Advanced Manufacturing Processes (AMPs)

Electrochemical Honing

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Chapter Description

- Aims
  - To provide and insight on Electrochemical Honing
  - To provide details on why we need ECH and its characteristics
- Expected Outcomes
  - Learner will be able to know about ECH
  - Learner will be able to identify role of ECH in todays sceneries
- Other related Information
  - Student must have some basic idea of conventional manufacturing and Finishing Processes
  - Student must have some fundamentals on materials

- References

  - **Sunil Pathak** and N.K. Jain (**2017**) "Critical review of Electrochemical Honing (ECH): sustainable and alternative gear finishing process. Part 1: conventional processes and introduction to ECH" **Transaction the Institute of Metal Finishing: The International Journal of Surface Engineering and Coating**, 95(3):147-157.
  - **Sunil Pathak** and N.K. Jain (**2017**) "Critical review of electrochemical honing: sustainable and alternative gear finishing process. Part 2: effects of various process parameters on surface characteristics and material removal rate" **Transaction the Institute of Metal Finishing: The International Journal of Surface Engineering and Coating**, (DOI:10.1080/00202967.2017.1338401)

Introduction to ECH

- Material removal in ECH is based on a controlled anodic dissolution of workpiece material using a cathodic tool in an electrolytic cell. Generally, a low DC voltage in the range of 8–30 V is applied between anode and cathode separated by a very small value of IEG (usually in the range of 0.1-1.0 mm) which is maintained by the specially designed cathode tool. Current density of the order of 10–100 A/cm^2 and volumetric MRR in the range of 0.1-1,000 mm^3/min are achieved.
- Electrolyte should be such that the material removed from the workpiece must not deposit on cathode tool. Products of electrochemical reaction are flushed away from the IEG using an aqueous solution of the salt-based electrolyte such as NaCl, $NaClO_3$, $NaNO_3$ or their combination supplied through the IEG at a flow rate in the range of 10-40 lpm. This helps in maintaining the clean environment in IEG thus helping electrochemical dissolution to continue.
- The electrolyte flow also takes away the heat generated due to passage of current and possibly due to electrochemical reactions. A passivating layer of metal oxide is generated on the workpiece due to evolution of oxygen at anode.
- It prohibits its further dissolution. Thickness of this protective layer is more at valleys as compared to that on the peaks. The honing tool selectively removes this passivating layer by remaining in continuous contact with the workpiece enabling electrolytic dissolution and mechanical honing to take place simultaneously.

Parameters that affect the ECH process performance.

Parameters related to ECM	Parameters related to mechanical honing	Parameters related to workpiece and tooling
➢ Power supply:	➢ Speed of rotation	➢ Electrochemical properties of workpiece
➢ Current	➢ Speed of translation	➢ Mechanical properties of workpiece
➢ Voltage	➢ Feed mechanism	➢ Tool design
➢ Pulse-on time	➢ Abrasive	
➢ Pulse-off time	• Type	
➢ Duty cycle	• Grit size	
➢ Electrolyte	• Grain size	
• Type		
• Composition		
• Concentration		
• Pressure		
• Temperature		
➢ Inter-electrode gap		

ECH Equipment

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ECH equipment consists of five subsystems namely

(a) DC power supply system;

(b) Electrolyte supply and cleaning system;

(c) Specially designed cathode and honing tool;

(d) System for providing the required relative motion between the workpiece, cathode and honing tool; and

(e) Finishing chamber for housing and holding workpiece, cathode and honing tool.

(f) Out of these subsystems details of DC power supply system and electrolyte supply and cleaning system are similar to those used in the ECM process.

Finishing of internal cylinders by ECH

- The tool used for finishing of internal cylinders by ECH is shown in Fig.
- It combines cathode and honing tool in a single unit.
- It consists of a Teflon shaft over which a hollow stainless steel sleeve is fitted.
- It has even number of equally spaced and radially outward protruding honing sticks on its periphery.
- These sticks are spring controlled which help in adjusting the required honing pressure.
- These honing sticks act as insulator and amount by which they protrude radially outward determines the IEG between the cylindrical workpiece and the cathode tool.
- Honing sticks preferentially remove the non-conductive passive layer of metal oxide from the high spots to correct errors or deviations in geometry of the cylindrical workpiece.
- The electrolyte enters the tool body via a sliding inlet sleeve from which it exits into the IEG through several rows of small holes in the tool body. The electrolyte exits from the top and bottom of the bore.
- Current is supplied to the tool through a slip-ring copper brush assembly.
- The tool is provided a precisely controlled combination of rotation and reciprocation simultaneously. Rotary motion is provided by a speed controlled DC servomotor, while reciprocating motion by a microprocessor programmed stepper motor

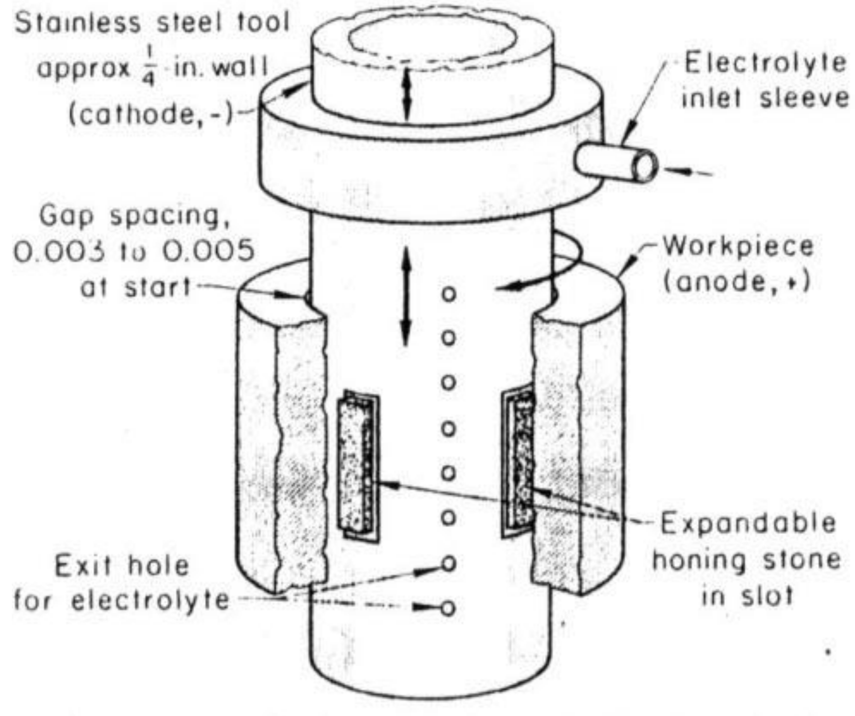


Fig. (a) Schematic and (b) photograph of a typical tool for finishing internal cylinders by ECH

Finishing of gears by ECH

For *spur gear finishing* by ECH (Fig.), a helical gear is made as honing gear, it can either be an abrasive impregnated gear or a gear having hardness more than the workpiece gear. It is mounted on a floating stock to ensure dual flank contact between the honing and workpiece gear. The honing gear is mounted in such a way having cross-axis arrangement with the workpiece gear so as to reduce the tooth surface contact and the pressure required for finishing

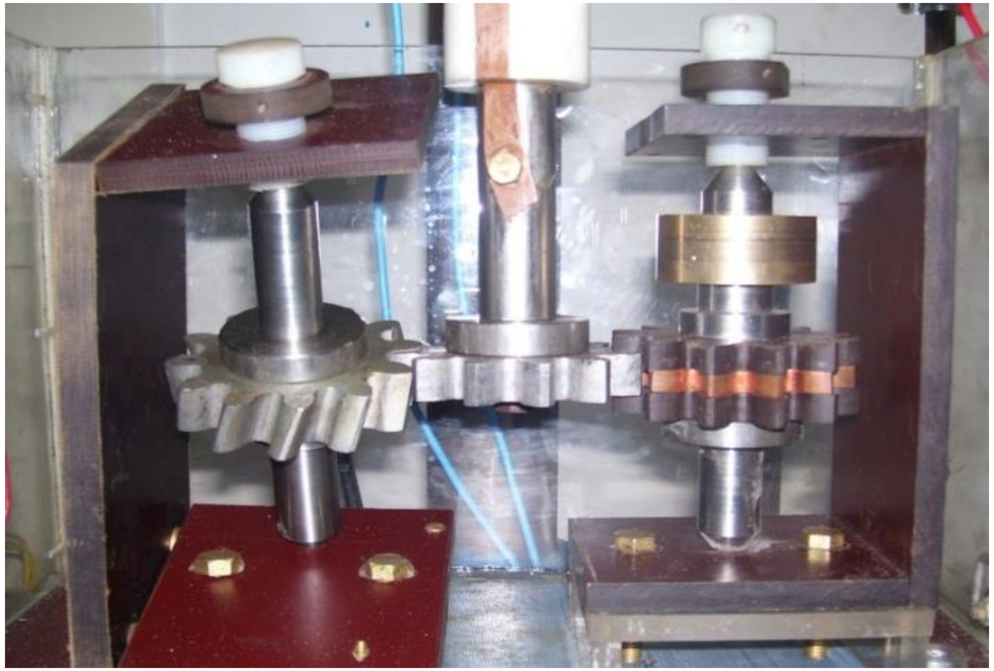


Fig: Photographs of machining chamber for high quality finishing

Helical gear finishing by ECH (Fig. a) does not require the cross-axis arrangement because honing and cathode gears have opposite helix angle that of the workpiece gear i.e. if workpiece gear is right-handed helical gear then cathode and honing gears will be left-handed and vice-versa.

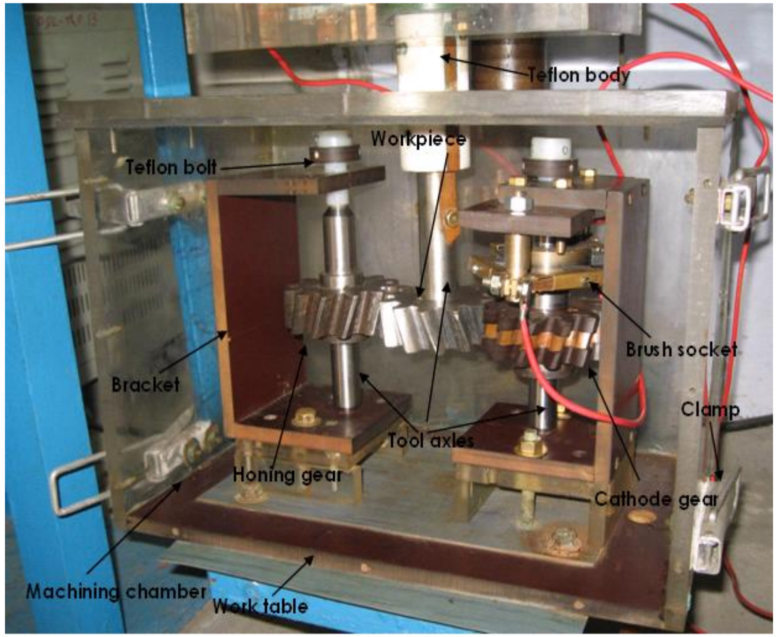
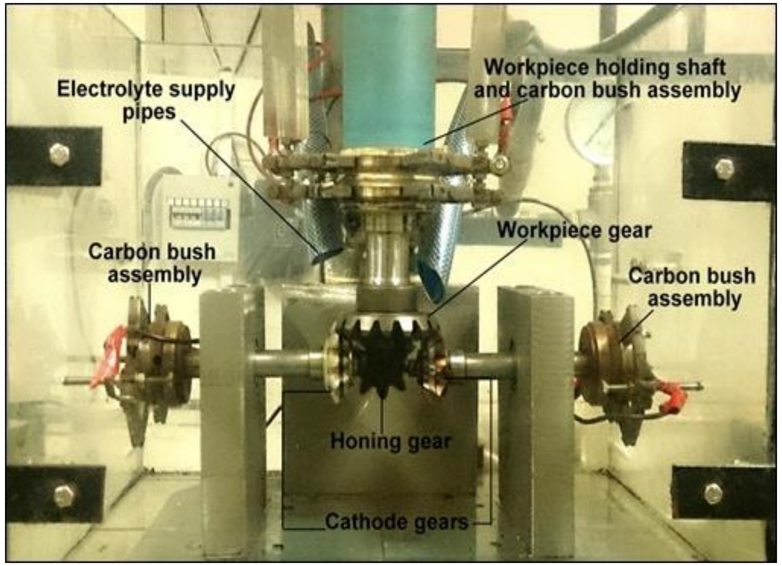
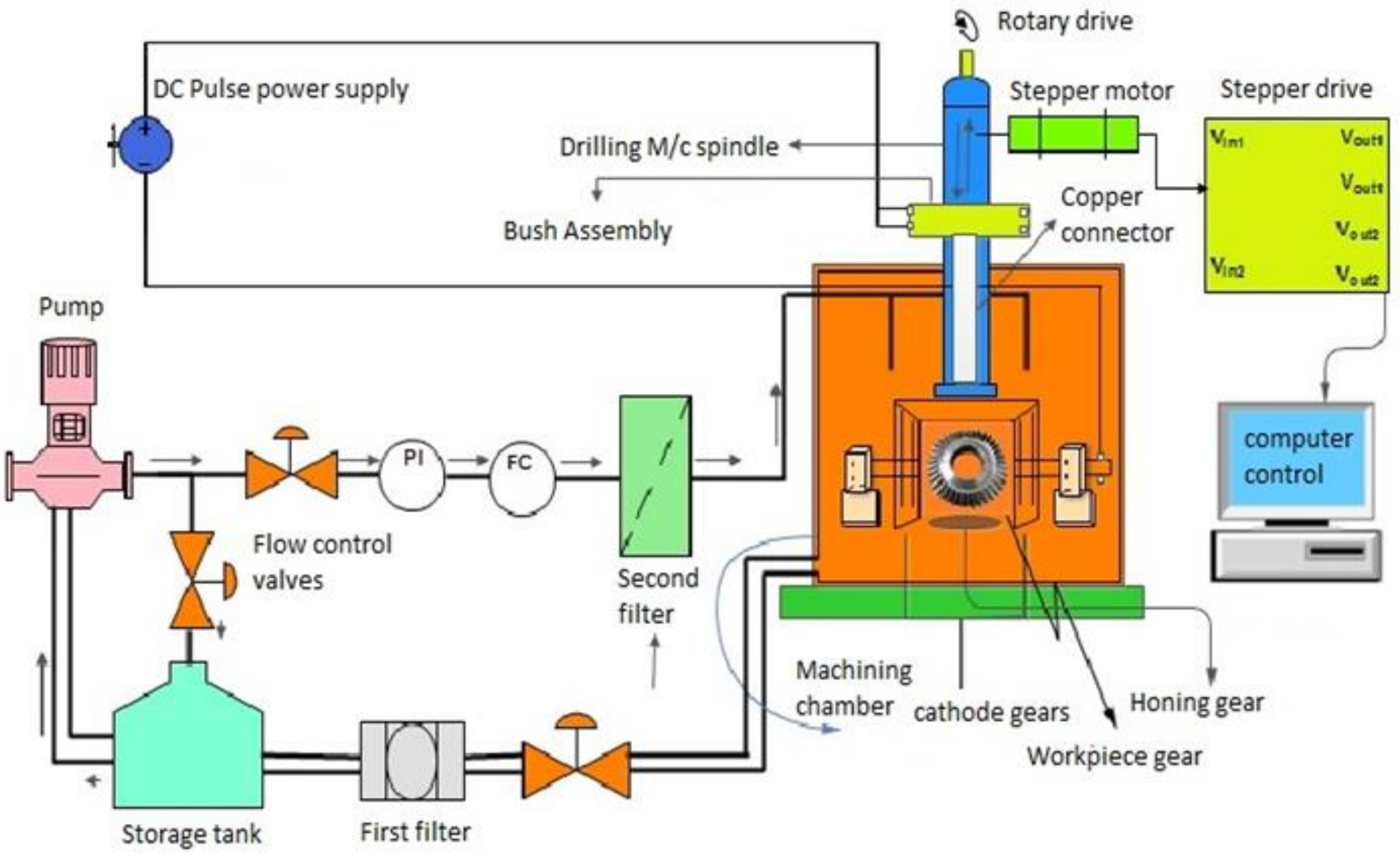


Figure b depicts the photograph of finishing chamber developed implementing the concept of the twin complementary cathode gears for bevel gear finishing by ECH. The tool is provided a precisely controlled rotation by a speed controlled DC servo motor, while reciprocating motion to the workpiece gear holding shaft for its proper engagement and disengagement with the ECH tools is provided by a microprocessor programmed stepper motor.

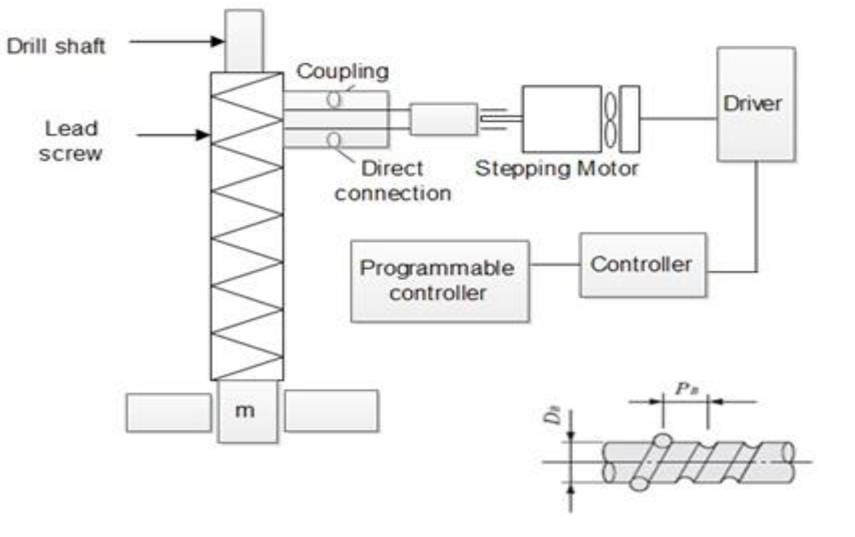


Setup for ECH of Conical gear



Major Components of Experimental Setup:

1. Pulse power supply system
2. Electrolyte and its supply system
3. Tool and tool motion system
4. Stepper motors and its control system
5. Work holding and positioning system
6. Frame and housing



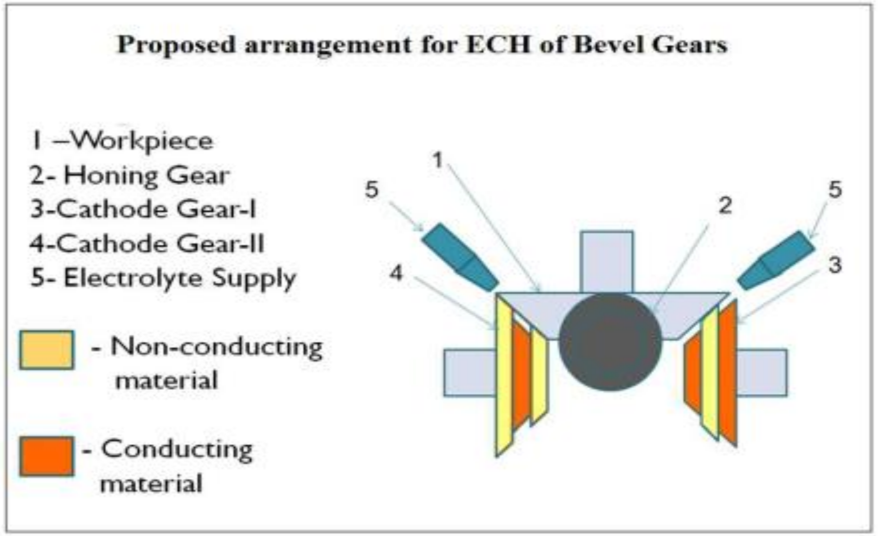
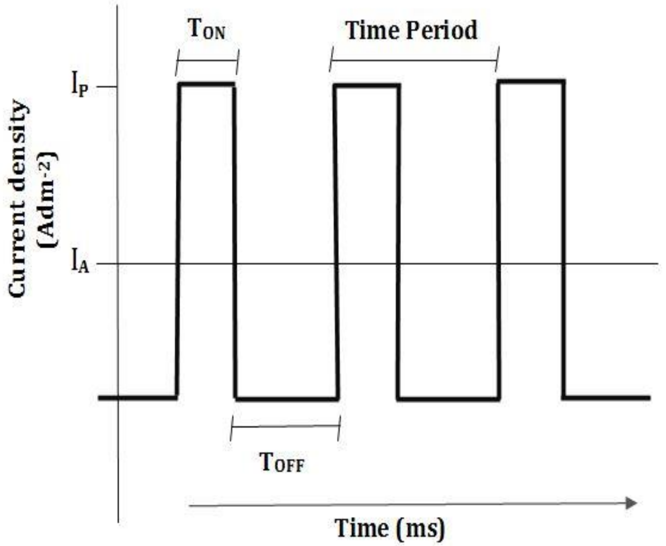


Fig. Schematic of tool arrangement.

Reference: Phd thesis Shaikh javed Habib, Sep 2013

Specification of pulse power supply

- Programmable High Current Power Supply associated with Pulse Power Supply Controller (Motoron semiconductor Corporation, Delhi)
- The Pulse power unit consists of 0-100V/100A DC.
- Space and mark ratio of 1:3 to 1:9
- Feasible values for Ton (5 microseconds to 10 ms)
- Feasible values for Toff (1ms to 1000 ms)
- Voltage/current control accuracy 99.9% of set point.
- Operating frequency 5.0-200 KHz
- Repeatability 100 percent



Advantages

- Material of any hardness (but electrically conducting) can be finished by ECH.
- ECH can achieve surface roughness up to 50 nm and tolerances up to ± 0.002 mm.
- It produces surfaces with distinct cross-hatch lay pattern which is very useful for lubricating oil retention, surfaces with compressive residual stresses required for the components subjected to cyclic loading, and completely stress-free surfaces.
- ECH not only produces high quality surface finish and surface integrity but also has ability to correct errors/deviations in geometry/shape such as out-of-roundness or circularity, taper, bell-mouthhole, barrel-shaped hole, axial distortion, boring tool marks, etc. for cylindrical surfaces and ability to correct form errors (i.e. deviations in lead and profile) and location errors (i.e. pitch deviations and runout) for cylindrical and conical gears.
- It takes less finishing time as compared to ECM and mechanical honing. ECH can finish materials up to 5–10 times faster than mechanical honing and four times faster than internal grinding. Gain is more pronounced for higher material hardness;
- Very less amount of heat thus making it suitable for the processing of parts those are susceptible to heat distortions.
- ECH automatically deburrs the work surface.
- Increased life of abrasive sticks/tool due to very limited role of mechanical honing.
- There is less distortion while finishing thin-walled tubes due to less pressure required between work surface and the honing tool.
- As a by-product, sharp or burred edges of a cross-holes or other intersections which break into the bore are automatically deburred as the main hole is being finished by ECH.

Limitations

- It can be used for finishing electrically conductive materials only.
- It is more costly than the mechanical honing due to its electrical, fluid handling elements, need for corrosion protection, costly tooling and longer setup time. This makes ECH more economical for longer production runs than for tool room and job-shop conditions.
- Difficult to finish the blind holes.
- ECH cannot correct location of hole or perpendicularity.

Applications

- ECH can be used to finish the various hard to finish materials such as cast tool steels, high-alloy steels, carbide, titanium alloys, Incoloy, stainless steel, Inconel, and gun steels.
- ECH is an ideal choice for superfinishing, improving the surface integrity, and increasing the service life of the critical components such as internal cylinders, transmission gears, carbide bushings and sleeves, rollers, petrochemical reactors, molds and dies, gun barrels, pressure vessels, etc. which are made of very hard and/or tough, wear-resistant materials, most of which are susceptible to heat distortions.
- ECH is widely used in automobile, avionics, petrochemical, power generation, and fluid power industries.
- It has been used for bore size ranging from 9.5 to 300 mm and length up to 600 mm.

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