UNCONVENTIONAL METHODS OF MACHINING
The definition

Conventional – using mechanical force to remove material

unconventional – using physical, chemical, electrical and other principles to remove material
unconventional methods

- Electrical principles:
  - Electrochemical Discharge Machining (EDM)

- Chemical principles:
  - Etching
  - ElectroChemical Machining (ECM)

- Physical methods
  - Beam machining (laser, plasma, electron beam)

- Mechanical
  - Water jet-stream machining
Electrical processes – 1) EDM

Electric discharge machining
- desired surface obtained by electric discharges (sparks)
- Two electrodes (tool electrode and workpiece electrode)
- Dielectric liquid
- High current values initiate sparks
- Spark remove material from both electrodes
EDM - process

1) Electrodes are placed close
Not touching each other

2) The gap is filled by dielectric

3) Electricity is switched on and voltage is set on two electrodes

Dielectric – hydrocarbon oils, kerosene, deionized water (Wire EDM)
EDM process

4) No current flow
   – dielectric insulate
5) Electrode gap is decreased
6) Electric discharge is generated
7) Discharge lowers the voltage and stop the discharge
8) Discharge heats the material and evaporates workpiece – dielectric cools rest of piece
EDM process

9) Dielectricum **flows the chips** away from the crater
10) New surface is generated

**NOTES:**
Both materials must be conductive
Discharge affects both electrodes
EDM types

1) Sinker EDM
Electrode has a negative shape of final surface. Large surfaces, many parts at one „stroke“

2) Micro EDM
Small element (cube, ball, wire) is used and moved along the surface. Surface of new shape is created in sequence
Sinker EDM - example
EDM types

3) Wire EDM

- Wire is pulled between two spools.
- The wire is under voltage.
- Discharge goes along the wire and „cuts“ the workpiece

Video 002
Wire EDM - examples
EDM types

4) EDM drilling
EDM – properties

- **Advantages**
  - Complex shapes not machinable can be made
  - Extremely hard materials (no HT damage)
  - Close tolerances
  - Small wall thickness, small forces
  - Weak material possible
  - Good surface finish can be achieved
  - Very fine holes

- **Disadvantages**
  - Slow material removal rate
  - Additional time for electrodes machining needed
  - Sharp corners are not possible due to tool wear
  - Specific power consumption is too high
  - High tool wear
  - Non-conductive materials are hard to machine (special setup)
ECM – electrochemical machining

Two electrodes (cathode – tool) and (anode – workpiece) placed in electrolyte

High current, lower voltage and no sparks.

No discharge, just dissolving of workpiece material

Low gap (80-800 µm)

Electrolyte flows away the dissolved material in form of metal hydroxide
ECM – electrochemical machining
ECM - types

- Similar to EDM
- Sink ECM, ECM drilling,

ECM deburring – removing burrs and chips from edges of new created surfaces

ECM works in inner holes, at hole intersections, complex surfaces

5-10 sec. Remover burrs, not affects workpiece
ECM - properties

- **Advantages**
  - Low forces
  - Hard material machining
  - No tool electrode wear (long durability)
  - No heat and no stress machining

- **Disadvantages**
  - High investments
  - High current (40 kA)
  - Saline electrolyte (risk of corrosion)
Etching

Method used mainly for decoration and technical purpose (preparation of clean surfaces)

Workpiece is covered by masking substance and placed in liquid or covered by etching paste. The etching process is rather slow. After the process the part is washed and demasked.
Etching – process

1) Residual stress must be removed – to prevent shape changes
2) Degreasing and cleaning process – to keep good masking adhesion
3) Masking – painting, covering with layer (rubber, vinyl or plastic PVC, PE, PS)
4) Making a patter (carving)
5) Exposed surfaces are etched by reafent. Temperature and agitaion of reagent is controlled.
6) After machining – good washing, cleaning and masking removal
Etching reagents

- **For aluminum**
  - Sodium hydroxide (NaOH)

- **For steels**
  - Hydrochloric or nitric acid (HCl, HNO3)
  - Ferric chloride for stainless steel (FeCl3)
  - Nital (mixture of ethanol, methanol and other)

- **For copper**
  - Cupric chloride (CuCl2)
  - Ferric chloride
  - Ammonium persulfate ((NH4)2S2O8)
  - Ammonia (NH3)
  - 25-50% nitric acid
  - Hydrochloric acid and hydrogen peroxide (HCl, H2O2)

- **For silica**
  - Hydrofluoric acid (HF)
Etching - examples

- Semiconductor production
- Decorative etching
Beam technologies

- **LASER** - *Light Amplification by Stimulated Emission of Radiation*
- Plasma – ionised state of matter similar to gas
- Electron beam – stream of high speed particles
Beam technologies

- Principle – the beam consist of particles that bring energy to the point of action. The material there is heated and melted, burned, blown away by stream or vaporized and removed by different methods.

- Beam technologies are no-force manufacturing processes.
Laser beam

- Laser is created in laser resonator (a chamber with two mirrors, one halfmirror)
- Three main types of laser are used
  - CO2 – cutting, boring, engraving – long time, medium power, beam laser
  - Nd (neodym) – boring, high energy low repetition (pulse)
  - Nd – Yag (yttrium-alluminium-garnet) – boring engraving, very high energy
Laser beam

- Environment
  - Air
  - Gas – neutral (Argon, CO2, Helium, Nitrogen)
  - Gas – active (O2
Laser - process
Laser - properties

- **Accuracy** - 0.010 mm
- **Rz** – 10-25 μm (depends on cutting depth)

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Amount of heat input required for various material at various thicknesses using a CO2 laser (watts)

Material thickness (mm)
Laser - properties

- Speed is given by material, its thickness and power of the machine.

<table>
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<td>750</td>
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Laser - machines

- Small table moving machines
- Large portal type machines
- X,Y coordinates (Z focusing)
Laser - applications

- Cutting – sheet metal
Laser application

- drilling
Laser - applications

- Engraving – all materials
- CO2 laser
Laser - properties

- **Advantages**
  - No force
  - High speed
  - Complex shapes
  - Variable (cutting, welding, boring, engraving)
  - Precise

- **Disadvantages**
  - High power consumption
  - High investments
  - Gas consumption
  - Not suitable for all materials (flammable)
  - Cut trace
Plasma beam

- Like the laser beam
- Rough technology
- Use of electric arc to excite particles from material, keep them at place to produce more power
- Gas focusing
Plasma - configuration

- Plasma arc – melting the material and blowing away
- Plasma torch – vaporizing, burning the material (higher power needed)
Plasma - machines

- Robust
- Big
- Portal type
Plasma - properties

- **Advantages**
  - Cheaper than laser
  - Higher output
  - Higher speed and depth
  - Manual operation

- **Disadvantages**
  - Not precise
  - „chamfer“ creation
  - UV radiation
  - Sparks, molten mat. drops, smoke and dust
Electron beam

- Like laser and plasma
- High power and speed electrons are focused on material
- Their kinetic energy is absorbed by material
- Electrons are absorbed by material
- Vacuum is needed!
- Ultrapress technology – 50 micron hole!
Electron beam - machines

- High power (up to 100 kW)
Electron beam - properties

- **Advantages**
  - Good control of process
  - Diameter to depth ratio
  - Not affected by optical properties of mat.

- **Disadvantages**
  - Expensive
  - Small workspace because
  - Vacuum is needed
Water jet stream machining

- A stream of water with high pressure is led through a nozzle to get a very thin stream of high speed water.
- Stream is clear or with added hard particles (korund, aluminium oxide, granet).
- Nozzle is CNC controlled.
A diagram of a water jet cutter:
1 - high-pressure water inlet
2 - jewel (ruby or diamond)
3 - abrasive (garnet)
4 - mixing tube
5 - guard
6 - cutting water jet
7 - cut material
WJ - process

There are six main process characteristics to water jet cutting:

- **High velocity stream** of abrasive particles suspended in a stream of Ultra High Pressure Water (200 – 1000MPa)
- **Large array of materials**, including heat-sensitive, delicate or very hard materials.
- **No heat damage** to workpiece surface or edges.
- Nozzles are typically made of **sintered boride**.
- Produces a **taper of less than 1 degree** on most cuts, which can be reduced or eliminated entirely by slowing down the cut process.
- **Distance of nozzle from workpiece** affects the **size of the kerf** and the removal rate of material. Typical distance is 0.5 – 5 mm.
WJ – process properties

- **Q1**: Separation Cut
- **Q2**: Through Cut
- **Q3**: Clean Cut
  - Typically closer than +/- 0.010"
- **Q4**: Good Edge Finish
- **Q5**: Excellent Edge Finish
  - Typically closer than +/- 0.005"
Water jet

- **Advantages**
  - More materials, non uniform (composites)
  - No heat affected zone
  - Environmentally firendly
  - Safe (non toxic)
  - Lower investments
  - Simple operation, simple service

- **Disadvantages**
  - Water (some materials cannot be cutted)
  - Low depth of cut, wide kern
WJ - examples
WJ – plywood machining
WJ – glass, stone
WJ - composite
An abrasive water jet tool cuts holes into a 105-mm artillery shell, allowing removal of hazardous materials.
Food Preparation: The cutting of certain foods such as bread can also be easily done with waterjet cutting. Since the waterjet exerts such a small force on the food, it does not crush it, and with a small kerf width, very little is wasted.
Beam technologies - comparison

Graph showing the comparison of different beam technologies such as Abrasive Waterjet, Gas Cutting, EDM, Plasma, and Laser, along with their respective accuracy ranges.
Overview

- Mechanical Processes
  - Abrasive Jet Machining (AJM)
  - Ultrasonic Machining (USM)
  - Water Jet Machining (WJM)
  - Abrasive Water Jet Machining (AWJM)

- Electrochemical Processes
  - Electrochemical Machining (ECM)
  - Electro Chemical Grinding (ECG)
  - Electro Jet Drilling (EJD)

- Electro-Thermal Processes
  - Electro-discharge machining (EDM)
  - Laser Jet Machining (LJM)
  - Electron Beam Machining (EBM)

- Chemical Processes
  - Chemical Milling (CHM)
  - Photochemical Milling (PCM)
Additive manufacturing

- All methods remove material → subtractive methods
- New way of production → addition of material
  (building a 3D model from 3D data)
Methods

- **SLA**
  Very high end technology utilizing laser technology to cure layer-upon-layer of photopolymer resin (polymer that changes properties when exposed to light).

- **FDM**
  Process oriented involving use of thermoplastic (polymer that changes to a liquid upon the application of heat and solidifies to a solid when cooled) materials injected through indexing nozzles onto a platform.

- **SLS**
  Selective Laser Sintering (SLS) utilizes a high powered laser to fuse small particles of plastic, metal, ceramic or glass.
SLA - stereolithography
Methods

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FDM – fused deposition modelling

- layers
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Hybrid machines

 combines additive and subtractive manufacturing – powder bed (SLS) + mill
 NOT POSSIBLE!

https://www.youtube.com/watch?time_continue=43&v=te9OaSZ0kf8
Hybrid machines

- combines additive and subtractive manufacturing – 3D welding + milling

https://youtu.be/Fr_PneeyO34
Videolinks

- EDM
  001- http://www.youtube.com/watch?v=c2njSX52SQo
  002- https://www.youtube.com/watch?v=pBueWfzb7P0
  003- https://www.youtube.com/watch?v=5OMH00G7JJM
- ECM
  004- https://www.youtube.com/watch?v=VzmVrJAlhew
- Laser
  005- http://www.youtube.com/watch?v=B4kAvPgCzk4
  006- http://www.youtube.com/watch?v=UeGVbtrrHjE
- Plasma
  007- https://www.youtube.com/watch?v=5yN2zoXJLqE
Videolinks

- Waterjet
  https://www.youtube.com/watch?v=UO21TOzXEH0
  https://www.youtube.com/watch?v=crgujRcyhhE
  https://www.youtube.com/watch?v=2jm4_HikMqk
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