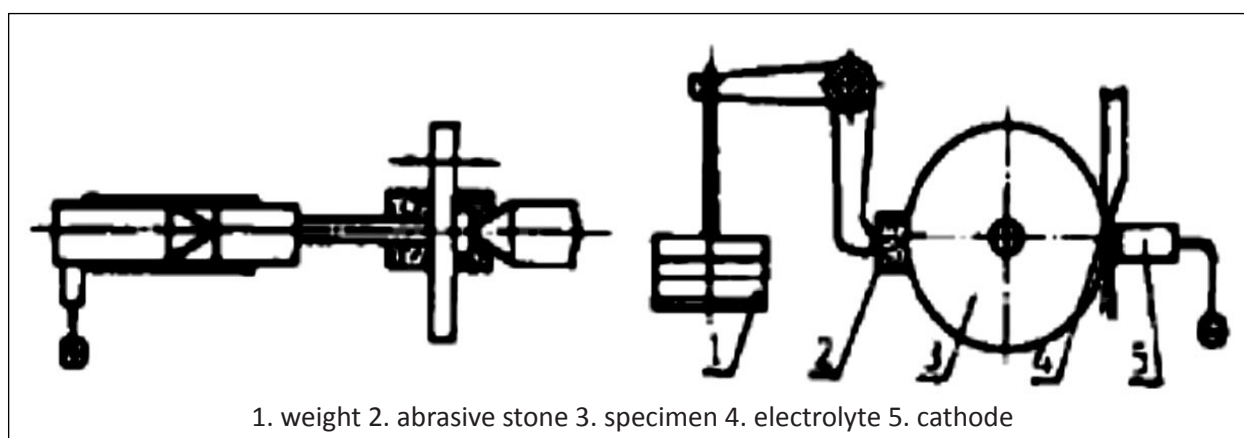


Fig 6

and with proper mechanical scrubbing action. A small lathe is converted for the experiment (Fig. 6). It is found that without mechanical scrubbing, the current density is decreased by 20% and the MRR by 50%. Pits of 3 mm diameter are also found without scrubbing. A formula for practical stock allowance for ECH is also derived.

#### 4. APPLICATIONS

ECH can supersede conventional machining and conventional superfinishing operations in difficult-to-machine conducting materials such as Titanium alloys, Inconel, superalloys etc. High surface finish ( $0.05\mu\text{m}$ ) and tolerance within  $\pm 0.002$  mm can be achieved [1]. No heat generation, no

thermal distortion, no burr components are found in ECH. It can correct geometrical inaccuracies on cylindrical workpieces such as waviness, out-of roundness, axis-distortion, taper hole, bell mouth hole, barrel shaped hole with very less time showing higher productivity.

In industries like aerospace, automobile, power generation, petrochemical, ECH is an ideal choice for high precision equipment made of very hard, tough materials. The applied area may cover internal cylinder, gear, gun barrel, shaft, connecting rod of internal combustion engine, engine blades and fuel control accessories of aircraft, rotating control rod and tail rotor shaft of helicopters etc.

## 5. CONCLUSION

For high speed rotating components of critical applications, the surface finish and geometrical accuracy play a vital role for reliability during operation and increasing the life cycle of the components. These are often made of difficult-to-machine hard and tough conducting materials. So Electrochemical honing can be an impeccable choice for the machining and to get surface finish in the range of superfinishing with higher productivity compared to conventional methods. Therefore series of experiments are needed to establish concrete relationship between process parameters and performance characteristics for different materials during electrochemical honing process.

## 6. REFERENCE

1. Dubey, AK; Shan, HS; Jain, NK: Analysis of surface roughness and out-of-roundness in the electro-chemical honing of internal cylinders, 'International Journal of Advance Manufacturing Technology', vol.38, 2008, 491–500
2. El-Hofy, Hassan: Advanced Machining Processes -Nontraditional and hybrid machining processes, McGraw-Hill, United States of America, 2005
3. Rao, PN: Manufacturing Technology, McGraw-Hill, New Delhi, 2013
4. Jain, NK; Naik, LR; Dubey, AK; Shan, HS: State-of-art-review of electrochemical honing of internal cylinders and gears, 'Proceedings of the Institution of Mechanical Engineers Part B: Journal of Engineering Manufacture', I.223,2009, 665-681
5. Wei, G; Wu, M; Chen, C: An investigation into the ability of correcting error in ECH, 'CIRP Annals-Manufacturing Technology', vol.35, no. 1,1986, 125-127
6. Randlett, EA Jr; Ellis, MP: Electrochemical honing, 'American Society of Tools and Manufacturing Engineers', Technical Paper, MR67-648, 1967, 1-13
7. Budzynski, AF: Electrochemical honing machine, 'Polish Technical Review', 12, 1978, 2-3
8. Budzynski, AF: Theoretical principles and technical factors of electrochemical honing, 'International Symposium on Electro machining', ISEM-6 Krakow, 1980.
9. Budzynski, AF: Research on optimization of the process of electrochemical honing (ECH), 'International Symposium on Electro machining', ISEM-7 Birmingham, 1983, 355–371
10. Budzynski, AF: Theoretical analysis and experimental investigations of the possibility of shaping rotating cylinder surface by ECH, 'International Symposium on Electro machining', ISEM-11, Lausanne, 1995, 567-576.
11. Kitaev, YV: Electrochemical honing equipment, 'Soviet Engineering arch', vol.5, no.6, 1985, 70-71
12. Fasil,T: Parametric optimization of electrochemical honing, M Tech. Dissertation, Mechanical and Industrial Engineering Department, I.I.T. Roorkee, 2004
13. Dubey, AK: Experimental investigations on electrochemical honing, 'Proceedings of the Institution of Mechanical Engineers Part B: Journal of Engineering Manufacture', vol.222, 2008, 413–426
14. Dubey, AK: Multi-performance modeling and optimization control strategies for electro-chemical honing: a critical evaluation, 'International Journal of Advance Manufacturing Technology', 2008, available at <http://link.springer.com/article/10.1007/s00170-008-1477-6>, accessed on 12-10-14.
15. Radwan, N; Kohail, A; Abbas, S; Mousa I: Study of Selective Parameters Influencing Surface Roghness and Metal Removal Rate of Internal Cylinders Produced By ECH, available at [http://www1.mans.edu.eg/faceng/Journal/Abt/2007/Sep2007\\_M1.pdf](http://www1.mans.edu.eg/faceng/Journal/Abt/2007/Sep2007_M1.pdf), accessed on 26-08-2014.
16. Wieck, K: Apparatus for electrolytically honing the exterior surface of a cylindrical workpiece, 'United States Pat42784, 1969.
17. Youssef, HA: Electrolytic Superfinishing of Sintered Carbides, 'Faculty of Engineering Bulletin', Alexandria University, X, 1971, 209-231.
18. Misra, JP; Jain PK; Dwivedi DK; Mehta NK: Study of Time Dependent Behaviour of ECH of Bevel Gears, 'International Conference on Design and Manufacturing', Procedia Engineering, vol. 64, 2013, 1259-1266.
19. Misra, JP; Jain, PK; Dwivedi, DK; Mehta, NK: Mixture D-Optimal Design of Electrolyte Composition in ECH of Bevel Gears, 'Advanced Materials Research', vol. 685, 2013, 347-351.
20. Singh, H: Experimental investigation of precision finishing of spur gears by pulsed-electrochemical honing process, M Tech. Dissertation, Mechanical and Industrial Engineering Department, I.I.T. Roorkee, 2010.
21. Singh, H; Jain PK: Remanufacturing with ECH-A Concept, '24th DAAAM International Symposium on Intelligent Manufacturing and Automation', Procedia Engineering, vol. 64, 2014, 1100-1104 ■