EXPERIMENT-01

1. Aim

To study the working principle of Electrochemical Machining (ECM), prepare the workpiece setup, and determine the Material Removal Rate (MRR) under varying process parameters.

2. Theoretical Background

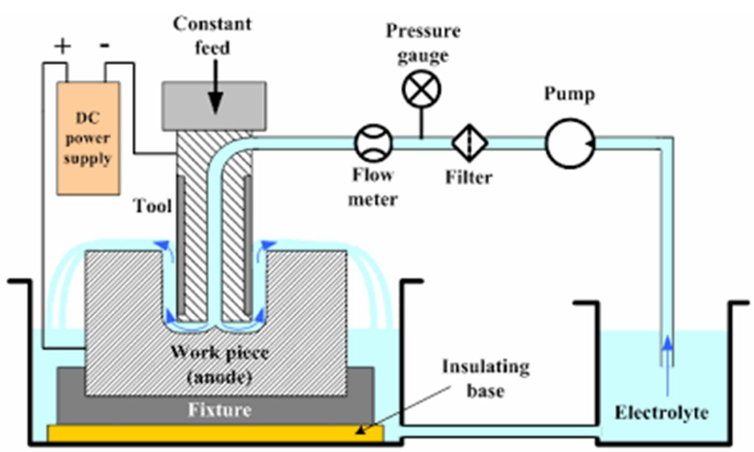
In ECM, the workpiece is made the **Anode (+)** and the pre-shaped tool is made the **Cathode (-)**. A high-velocity electrolyte solution (typically aqueous NaCl or NaNO_3) is pumped through the tiny inter-electrode gap (IEG) between them. When a low-voltage, high-density direct current (DC) is applied, the metal ions detach from the workpiece atom-by-atom.

The theoretical material removal rate is governed by Faraday's first and second laws:

MRR= $\frac{A.I}{Z.F}$

Where:

- A = Atomic weight of the workpiece material (g/mol)
- I = Current passed through the circuit (Amperes)
- z = Valency of dissolution of the workpiece
- F = Faraday's constant (96,500 Coulombs/mol})



Schematic Layout of an ECM System

3. Equipment & Materials Required

- **ECM Machine Setup:** Enclosed machining chamber, variable DC power supply (0–30 V, up to 500 A), electrolyte circulation pump, and an automatic tool feed system.
- **Work piece (Anode):** Mild steel, stainless steel, or copper block (50 mm X50 mm 10 mm).
- **Tool (Cathode):** Brass or copper electrode shaped to the desired cavity profile (must have internal or external insulation to prevent stray cutting).
- **Electrolyte Solution:** 10–20% weight-by-volume aqueous Sodium Chloride (NaCl) or Sodium Nitrate ($NaNO_3$) dissolved in distilled water.
- **Instruments:** Digital weigh scale (0.001 g accuracy), vernier caliper, stopwatch, and a pH meter.

4. Working Procedure

1.Clean and Weigh the Workpiece: Initial Prep.

Thoroughly degrease the workpiece using acetone to remove surface oil and oxides. Measure its initial mass (W_1) using the digital balance.

2.Mask Stray Cut Areas: Insulation.

Apply a non-conductive masking agent (like epoxy resin or specialized vinyl tape) to areas of the workpiece where material removal is undesirable. This prevents stray current dissolution caused by fringe electrical fields.

3.Prepare and Test the Electrolyte: Fluid Check.

Mix the electrolyte in the reservoir tank. Use a hydrometer to check concentration and a pH meter to ensure the solution is neutral to slightly alkaline (pH 7 to 8.5) to maintain stable conductivity.

4.Mount Tool and Workpiece: Fixing.

Secure the workpiece into the fixture inside the machining chamber. Connect the **positive terminal** of the DC supply to the workpiece and the **negative terminal** to the tool holder. Ensure the tool and workpiece are perfectly parallel.

5.Establish Inter-Electrode Gap & Flow: Fluid On.

Set the initial Inter-Electrode Gap (IEG) using slip gauges (typically **0.1 mm to 0.5 mm**). Start the electrolyte pump first and adjust the pressure regulator to achieve a high-velocity, uniform flow through the gap to flush away metal hydroxides.

6.Energize and Feed: Machining.

Close the safety enclosure. Turn on the DC power supply, set the voltage (e.g., 12 V), and turn on the automatic tool feed motor to match the expected linear material removal rate. Machining will begin without any physical tool contact.

5. Observation & Data Collection Table

Trial No.	Voltage (V)	Initial Weight W1 (g)	Final Weight W2 (g)	Machining Time t (min)	Avg Current I (A)	Exp. MRR ($\Delta W/t$)
1	10 V			5.0		
2	15 V			5.0		
3	20 V			5.0		

6. Safety Precautions

- **Hydrogen Gas Hazard:** ECM generates hydrogen gas at the cathode. Ensure the machine exhaust system is active to prevent explosive gas accumulation.
- **Never Short-Circuit:** The tool must never touch the workpiece while the power supply is on. Modern ECMs feature rapid short-circuit protection circuits that cut power within microseconds to prevent tool destruction.
- **Corrosion Protection:** Wash down all machine components with clean water after use; electrolyte salt deposits are highly corrosive.

EXPERIMENT-02

1. Aim

To study the working principle of an Electrical Discharge Machine (EDM), understand its constructional features, and perform die-sinking operations on a given workpiece using a copper/brass electrode.

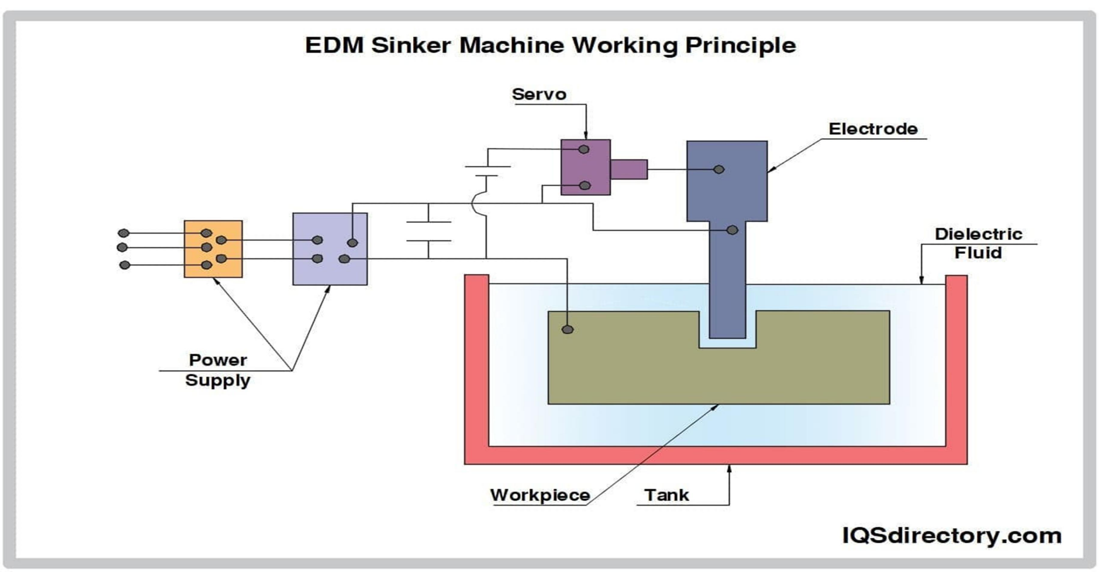
2. Operational Principle

Electrical Discharge Machining (EDM), commonly known as **Spark Erosion Machining**, is a non-traditional thermal process. It removes material from a conductive workpiece using a series of rapidly recurring electrical spark discharges between an **electrode (the tool)** and the **workpiece**.

Both the tool and the workpiece are completely submerged in a non-conducting liquid called a **dielectric fluid** (typically EDM oil or kerosene). A small, precise gap known as the **spark gap** (0.01 mm to 0.5 mm) is maintained between them using an automatic servo system.

When a high DC voltage is applied across the gap, the dielectric fluid breaks down and ionizes, turning into an electrically conductive plasma channel. A powerful spark jumps across the gap, generating localized temperatures between $\mathbf{8000^0C}$ **and** $\mathbf{12000^0}\boldsymbol{C}$ This extreme heat instantly melts and vaporizes a microscopic speck of metal from the workpiece surface. When the current pulse turns off, the dielectric fluid flushes away the frozen metal droplets (debris), leaving behind a tiny crater. This cycle repeats thousands of times per second, accurately replicating the shape of the tool into the workpiece.

3. Machine System Layout



4. Machine Specifications & Tooling

- **Machine Tool:** CNC or Manual Die-Sinking EDM Machine setup.
- **Workpiece Material:** High-carbon steel, Die steel, or Hardened Alloy blocks.
- **Electrode (Tool):** Highly conductive material like Electrolytic Copper, Brass, or Graphite machined to the target profile.
- **Dielectric Medium:** Commercial-grade EDM oil or Kerosene.
- **Flushing System:** Pressure flushing lines equipped with micro-filters.

5. Machine Setup Procedure

1.Mount and Secure the Workpiece: Preparation.

Clean the workpiece block thoroughly to remove any rust or scales. Clamp it securely to the magnetic or mechanical fixtures inside the dielectric work tank.

2.Fix and Align the Electrode Tool: Alignment.

Mount the copper tool electrode into the tool holder chuck. Use a dial indicator to check that the electrode face is completely parallel and square with the workpiece table surface to ensure uniform depth.

3.Set Spark Gap and Zero the Z-Axis: Zeroing.

Carefully lower the machine head until the electrode gently touches the workpiece surface (electrical touch sensing). Record this position as the zero reference coordinate ($Z = 0$) on the digital readout (DRO).

4.Fill Tank and Start Dielectric Pump: Submerging.

Close the work tank door securely. Turn on the fluid pump to fill the tank until the dielectric fluid submerges the top surface of the workpiece by at least **50 mm** to safely prevent fire hazards. Position the flushing nozzles directly at the cutting zone.

5.Set Machine Electrical Parameters: Control Panel.

Set the targeted discharge parameters on the machine control console based on the roughing or finishing requirement:

- **Discharge Current (Ip): 5 to 20 Amps**
- **Pulse-On Time (Ton): 50 to 200 microseconds**
- **Pulse-Off Time (Toff): 10 to 50 microseconds**

6.Start the Sparking Cycle: Machining.

Turn on the pulse power supply and switch on the automatic servo feed. The machine will lower the tool automatically, maintain the spark gap, and erode the metal. Monitor the machine stability until the target cavity depth is successfully cut.

6. Observation & Experimental Data Table

Trial No.	Current (Ip) (Amps)	Pulse-On Time (Ton) (µs)	Pulse-Off Time (Toff) (µs)	Initial Machining Depth (mm)	Surface Finish Grade (Rough / Smooth)
1	4.0	50	20	5.0	Very Smooth (Fine Finish)
2	10.0	100	30	5.0	Medium Finish
3	20.0	250	50	5.0	Very Rough (High Metal Removal Rate)

7. Safety Precautions

- **Fire Prevention:** Kerosene and EDM oils are highly flammable. **Never** initiate sparking before the workpiece and tool are completely submerged under the fluid. A low oil level will cause immediate fires from open sparking.
- **Avoid Touching Live Elements:** The pulse power generator outputs high open-circuit voltages. Keep hands out of the fluid tank while the sparking sequence is actively running.
- **Effective Flushing:** Ensure clean, filtered dielectric fluid constantly streams through the spark gap. Poor flushing causes metal debris to accumulate in the gap, leading to localized "arcing" which permanently damages both the tool and your job.

EXPERIMENT-03

1. Aim

To study the working principle of an Ultrasonic Welding machine, perform the machine setup, and join two overlapping sheet specimens to make a lap joint.

2. Working Principle

Ultrasonic welding is a **solid-state** joining process, which means **no melting** of the metal takes place.

The process relies on a combination of static clamping force and high-frequency acoustic vibrations. A solid-state power generator converts standard electrical power (50 Hz) into high-frequency electrical energy (**20 kHz to 40 kHz**). This signal is fed into a **transducer**, which uses piezoelectric crystals to convert the electrical current into microscopic mechanical vibrations.

These vibrations travel through an amplitude-modulating **booster** and exit via a tuned acoustic tool called the **sonotrode (welding horn)**. When the horn clamps down on two overlapping sheet specimens, it vibrates them rapidly parallel to the joint interface against a rigid **anvil**. This high-speed scrubbing action breaks away surface oxides and causes localized plastic deformation at the contact points. Under pressure, the clean atoms diffuse together to form a strong atomic bond in a fraction of a second.

3. Machine System Layout

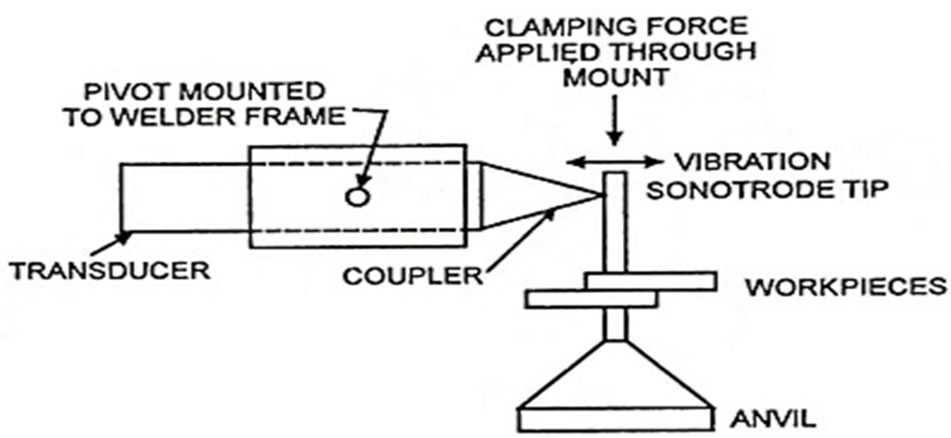


Fig. 6.14. ***Ultrasonic Welding***

4. Tools and Materials Required

- **Ultrasonic Welding Machine:** Press-type setup with integrated pneumatic actuator lines.
- **Workpiece Specimens:** Two Aluminium or Copper sheet strips (100mm X25mm X0.5 mm.
- **Cleaning Solvent:** Acetone or Isopropyl Alcohol with micro-grain wipes.
- **Safety Equipment:** Certified ear defenders and safety glasses.

5. Machine Setup Procedure

1.Clean the Specimen Surfaces : Decontaminating.

Wipe the joint tracking areas of both sheet metal specimens with a cloth dipped in cleaning solvent. This removes stamping oils, grease, and protective waxes that would otherwise damp the frictional vibrations and ruin the bond.

2.Position the Sheets on the Anvil: Loading.

Place the bottom sheet strip firmly inside the anvil nest slot. Lay the top sheet specimen over it, matching your design overlap parameters (e.g., a **20 mm** overlap lap joint configuration).

3.Perform Acoustic Stack Calibration: Tuning Check.

Turn on the power generator and trigger an electronic "Horn Scan" or frequency tune utility on the controller interface. The system identifies and locks onto the exact resonant frequency of the sonotrode.

4.Program Primary Process Parameters: Control Panel.

Input the processing parameters on the digital control screen tailored to your sheet thickness:

- **Weld Time: 0.4 to 0.6 seconds** (The duration the vibration is active).
- **Hold Time: 0.2 seconds** (The time the horn continues to apply static pressure after vibrations cease to let the bond solidify).
- **Pneumatic Air Pressure: 3.5 bar** (The constant clamping force).

5. Execute the Weld Cycle: Joint Firing.

Close the acoustic safety cabinet door. Simultaneously press and hold both green dual-palm safety start buttons. The pneumatic actuator lowers the sonotrode, applies pressure, fires the high-frequency vibrations, holds the part, and automatically retracts.

6. Observation & Experimental Data Table

Trial No.	Material Used	Clamping Pressure (bar)	Weld Time (s)	Hold Time (s)	Visual Inspection & Joint Condition

Trial No.	Material Used	Clamping Pressure (bar)	Weld Time (s)	Hold Time (s)	Visual Inspection & Joint Condition
1	Aluminum	2.0	0.2	0.2	Weak joint; no knurl impression, sheets separate easily.
2	Aluminum	3.5	0.5	0.2	**Strong joint; uniform knurl impression, robust solid-state bond.**
3	Aluminum	5.5	1.2	0.2	Defective joint; horn sheared/cut completely through the sheets.

. Safety Precautions

- **Hearing Protection:** The machine emits a loud, high-pitched acoustic screech during operation. Always wear ear defenders or earplugs to avoid hearing strain.
- **Dual-Palm Controls:** Never attempt to bypass the two-hand start switches. They are critical safety overrides that ensure your hands are completely clear of the crushing zone while the pneumatic actuator head moves down.
- **Avoid Empty Firing: Never** press the cycle buttons if there are no metal sheets loaded between the tools. Allowing the vibrating sonotrode face to contact the steel anvil directly will instantly grind flat the precision knurl patterns and risk shattering the internal transducer crystals.

8. Conclusion

The operating mechanism of the ultrasonic welder was studied and a solid-state lap joint was successfully prepared using the given thin sheet metal specimens. It was verified that weld time and clamping pressure must be balanced precisely to create a high-strength joint without thinning or cutting through the base metal.

9. Conclusion

The constructional working principles of the Electrical Discharge Machine were thoroughly studied. A profile cavity was successfully machined on the given workpiece block. It was observed that increasing the discharge current increases the metal removal rate but results in a rougher surface finish.

EXPERIMENT-04

1. Aim

To study the working principle of a Laser Beam Welding (LBW) machine, understand its constructional systems, and perform a welding operation to successfully join two sheet specimens in a specified design (Lap/Butt joint).

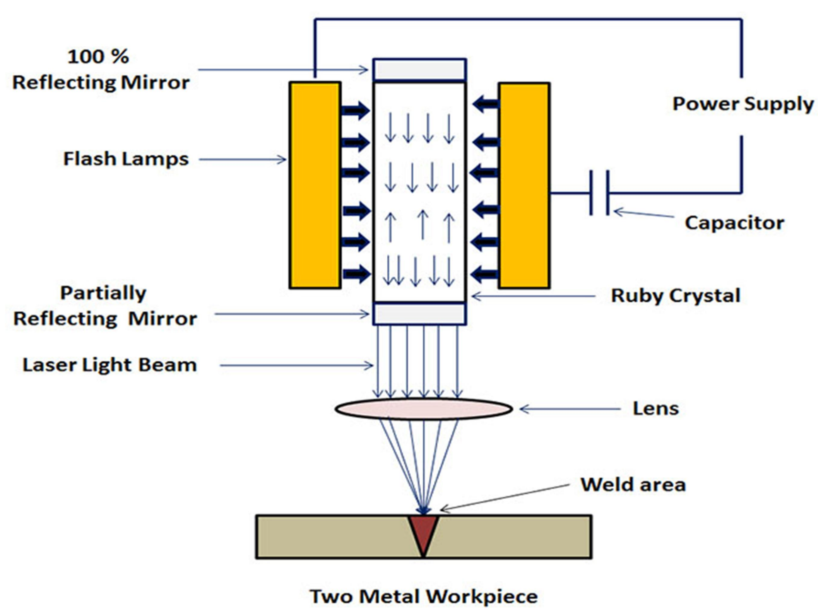
2. Working Principle

Laser Beam Welding (LBW) is an advanced, non-traditional fusion welding process. It uses a highly concentrated, coherent beam of monochromatic light known as a **Laser** (Light Amplification by Stimulated Emission of Radiation) as the primary heat source.

The laser system uses an optical cavity containing a lasing medium (such as an Nd:YAG crystal or a Fiber optic core) stimulated by flash lamps or diodes. The resulting light photons bounce between mirrors, amplifying into a high-energy parallel beam. This raw beam passes through a specialized focusing lens assembly, shrinking the laser diameter down to a microscopic spot size (0.1 mm to 1.0 mm).

When this ultra-dense light beam hits the joint interface of the workpieces, the light energy instantly transforms into intense thermal energy. The temperature rapidly exceeds the melting point of the base metals, forming a narrow, deep molten pool known as a **Keyhole** (a vapor-filled cavity surrounded by molten metal). As the focused laser moves along the seam line, the molten metal flows behind it and solidifies, creating a deep, high-precision weld bead with a minimal heat-affected zone (HAZ) without requiring any filler metal.

3. Machine System Layout



4. Tools and Materials Required

- **Laser Welding Setup:** Industrial Nd:YAG, Fiber, or CO_2 laser welding machine with an integrated CNC linear axis table.
- **Workpiece Materials:** Stainless Steel or Mild Steel sheet strips (100 mmX 25X mmX1.0 mm).
- **Shielding Gas Supply:** High-purity Argon or Helium gas cylinder equipped with a flowmeter regulator.
- **Cleaning Agent:** Acetone solvent spray with anti-static cleaning wipes.
- **Safety Equipment:** Laser protective safety goggles matching the specific laser wavelength (OD 7+), leather welding gloves, and a localized fume extractor hood.

5. Machine set up and Procedure

1.Clean and Align the Workpiece Joint: Surface Prep.

Thoroughly wipe the mating edges of both metal sheets with acetone. Laser welding is highly sensitive to impurities; any grease, rust, or oils trapped in the seam will cause immediate weld defects or porosity.

2.Clamp the Sheets onto the CNC Table: Fixturing.

Position the sheets together securely on the CNC worktable bed based on your chosen design (e.g., tightly abutted for a Butt Joint or overlapped by 15 mm for a Lap Joint). Secure them using heavy toggle clamps to prevent any thermal warping during welding.

3.Adjust the Laser Focal Point Height: Optics Tuning.

Move the laser welding head vertically to place the beam's focal point precisely on the top surface of the workpiece. An out-of-focus beam will widen the laser spot, scattering the energy and failing to melt the metal seam properly.

4.Turn on the Shielding Gas Flow: Atmosphere.

Open the valve on the protective gas cylinder and adjust the flowmeter regulator to **10-15 L/min**. Ensure the nozzle delivers the Argon gas directly over the weld tracking zone to isolate the molten pool from atmospheric oxygen.

5.Input Machine Welding Parameters: Programming.

Enter the designated structural parameters into the CNC operator control unit according to the material specifications:

- **Laser Power: 800 to 1500 Watts**
- **Welding Travel Speed: 15 to 30 mm/s**
- **Pulse Frequency (if applicable): 10 to 50 Hz**

6.Initiate the Laser Weld Program: Execution.

Ensure all lab operators are wearing certified laser safety goggles. Put on the machine enclosure shield, run the CNC alignment simulation trail with the laser turned off, and then activate the laser beam cycle to execute the permanent weld run.

6. Observation & Experimental Data Table

Trial No.	Laser Power (W)	Welding Speed (mm/s)	Shielding Gas Flow (L/min)	Visual Weld Bead Appearance	Penetration & Fusion Quality
1	600	25	12	Dull color, intermittent bead	Poor penetration (Under-welded)
2	1200	20	12	**Bright, uniform, narrow bead**	**Excellent full-depth penetration**
3	1800	10	12	Wide, sagging bead with burn-through	Excessive melting / Heat damage

7. Safety Precautions

- **Ocular Hazards:** The raw and reflected laser beam causes **instant, irreversible blindness** if it hits the eye. Never look directly toward the laser head nozzle while active. Every student inside the workshop must wear wavelength-certified laser safety goggles.
- **Fume Management:** Laser vaporization releases microscopic hazardous metallic particulates and ozone gas. Keep the localized extraction fan active throughout the welding process to draw away fumes.
- **Reflection Hazards:** Never place shiny, highly reflective materials (like unpolished copper or mirrors) loosely inside the work enclosure. Reflections can deflect the laser beam into the room, destroying optical lenses or causing fires.

8. Conclusion

The fundamental principles and operational steps of the Laser Beam Welding system were studied. A high-precision lap/butt joint design was successfully executed on sheet metal plates. It was verified that balancing laser power and travel speed is essential to secure deep weld penetration while avoiding material burn-through.

EXPERIMENT-05

1. Aim

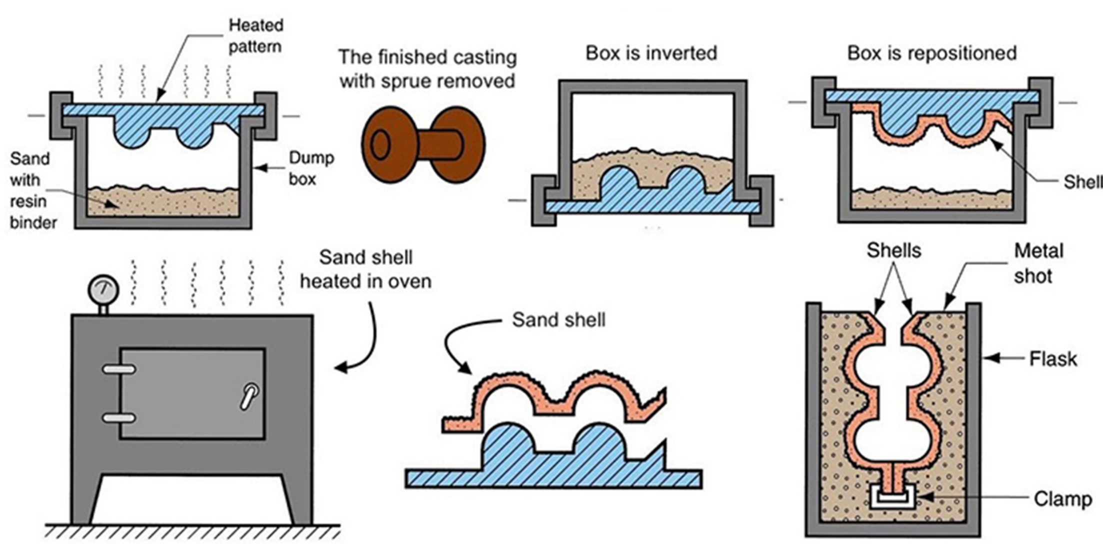
To study the shell molding process and prepare a precision sand shell mold from a heated metal pattern to produce a cast component.

2. Working Principle

Shell molding is a high-precision variation of the sand casting process. Instead of ramming heavy green sand into a large box (flask), this process produces a thin, rigid, biscuit-like sand shell (**5 mm to 10 mm thick**) that acts as the mold cavity.

The process relies completely on a thermal-chemical reaction:

- **The Molding Mixture:** The molding sand is a dry mixture of fine, washed silica sand pre-coated with **3% to 6% thermosetting phenolic resin** (such as phenol-formaldehyde) and a chemical catalyst.
- **Skin Formation:** When this dry sand-resin mixture is dumped over a metal pattern preheated to **200°C–250°C**, the heat melts the resin adjacent to the pattern face. The liquid resin flows between the sand grains and rapidly binds them together, creating a soft, leathery sand skin over the pattern contours within 30 seconds. The unbonded excess sand is turned upside down and cleared out.
- **Curing:** The pattern plate, carrying the soft sand skin, is placed inside a curing oven at **300°C**. The heat causes the resin to fully cross-link and harden into a rock-like, rigid shell structure capable of holding molten metal.



Tools and Materials Required

- **Pattern Equipment:** A split metal pattern plate made from cast iron or aluminum, equipped with manual or mechanical ejector pins.
- **Investment Setup:** A pivoting dump box filled with fine silica sand pre-blended with thermosetting phenolic resin.
- **Heating Equipment:** A temperature-controlled electric curing oven and an infrared laser thermometer.
- **Consumables:** Silicone-based liquid mold-release spray, high-strength mold clamps or foundry adhesive, and loose steel shots (or gravel) for backup support.
- **Melting Setup:** A workshop crucible furnace to prepare the molten alloy (e.g., aluminum or brass).

4. Machine Setup & working Procedure

1.Heat the Metal Pattern Plate: Preheating.

Clean the face of the metal pattern plate thoroughly. Place it inside the preheating oven until its surface temperature reaches a stable baseline between **200°C and 250°C**. Verify the temperature using an infrared pyrometer.

2.Apply Parting Compound Spray: Release Agent.

Extract the hot pattern plate safely using insulated gloves. Immediately apply a light, even mist of silicone mold-release spray over all pattern details and around the ejector pins. This thin film prevents the melting resin from sticking to the metal.

3.Invert the Dump Box for Sand Investment: Investment.

Clamp the heated, lubricated pattern plate face-down over the open mouth of the sand dump box. Swiftly invert the dump box 180**°C** so that the resin-sand mixture drops directly onto the hot metal face. Maintain this position for **20 to 30 seconds** to build up a 6 mm thick sand skin.

4.Drain Excess Sand and Bake the Shell: Evacuation.

Swing the dump box back to its upright position, allowing all unbonded sand to fall away. Unclamp the pattern plate—which is now coated in a soft sand skin—and place the entire assembly into the curing oven at **300°C for 2 minutes** until the shell turns a rigid, dark golden-brown.

5.Eject the Hardened Shell Half: Stripping.

Remove the hot pattern assembly from the oven. Carefully depress the mechanical ejector pin leverage system to push the cured, hard sand shell cleanly off the metal pattern plate without cracking its thin walls. Repeat steps 1–5 to create the matching second half of the mold.

6.Assemble, Clamp, and Pour the Metal: Pouring Prep.

Align the matching shell halves (cope and drag) together and lock them tight using high-strength metal clamps or specialized foundry adhesive. Place the clamped shell vertically inside a casting flask and fill the surrounding empty space with loose steel shots to support the thin walls. Pour the liquid metal smoothly down the sprue.

5. Observation & Process Parameter Table

Trial No.	Pattern Temp (∘C)	Investment Time (seconds)	Curing Time (minutes)	Visual Quality of Hardened Shell	Surface Finish of Finished Casting
1	160°C	15 s	2.0 min	Thin, fragile shell; details broke off.	Poor, incomplete profile.
2	**230°C**	**25 s**	**2.0 min**	**Optimum thickness, hard shell, crisp details.**	**Excellent, smooth surface.**
3	300°C	45 s	4.0 min	Shell too thick; resin charred and burnt.	Severe gas defects / Rough surface.

6. Safety Precautions

- **High-Temperature Burn Hazard:** Handling pattern plates heated up to 300°C and working near melting furnaces carries severe thermal burn risks. Operators must wear heavy-duty insulated leather foundry gloves, safety face shields, and leather aprons at all times.
- **Toxic Gas Ventilation:** The baking and thermal breakdown of phenolic resins releases strong, hazardous chemical fumes (ammonia and phenol vapors). Ensure the laboratory exhaust hoods and ventilation fans run continuously throughout the workshop session.
- **Handle Shells Gently:** Thin sand shells are hard but brittle like biscuits. Avoid dropped impacts or applying skewed pressure when extracting them from the ejector pins to prevent fracturing the mold walls.

8. Conclusion

The operational principles of the shell molding casting process were successfully studied. A high-precision thin sand shell mold was prepared under optimum temperature settings and used to cast a high-quality product. It was verified that pattern preheat temperature and investment time directly control the thickness and structural strength of the shell mold.