EMT 2540
Advanced Production Technology

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Department of Mechatronic Engineering

Introduction

Course description:

1. Powder metallurgy
2. Specialized machining processes
3. Welding and fabrication techniques
4. Jigs and fixtures
5. Decorative and protective surface treatment
6. Mass production tools and techniques; machining centers.
7. Practical exercises in powder metallurgy and specialized machining processes. Recent advances in production technology.

Course Textbooks

1. DeGarmo E.P. and Black J.T. (1996) Materials and Processes in Manufacturing, Wiley, John and Sons, Inc.

2. Larry J, Harold V.J, (2002) Welding: Principles and Application, Delmar Publishers, Inc.

References:

1. Chapman W. A. J. (1986) Workshop Technology - Part 3, Arnold International, Students Ed.

2. Hindustani Machine Tools (HMT), (1980) Production Technology Tata McGraw-Hill Pub. Co, Bangalore India

3. International Journal of Production Research.

Mode of examination:

Continuous assessment and written University examination shall contribute 30% and 70%, respectively of the total marks.

Chapter 1: Powder Metallurgy (P/M)

Definition:

- Process by which fine powdered materials are blended, pressed into a desired shape (compacted), and then heated (sintered) in a controlled atmosphere to bond the contacting surfaces of the particles and establish desired properties.

- Is one of the four major methods of shaping metals (machining, hot and cold plastic deformation, casting, and **powder metallurgy**).

- Lends itself to mass production of small, intricate parts of high precision, often eliminating the need for additional machining or finishing.

- **Application:** automotive industry, household appliances, recreational equipment, hand and power tools, hardware items, office equipment, industrial motors, and hydraulics. Rapid growth in aerospace, advanced composites, electronic components, magnetic materials, metalworking tools and a variety of biomedical and dental application

1.1 The Basic Process

a) Powder manufacture

b) Mixing or blending

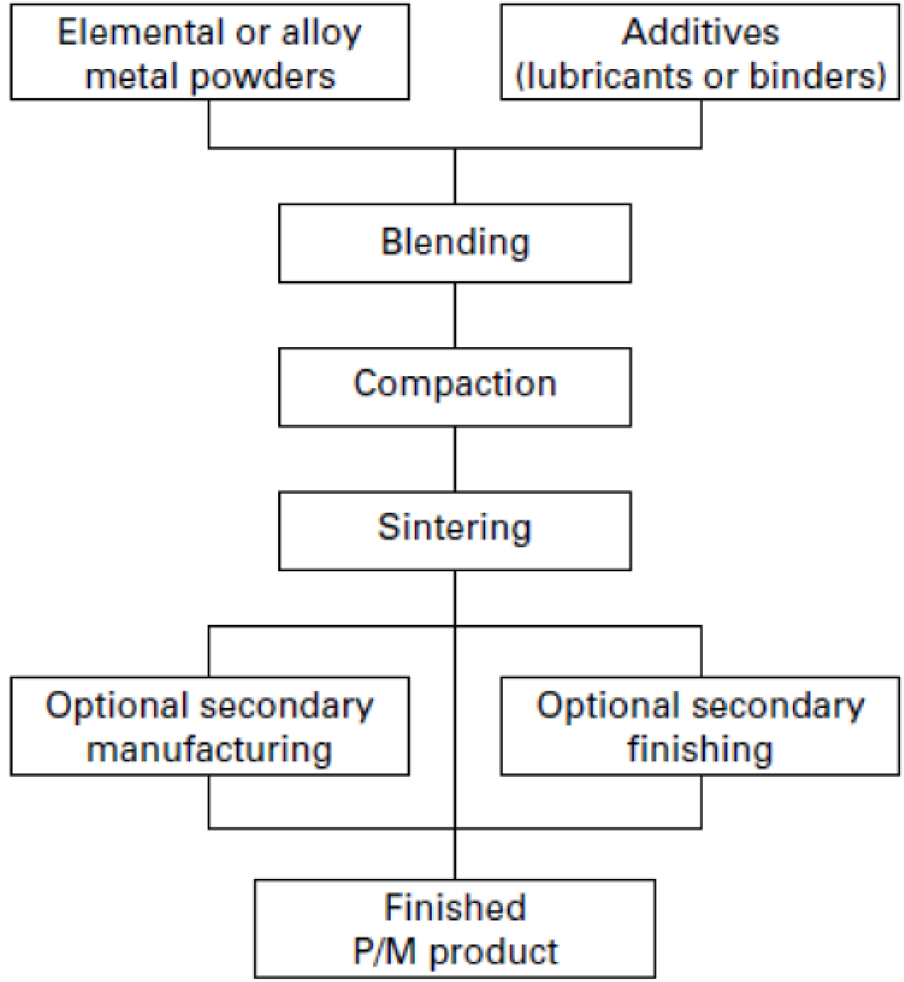
c) Compacting

d) Pre-sintering

e) Sintering

f) Hot Pressing

g) Secondary operations



The basic powder metallurgy process

1.2 Powder Manufacture

- Metals and their alloys are used in P/M include iron, alloy steel, stainless steel, copper, tin, lead.

- Chemistry and purity, particle size, size distribution, particle shape, and the surface texture of the particles are some important properties of the powder which impart the properties of the final product.

- Particle size should be in the range of 10 – 100 microns

- The three most important methods of producing metal powders are:

    (a) Atomization

    (b) chemical methods

    (c) electrolytic processes

1.2.1 Atomization

- Liquid material is fragmented into small droplets that cool and solidify into particles.

- 80% of commercial powders are produced by some form of melt atomization.

- This method is generally used for metals with low melting points such as: Zn, Pb, Sn, Al and Mg.

Chapter 1: Powder Metallurgy (P/M)

1.2.1 Atomization

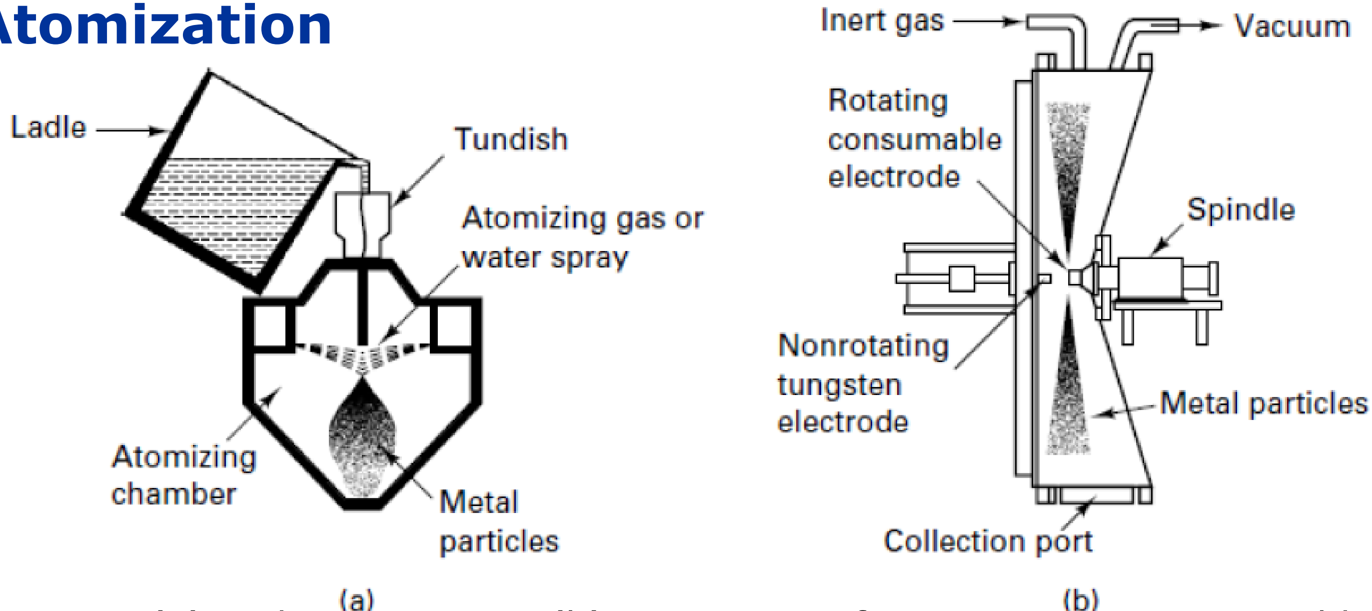


Figure 1.2.1: (a) melt atomization (b) atomization from a rotating consumable electrode.

a. Melt atomization

- Jets of high-pressure gas (nitrogen, argon, or helium) strike a stream of liquid metal as it emerges from an orifice.
- Pressurized liquid can replace the pressurized gas, converting the process to liquid atomization or water atomization.

b. Atomization from a rotating consumable electrode

- An electric arc impinges on a rapidly rotating electrode.
- Centrifugal force causes the molten droplets to fly from the surface of the electrode and freeze in flight.

1.2.2 Chemical methods

– Chemical methods such as reduction, decomposition and condensation are used to produce metal powders.

a. Reduction

– Metal powders are formed by chemical reaction between metal oxides and reducing agents (e.g. hydrogen or carbon monoxide).
– This method is used for metals with high melting points such as W and Mo

$$WO_3 + 3\,H_2 \rightarrow W + 3\,H_2O$$

Tungsten

b. Decomposition

– Used to produce metals from carbonyls through thermal decomposition

– Example: Carbonyls of Ni & Fe i.e. $Ni(CO)_4$, $Fe(CO)_5$

$$Ni(CO)_4 \rightarrow Ni + 4CO$$

Chapter 1: Powder Metallurgy (P/M)

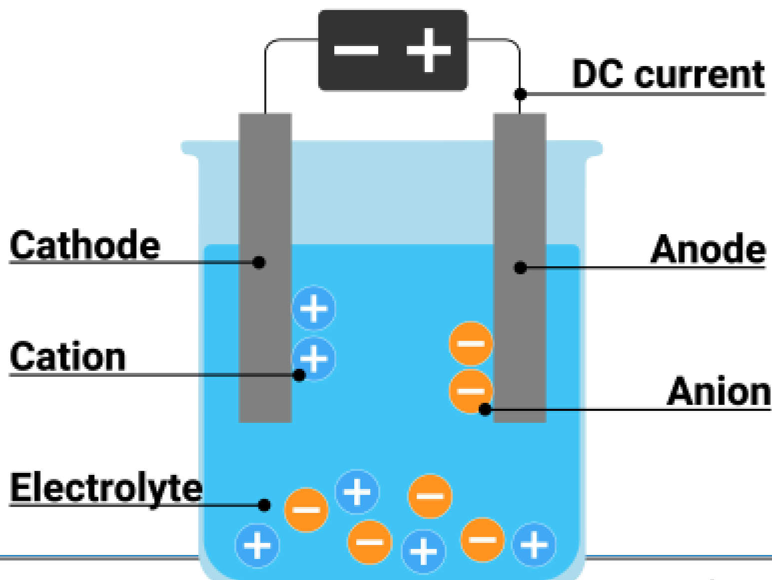
1.2.2 Chemical methods

c. Condensation

– A metal rod is vaporised by heating it to very high temperatures and the vapours are condensed.

– Example: Zn, Mg, Cd powders can be prepared by this method.

1.2.3 Electrolytic Process



– The electrolytic process takes place in the electrolytic cell.

– The source of desired metal is the anode.

– As the anode is dissolved, the desired metal is deposited on the cathode.

Other methods of powder manufacture include:
- Pulverization or grinding of brittle materials (comminution).
- Precipitation from solution.
- Shooting

1.2.4 Mechanical Pulverization (or) Comminution

– Done using a mechanical pulverizer such as counter rotating blades or rapidly moving hammers.

– The mechanical forces disintegrates the metal particles into fine powder.

– Pulverization is usually followed by ball milling.

– Examples of powders are Mg, Zn, Pb.

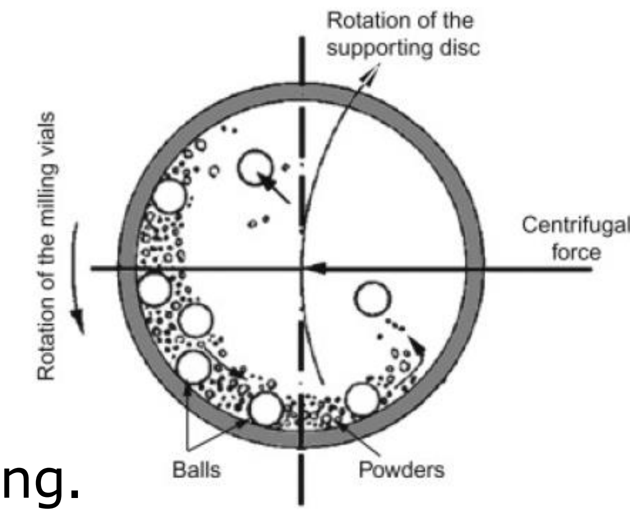


Figure 1.2.2: Ball milling process

1.3 Mixing and Blending

- Done in order to get uniform and very good results especially when an alloy is to be manufactured.

- Lubricants and volatilizing agents are also added to give a desired amount of porosity and lubricity.

1.4 Powder Compaction

Def.: the process of converting loose powder into the desired shape.

Aim: Forming of metal powders into compacts of desired shapes with sufficient strength to withstand ejection from the tools and handling it without breakage and damage.

Chapter 1: Powder Metallurgy (P/M)

1.4.1 Classification of compacting

1. Pressure shaping techniques

i. Die compaction

ii. Isostatic pressing

iii. Powder extrusion

iv. Powder forging

v. High energy rate forming

vi. Vibratory compaction

vii. Continuous compaction

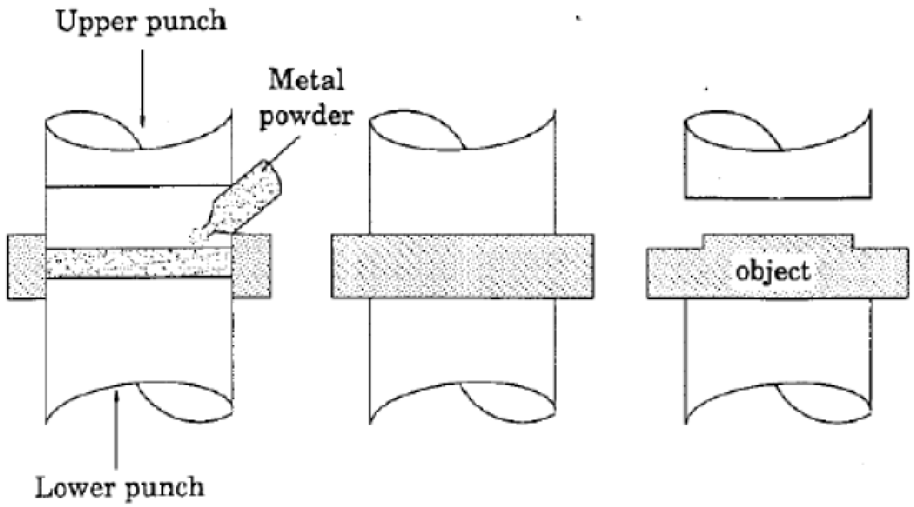
2. Pressure-less shaping techniques

i. Slip casting

ii. Gravity compaction

iii. Continuous pressureless compaction

i. Die compaction



- The dies consists of two parts: lower punch and upper punch.
- The lower punch is provided with shaping hole, in which metal powder is introduced.
- Pressure is given by movement of upper and lower punches towards each other.

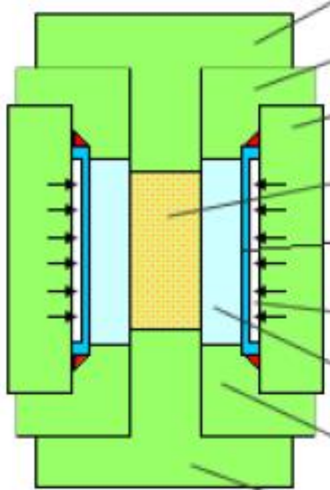
- Pressure may be obtained by either mechanical or hydraulic presses

- **Mechanical presses** ratings of 10 - 50 tons and speeds of 6 - 150 strokes/min.

- **Hydraulic presses** ratings up to 5,000 tons, but slower stroke speeds generally less than 20 strokes/min.

Chapter 1: Powder Metallurgy (P/M)

ii. Isostatic Pressing



- The consolidation of powdered metal contained in a tightly sealed flexible mould.

- The mould is then kept into shaped bodies in which a **uniform** pressure is applied **simultaneously** and **equally** in all directions thereby achieving **uniform** density and strength.

Hydrostatic Pressing - pressure transmitting medium is liquid such as water, water-soluble oil, glycerine or hydraulic oils

Isostatic Pressing - If the pressing media used are gases, powders, rubber or Plastics.

iii. Powder Forging

– Forging is the working or forming of powder metal into a required shape by pressing.

Classification:

a. Hot forging or Hot working

– The mechanical working of metal powder above the recrystallisation temperature.

b. Cold forging or Cold working

– The mechanical working of metal powders below the recrystallisation temperature is called "cold forging". Example: Powder extrusion

Chapter 1: Powder Metallurgy (P/M)

iv. Powder Extrusion

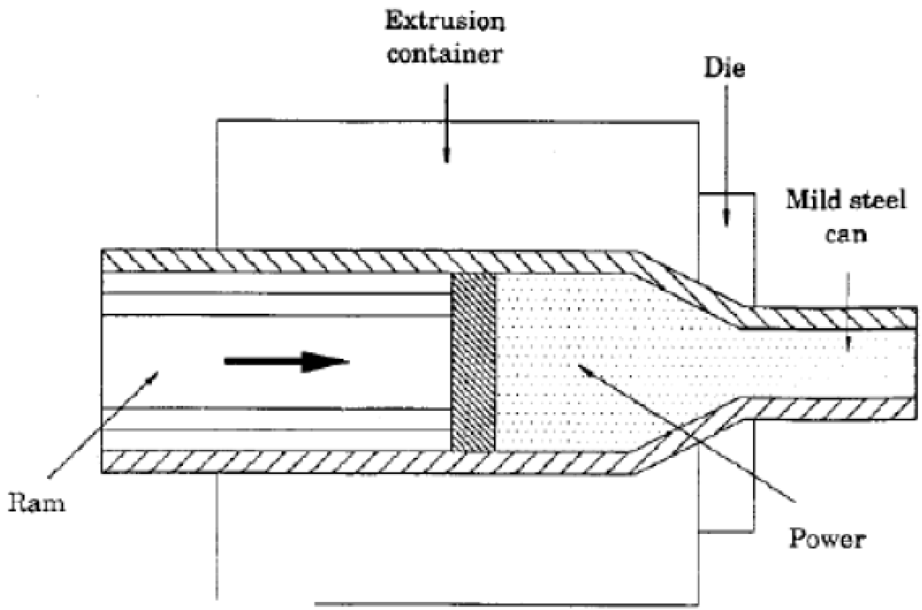


Figure 1.4.3: Powder extrusion

v. Continuous compaction

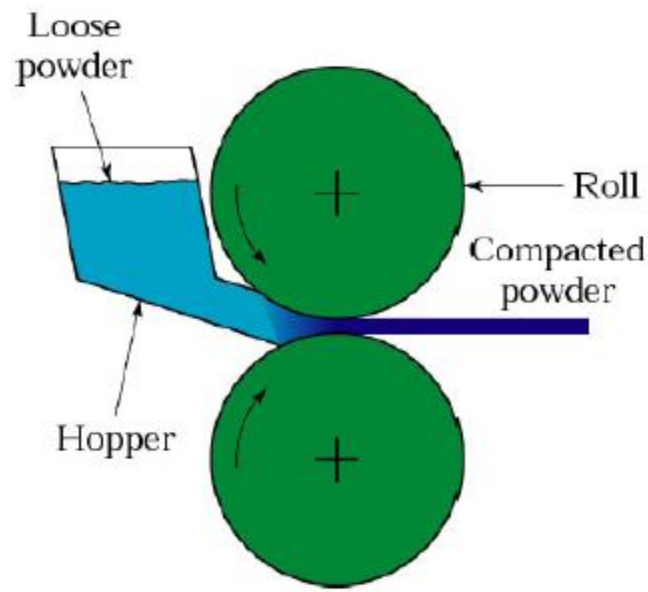


Figure 1.4.4: Roll compacting or powder rolling

Other processes: - High-energy rate forming
- Vibratory compaction

Pressure-less shaping techniques

i. Slip casting

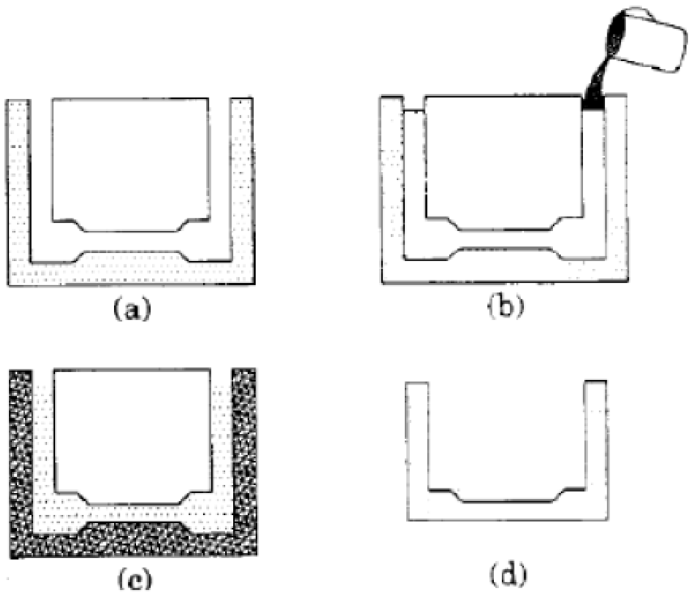


Figure 1.4.5: Principles of slip casting. (a.) Assembled mould (b.) Filling the mould (c.) Absorbing water from the slip (d.) Finished piece, removed from the mould and then trimmed

ii. Gravity compaction

iii. Continuous pressureless compaction

Chapter 1: Powder Metallurgy (P/M)

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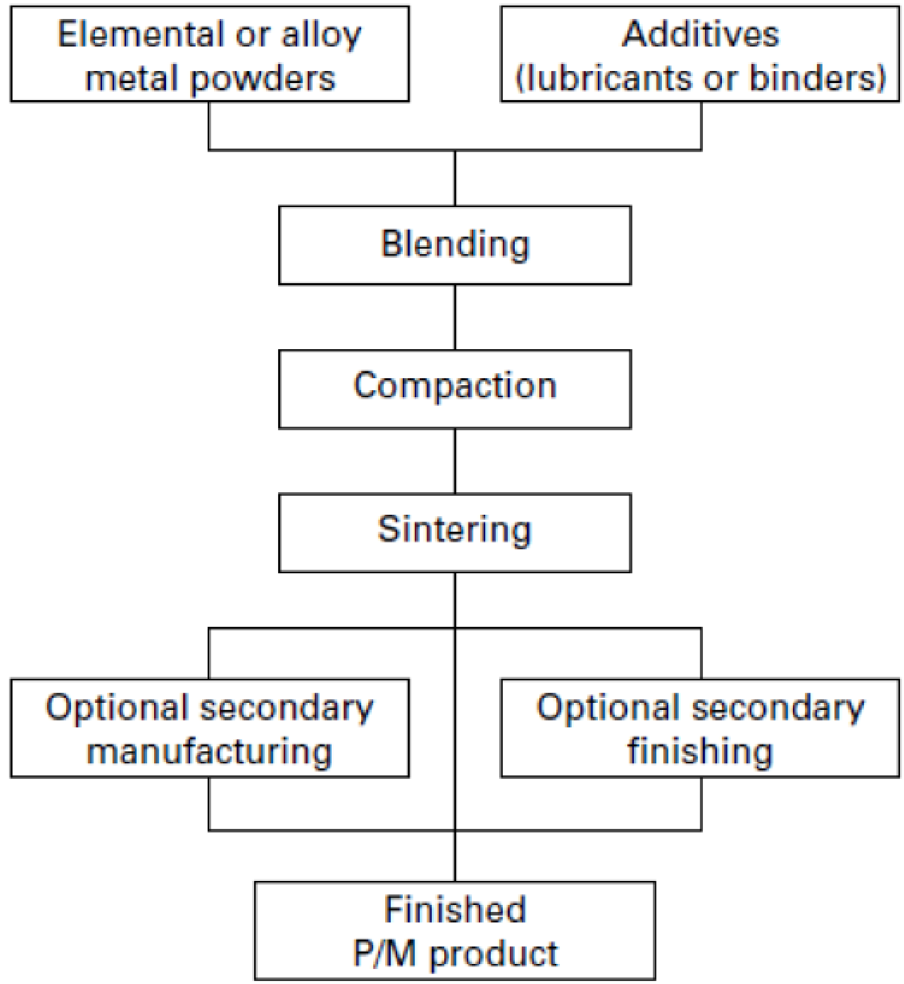


The basic powder metallurgy process

1.5 Sintering

– Def.: The heating of loose or compact aggregate of metal powders below the melting point of the base metal with or without the application of external pressure in order to transform it to a more dense material by inter particle bonding.

Sintering process is concerned with:

i. the diffusion of particle to particle
ii. the formation of grain boundary, and
iii. the closing of voids present in the green briquettes

– Density, mechanical strength, ductility, electrical and thermal conductivity increases with increased amount of sintering.

Types of sintering

i. Solid phase sintering
ii. Liquid phase sintering

Chapter 1: Powder Metallurgy (P/M)

1. Solid phase sintering

- most widely used method
- temperature is 60 - 80% of the melting temperature
- controlled atmosphere furnace or a vacuum furnace
- increased strength → disappearance of the individual particle boundaries → solid state diffusion and recrystallization
- The rate of diffusion depends on: particle size, % of each metal present and temperature.

2. Liquid phase sintering

- carried out at a temperature at which a liquid phase exist
- sintering temperature: may be above the melting point of one of the alloy constituents or above the melting point of an alloy formed during sintering
- properties of sintered compacts are dependent upon compacting pressure, sintering temperature and time.

Advantages of LPS

- It produces very good density
- The rate of diffusion is greatly increased
- Produces excellent mechanical properties.

1.6 Hot Pressing

- The powder is placed into a die pressure and temperature is applied simultaneously.
- Moulding and sintering takes place at the same time, resulting into higher densities and greater productions.

Advantage:

- A reduction in gas content and shrinkage effects, along with higher strength, density, hardness and elongation.

Disadvantages

- Hot pressing cannot be used for the production of very hard cemented-carbide parts.
- High cost of dies to withstand pressure at elevated temperatures.

1.7 Secondary Operations / Finishing

(i) Sizing
(ii) Coining
(iii) Infiltration
(iv) Impregnation
(v) Heat treatment

1.8 Applications of Powder Metallurgy

- Porous products
- Bearings for automobiles e.g. engine main bearing
- Oil pump gears
- Cemented carbides (for cutting tools, wire drawing dies & deep drawing dies)
- Refractory metal composites. (jet engine nose, cone crucible etc.)
- Diamond impregnated tools (e.g. glass cutter grinding wheel dressers)
- Electrical contact materials (e.g. circuit breakers, resistance-welding electrodes, contact switches, carbon bushes etc.)
- Magnetic materials (e.g. pole piece of generators, motors transformer cores, computer memories hard discs etc.)

1.9 Advantages of Powder Metallurgy

1. Elimination or reduction of machining
2. High production rates
3. Complex shapes
4. Wide variations in compositions are possible
5. Wide variations in properties are available.
6. Scrap is eliminated or reduced.

1.10 Disadvantages of Powder Metallurgy

1. Inferior strength properties
2. Relatively high tooling cost
3. High material cost
4. Size and shape limitations
5. Dimensions change during sintering
6. Density variations produce property variations
7. Health and safety hazards

Chapter 1: Powder Metallurgy (P/M)

Chapter 2: Specialized machining processes

Traditional / conventional

- Presence of a tool/work piece contact

- Relative motion btw tool and work piece

Non-traditional / Specialized machining process

- No relative motion btw tool and work piece
- Absence of tool-work piece contact

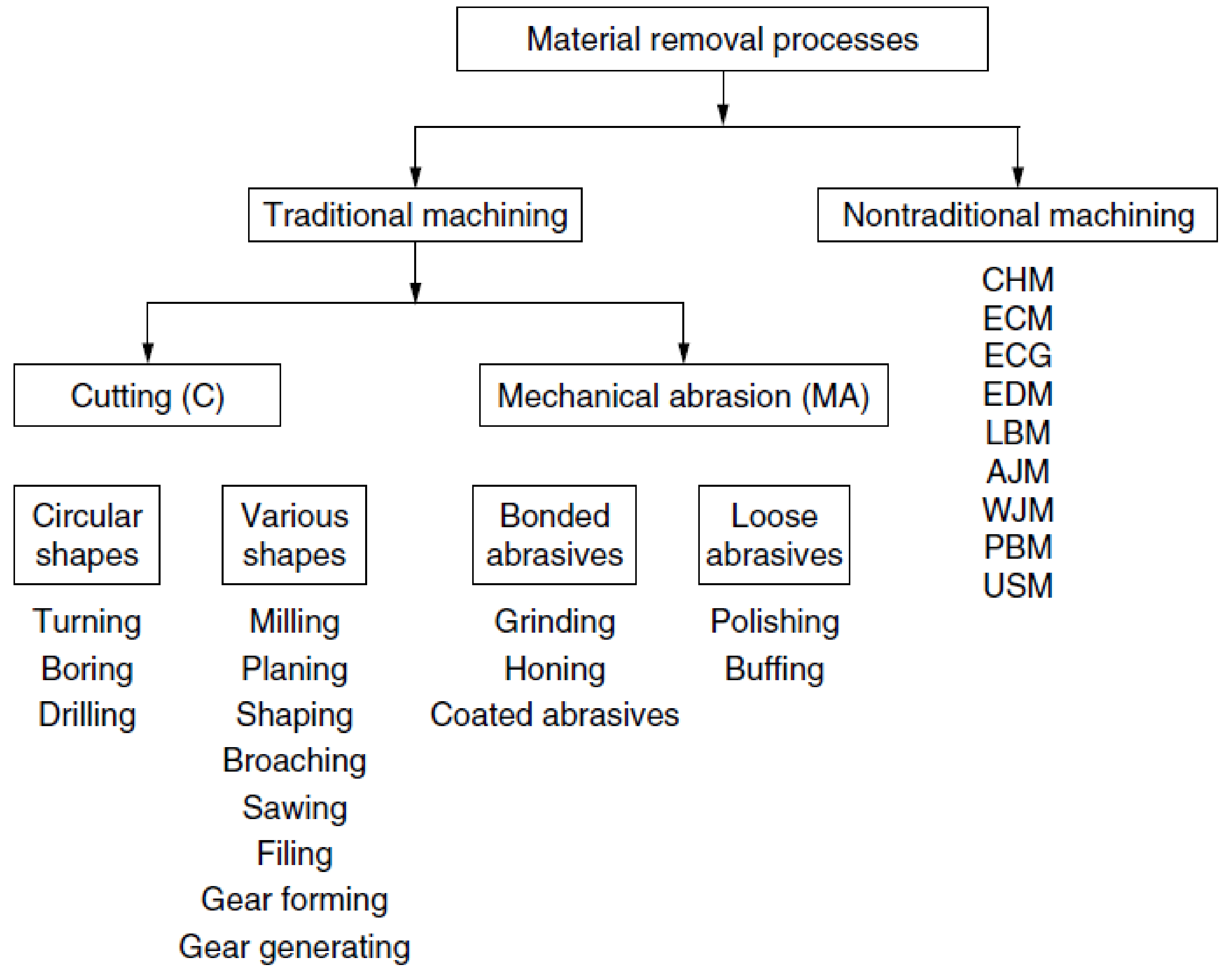


Figure 2.0.1: **Material removal processes**

Chapter 2: Specialized machining processes

Non-traditional manufacturing processes / Specialized machining processes

Def.: A **group** of processes that remove excess material by various techniques involving mechanical, thermal, electrical or chemical energy or combinations of these energies but do not use a sharp cutting tools as for traditional manufacturing processes.

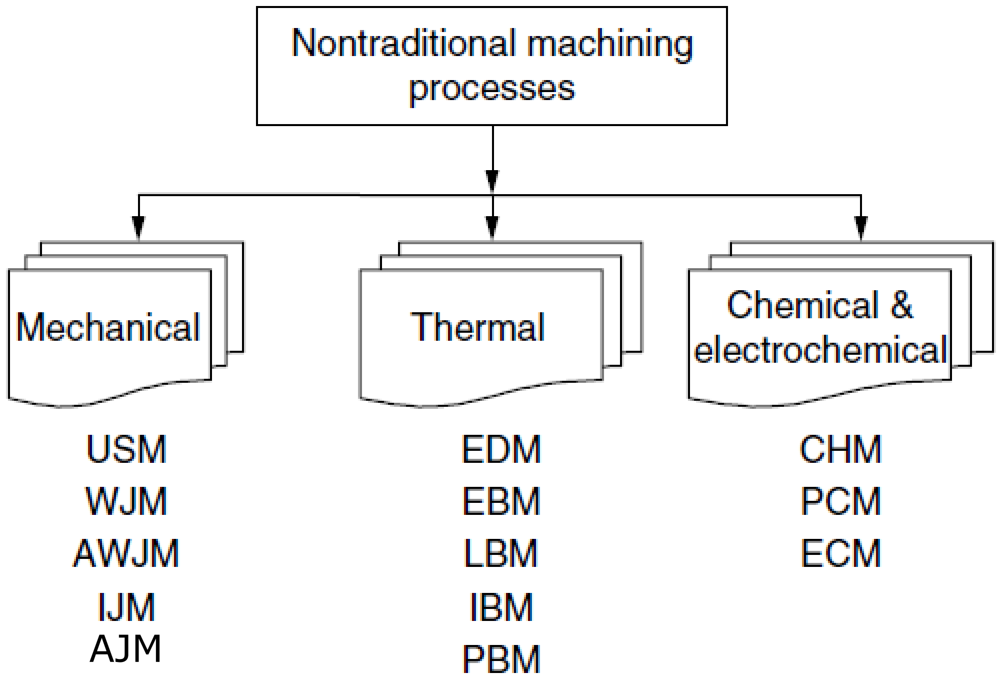


Figure 2.0.2: Non-traditional machining processes.

Chapter 2: Specialized machining processes

Traditional machining	**Non-traditional machining**
• The cutting tool and workpiece are always in physical contact, with a relative motion against each other which results in friction and a significant tool wear	• There is no physical contact between the tool and workpiece. Although in some non-traditional processes tool wear exists, it rarely is a significant problem.
• Material removal rate is limited by the mechanical properties of the work material.	• Easily deal with such difficult-to-cut materials like ceramics and ceramic based tool materials, fiber reinforced materials, carbides, titanium-based alloys;
• The relative motion between the tool and workpiece is typically rotary or reciprocating. Thus, the shape of the work surfaces is limited to circular or flat shapes.	• Most non-traditional processes were developed to solve this problem;
• Machining of small cavities, slits, blind or through holes is difficult with traditional processes	• Machining of small cavities, slits, blind or through holes is a simple work for some non-traditional processes
• Traditional processes are well established, use relatively simple and inexpensive machinery and readily available cutting tools	• Non-traditional processes require expensive equipment and tooling as well as skilled labour, which increases significantly the production cost;

Chapter 2: Specialized machining processes

2.1 Ultrasonic Machining

- This is the removal of hard and brittle materials using an axially oscillating tool at ultrasonic frequencies [18 - 20 (kHz)].

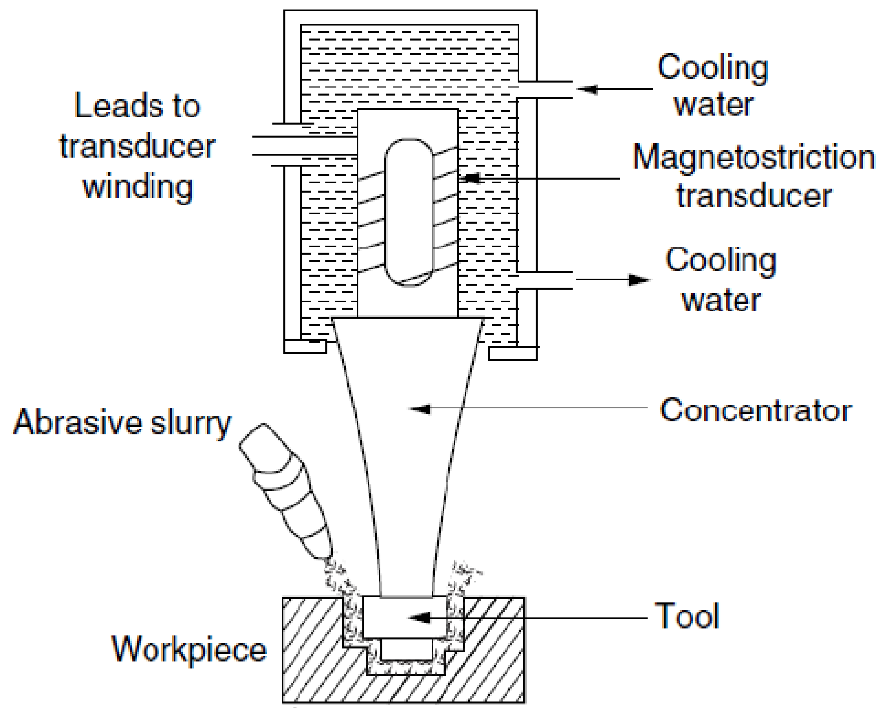
- The abrasive slurry of B_4C or SiC is continuously fed into the machining zone between a soft tool (brass or steel) and the workpiece.

- The oscillating tool - 10 to 40 μm,

2.1.1 The machining system

- Magnetostrictor
- Concentrator
- Tool
- Power source
- Slurry feeding arrangement

Abrasive slurry 50% (by volume) fine abrasive grains of boron carbide (B_4C), aluminium oxide (Al_2O_3), or silicon carbide (SiC) in 50%



Main elements of an ultrasonic machining system.

2.1.2 Factors affecting material removal rate

i. **Tool oscillation** – MRR increases with a rise in the amplitude of the tool vibration

ii. **Abrasive grains** – MRR rises at greater grain sizes until the size reaches the vibration amplitude, at which stage, the material removal rate decreases. An increase of slurry viscosity reduces the removal rate.

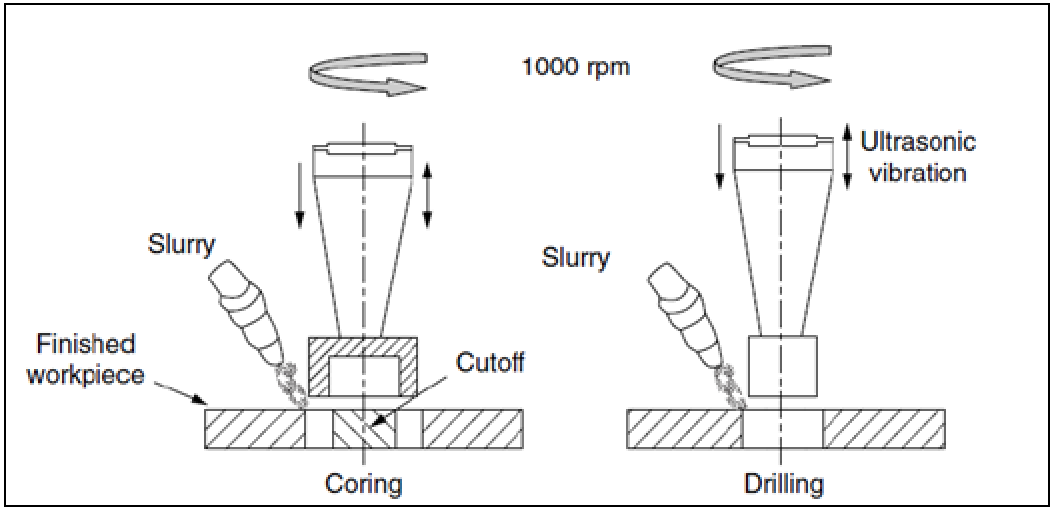
iii. **Workpiece impact-hardness** - MRR is affected by the ratio of the tool hardness to the workpiece hardness. In this regard, the higher the ratio, the lower will be the material removal rate.

iv. **Tool shape**: MRR is affected by the tool shape and area. An increase in the tool area decreases the machining rate.

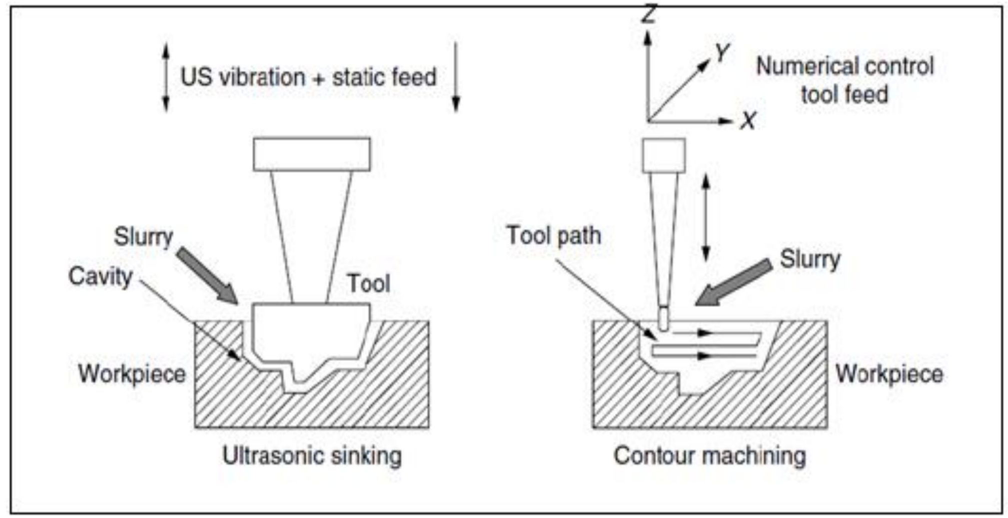
Chapter 2: Specialized machining processes

2.1.3 Applications of Ultrasonic machining

i. Drilling and coring

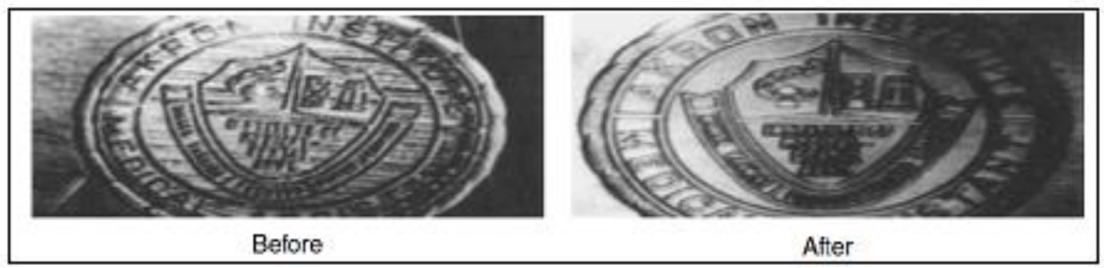


ii. Ultrasonic sinking and contour machining



iii. Production of EDM electrodes

iv. Ultrasonic polishing



Chapter 2: Specialized machining processes

2.1.1 The machining system

Chapter 2: Specialized machining processes

2.2 Abrasive Jet Machining

– A focused stream of abrasive grains of Al_2O_3 or SiC carried by high-pressure gas or air at a high velocity is made to impinge on the work surface through a nozzle of 0.3 - 0.5 mm diameter.
– Best suited for machining holes in superhard materials
– Used to cut, clean, peen, deburr, deflash, and etch glass, ceramics, or hard metals.

2.2.1 Machining system

- A gas (nitrogen, CO_2, or air) is supplied under a pressure of 2 to 8 kg/cm^2.

- A mixing chamber contains abrasive particles and vibrates at 50 Hz

- The gas and entrained abrasive particles (10 - 40 μm), passes through a 0.45 mm diameter tungsten carbide nozzle at a speed of 150 to 300 m/s.

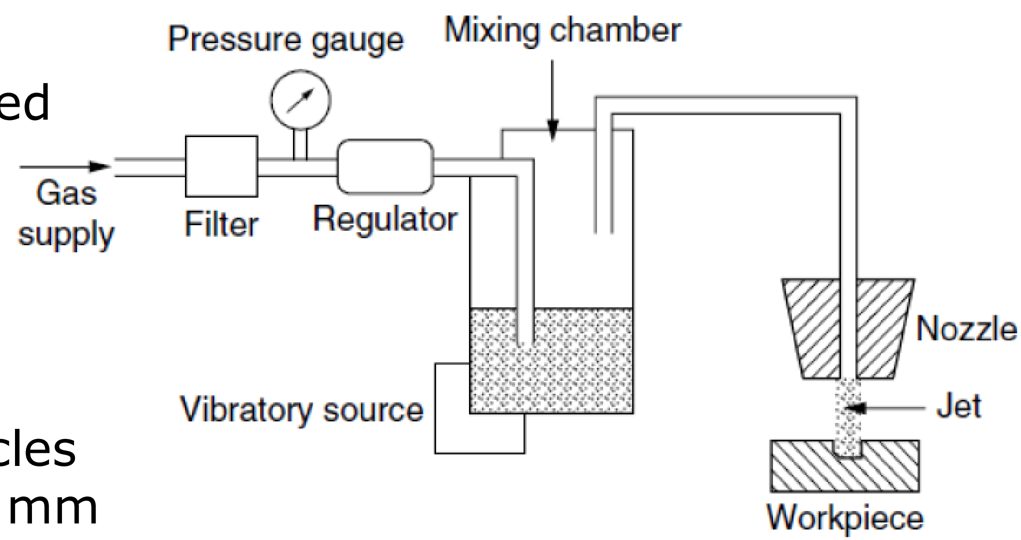


Figure 2.2.1: AJM system

The material removal rate, cut accuracy, surface roughness, and nozzle wear are influenced by the size and distance of the nozzle; composition, strength, size, and shape of abrasives; flow rate; and composition, pressure, and velocity of the carrier gas.

2.2.2 Applications of abrasive jet machining

1. Drilling holes, cutting slots, cleaning hard surfaces, deburring, polishing, and radiusing.
2. Machining intricate shapes or holes in sensitive, brittle, thin, or difficult-to-machine materials.
3. Insulation stripping and wire cleaning without affecting the conductor.
4. Micro-deburring of hypodermic needles.
5. Frosting glass and trimming of circuit boards, hybrid circuit resistors, capacitors, silicon, and gallium.
6. Removal of films and delicate cleaning of irregular surfaces because the abrasive stream is able to follow contours

Chapter 2: Specialized machining processes

Chapter 2: Specialized machining processes

Non-traditional manufacturing processes / Specialized machining processes

Def.: A **group** of processes that remove excess material by various techniques involving mechanical, thermal, electrical or chemical energy or combinations of these energies but do not use a sharp cutting tools as for traditional manufacturing processes.

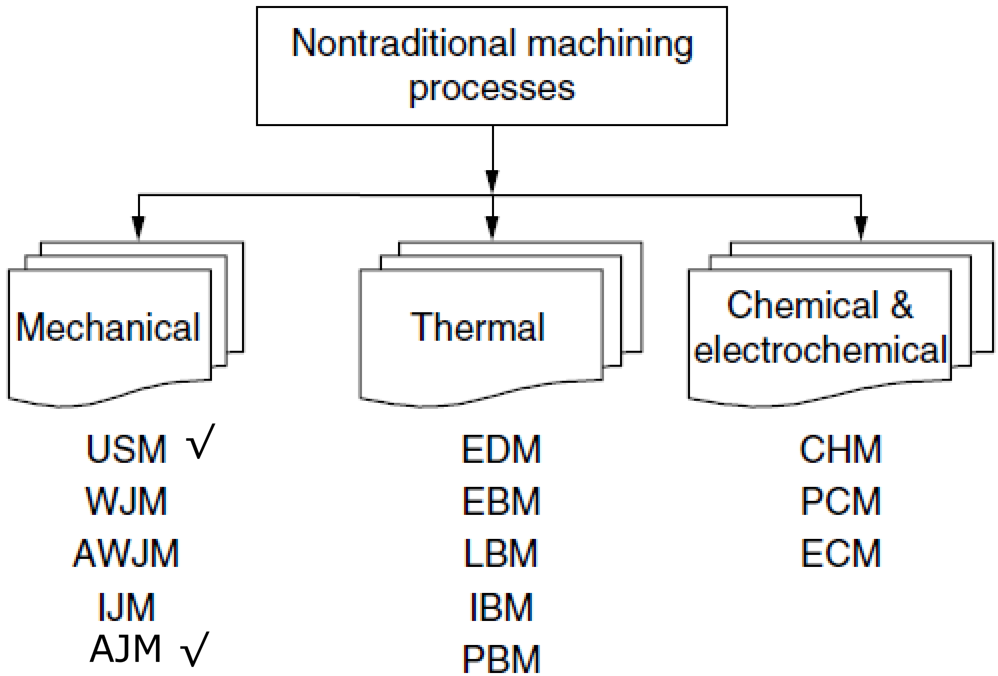


Figure 2.0.2: Non-traditional machining processes.

2.3 Chemical Milling

- Chemical milling (CHM) is the controlled chemical dissolution (CD) of the workpiece material by contact with a strong reagent.

- Used to produce pockets and contours and to remove materials from parts having a high strength-to-weight ratio.

Steps in CHM:

1. Preparing and pre-cleaning the workpiece surface.
2. Masking
3. Scribing of the mask
4. Etching and rinsing
5. Mask removal

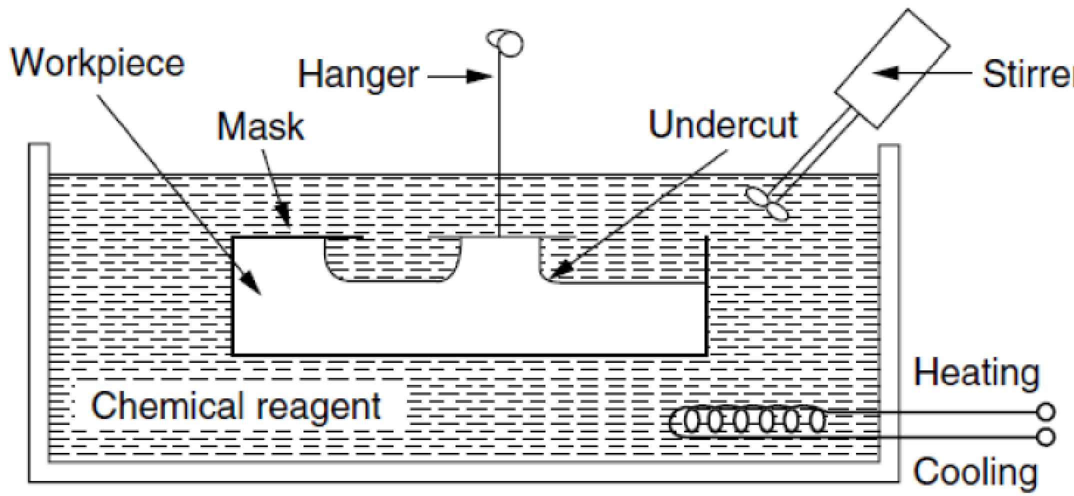


Figure 2.3.1: CHM setup

2.3.1 Tooling for CHM

Four different types of tools are required: maskants, etchants, scribing templates, and accessories.

Maskants: Protect parts of the work piece where CD action is not needed. Maskants should possess the following properties:

1. Tough to withstand handling
2. Adhere to the workpiece
3. Scribe easily
4. Inert to the chemical reagent
5. Able to withstand the heat generated
6. Be removed easily and inexpensively

Etchants: Etchants are acid or alkaline solutions. Main technical goals:

1. Good surface finish
2. Uniformity of metal removal
3. Control of selective and inter-granular attack
4. Control of hydrogen absorption in the case of titanium alloys
5. Maintenance of personal safety

6. Best price and reliability for the materials of the process tank.

7. Maintenance of air quality and avoidance of environmental problems.

8. Low cost per unit weight dissolved.

9. Ability to regenerate the etchant solution and/or readily neutralize and dispose of its waste products.

Scribing templates: Scribing templates are used to define the areas for exposure to the chemical machining action.

Accessories: Accessories include tanks, hooks, brackets, racks, and fixtures.
- Used for single - or multiple -piece handling into and out of the etchants and rinses.

Process parameters in CHM

- Reagent solution type
- Concentration
- Properties
- Mixing
- Operating temperature
- circulation

Applications

- Common metals including aluminium, copper, zinc, steel, lead, and nickel.
- Exotic metals such as titanium, molybdenum, and zirconium.
- Non-metallic materials including glass, ceramics, and some plastics

2.4 Electrochemical Machining

ECM is a process that relies on the removal of workpiece atoms by electrochemical dissolution (ECD) in accordance with the principles of Faraday.

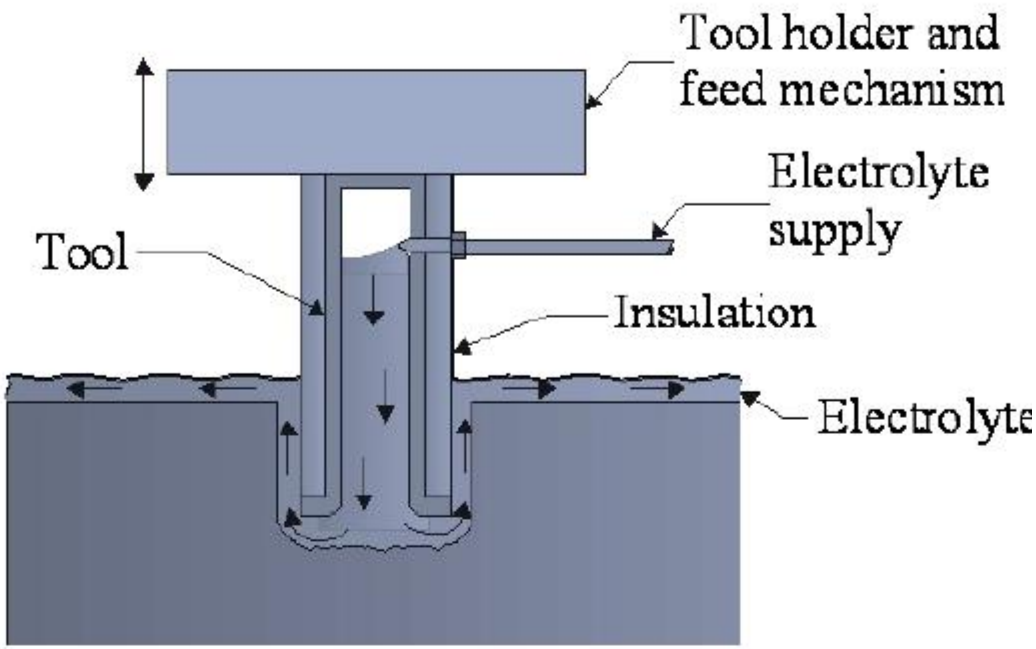


Figure 2.4.1: ECM process

Figure 2.4.2: Parts made by ECM

Chapter 2: Specialized machining processes

2.4.1 Advantages of ECM

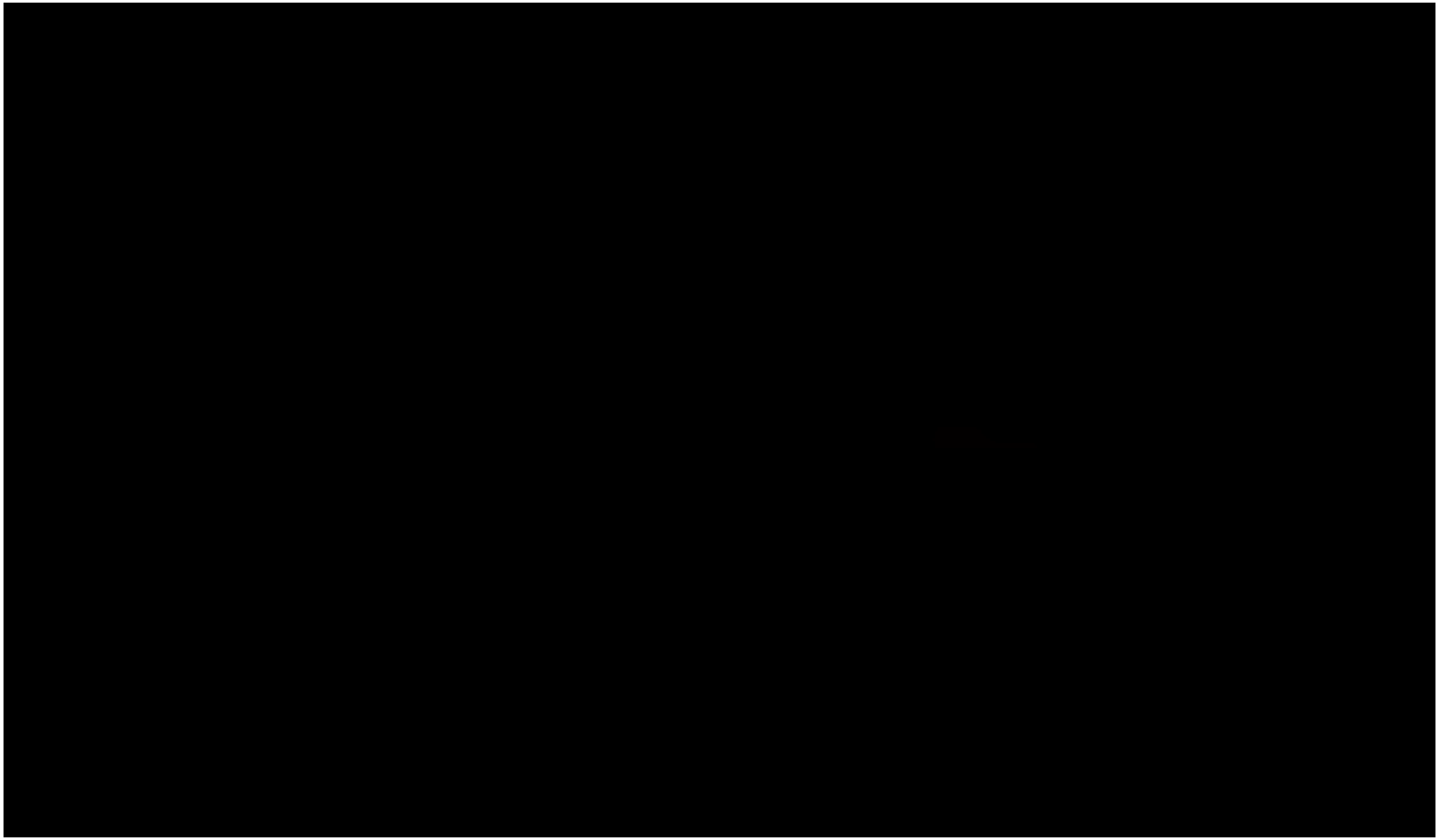
- No thermal or mechanical stress subjection.
- No tool wear during ECM process.
- Fragile parts can be machined easily as there is no stress involved.
- ECM deburring can deburr difficult to access areas of parts.
- High surface finish (up to 25 µm) can be achieved by ECM process.
- Complex geometrical shapes in high-strength materials
- Deep holes can be made by this process.

2.4.2 Limitations of ECM

- ECM is not suitable to produce sharp square corners or at bottoms because of the tendency for the electrolyte to erode away sharp profiles.

- ECM can be applied to most metals but, due to the high equipment costs, is usually used primarily for highly specialised applications.

Chapter 2: Specialized machining processes



Chapter 2: Specialized machining processes

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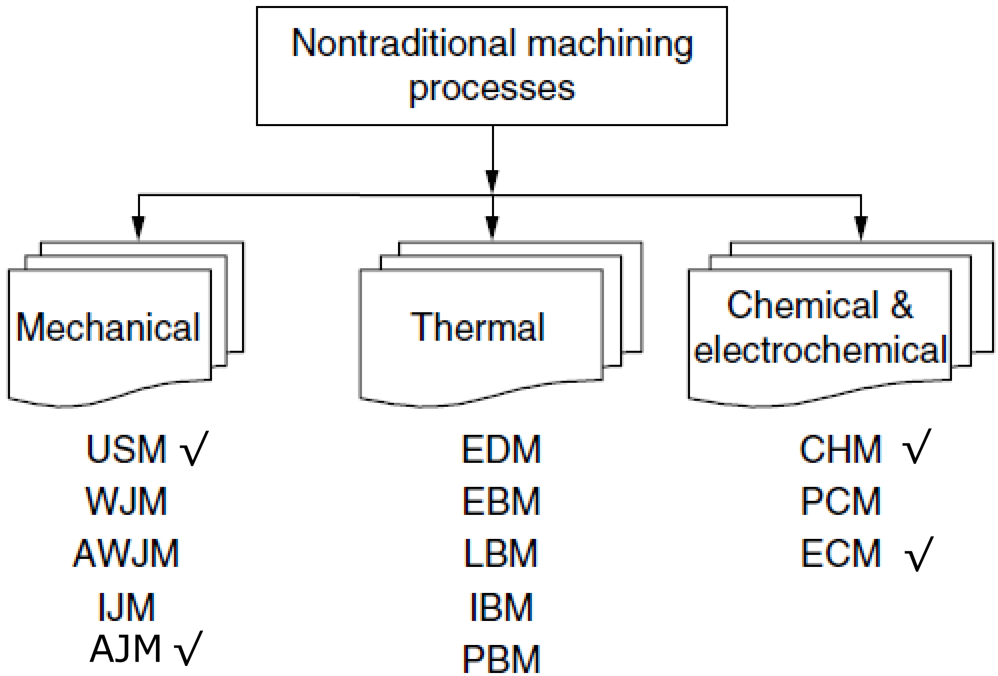


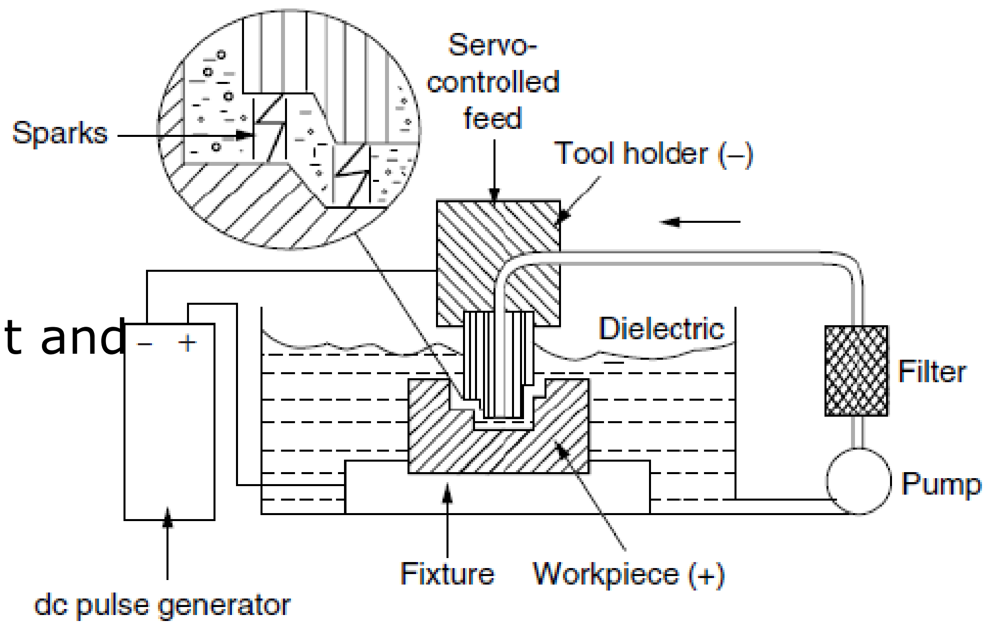
Figure 2.0.2: Non-traditional machining processes.

2.5 Electrodischarge Machining (EDM)

- Removal of material is based upon the electrodischarge erosion (EDE) effect of electric sparks occurring between two electrodes that are separated by a di-electric liquid.

2.5.1 The machining system

- Tool feed servo-controlled unit
- Power supply
- Dielectric circulation unit
- EDM Electrodes – high melting point and good electrical conductivity. Graphite, copper, copper tungsten, silver tungsten, steel, brass



- The frequency of sparks: 500 - 500,000 sparks per second
- Tool – work piece gap width (200–500 μm)

Dielectric fluids: The main functions of the dielectric fluid are to:

1. Flush the eroded particles from the machining gap.
2. Provide insulation between the electrode and the workpiece.
3. Cool the section that was heated by the discharging effect.

Process Parameters: The performance of EDM is determined by three main properties:

- Material removal rate
- Surface quality
- Accuracy

Process parameters include:

- pulse characteristics
- work piece thermal properties, (melting and boiling point, conductivity)
- dielectric properties
- tool electrode (material, movement, wear)

Chapter 2: Specialized machining processes

2.5.2 Application

Typical applications include:

- Micro-EDM: Micromachining of holes, slots, and dies.
- EDM drilling such as the creation of cooling channels in turbine blades
-
- ED sawing where billets and bars are created.
- Machining of spheres, dies and molds
- Wire EDM a special form of EDM
-
- EDM of insulating ceramics.
- Texturing

Chapter 2: Specialized machining processes

2.5.2 Application

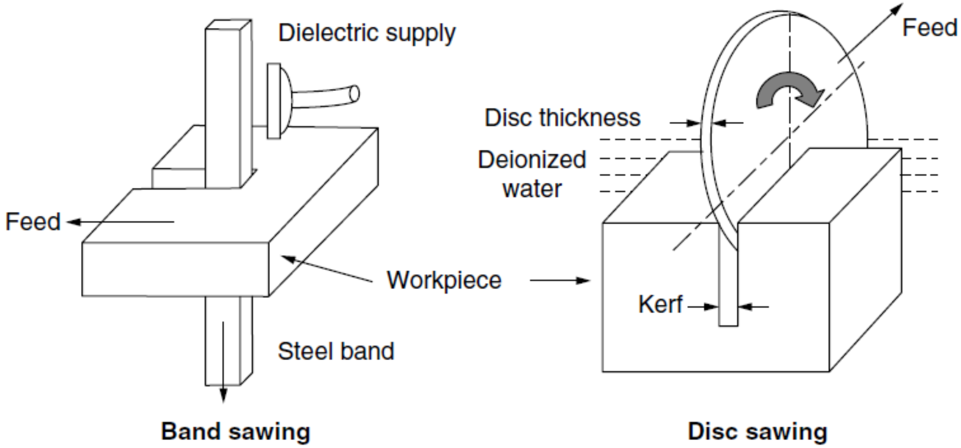


Figure 5.17 ED sawing schematic.

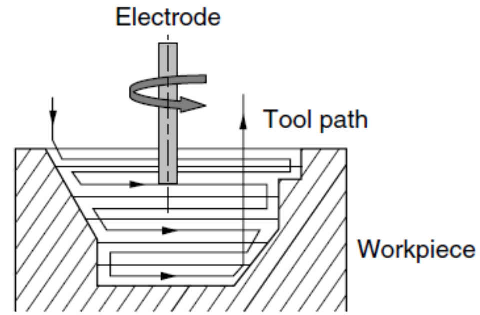


Figure 5.19 EDM die milling.

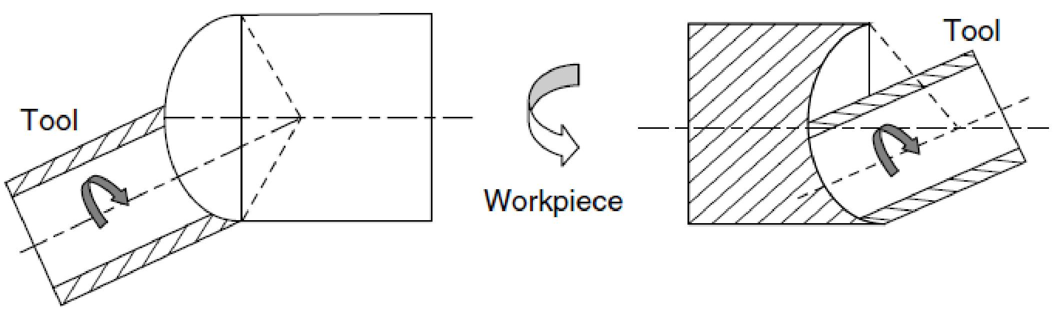


Figure 5.18 Rotary EDM.

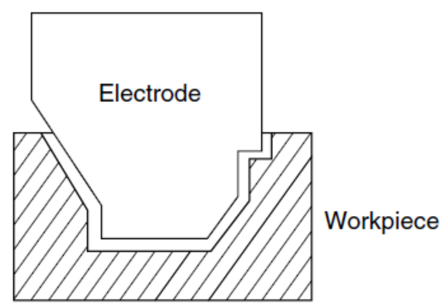


Figure 5.20 EDM die sinking.

2.5.2 Application

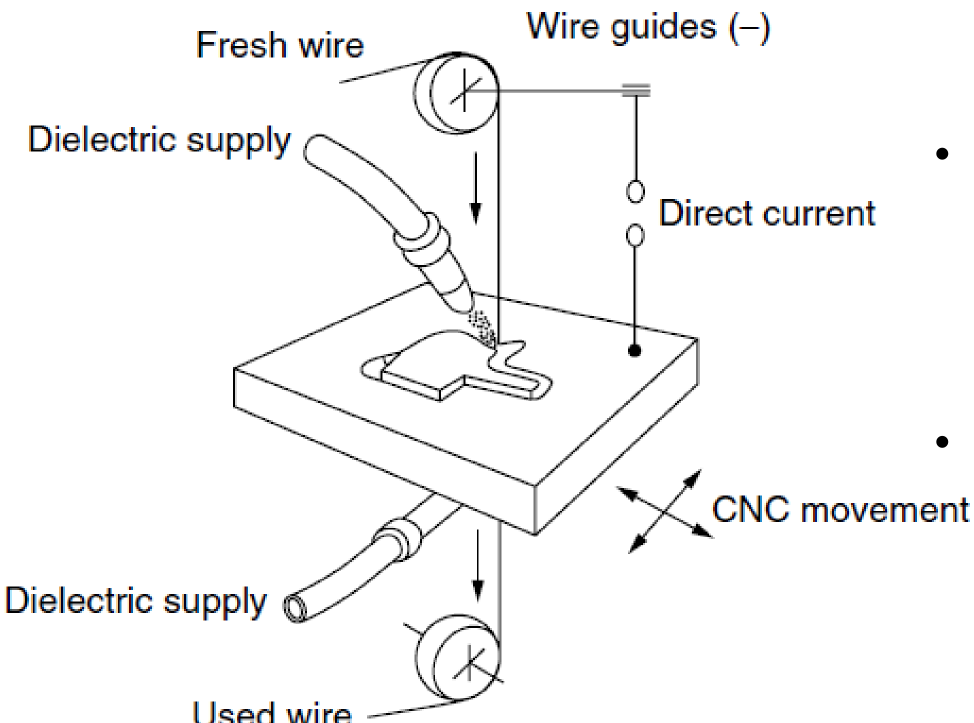


Figure 5.23 Wire EDM schematic.

- Wire EDM is a special form of EDM which uses a continuously moving conductive wire electrode.
- Material removal occurs as a result of spark erosion as the wire electrode is fed, from a fresh wire spool, through the workpiece.
- In most cases the horizontal movement of the worktable, controlled by CNC, determines the path of the cut, as illustrated in Fig. 5.23.
- Application includes the machining of superhard materials such as polycrystalline diamond (PCD) and cubic boron nitride (CBN) blanks,

2.6 Laser Beam Machining

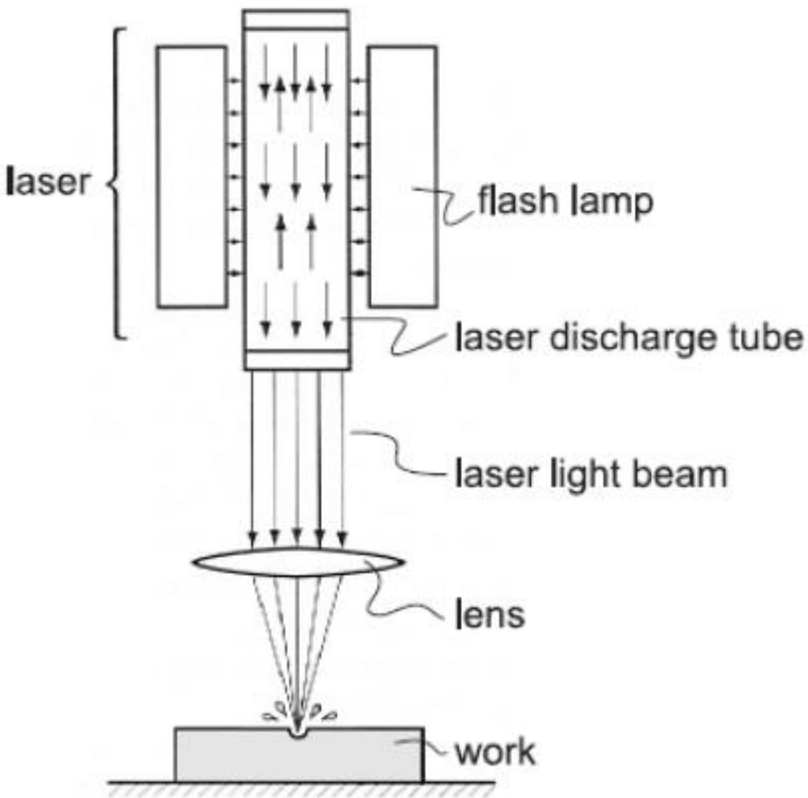
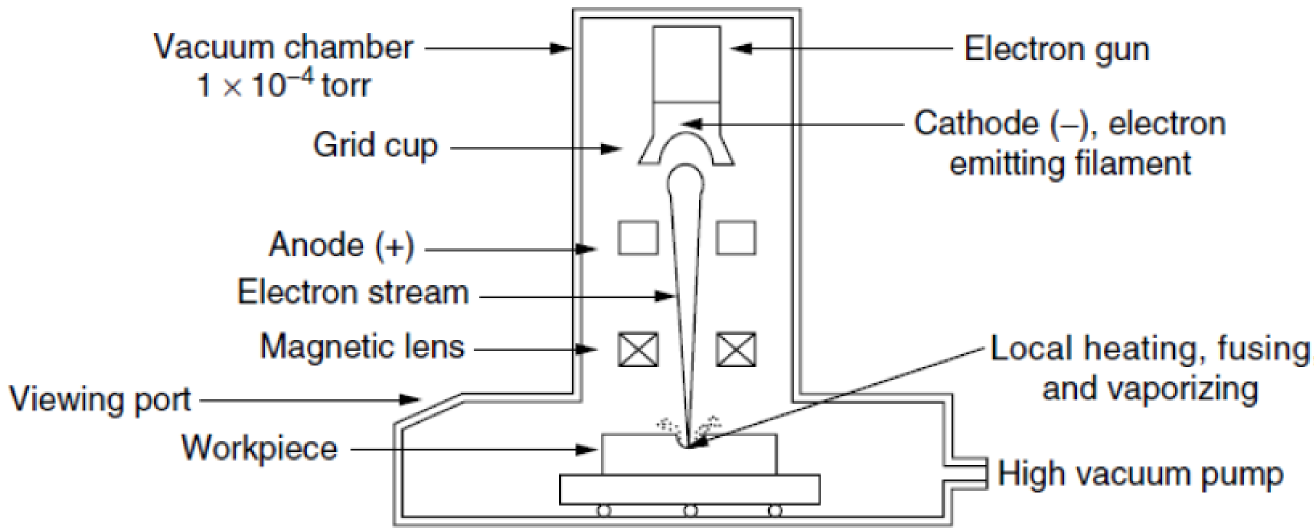


Figure 2.6.1: The set-up of laser beam machining process.

- Laser - light amplification by stimulated emission of radiation.
- A highly collimated, monochromatic, and coherent light beam is generated and focused to a small spot.
- High power densities (10^6 W/mm^2)
- Material removal is by vaporization and ablation (melting and evaporation).
- carbon dioxide (CO_2) gas lasers.
- Range of work materials include metals with high hardness and strength, soft metals, ceramics, glass, plastics, rubber, cloth, and wood.
- Applications: heat treatment, welding, measurement, drilling, slitting, slotting, and marking operations.

Chapter 2: Specialized machining processes

2.7 Electron beam machining (EBM)



Applications:

- High-precision cutting applications
- Drilling of extremely small diameter holes 0.05mm
- Drilling holes with high depth-to-diameter ratios 100:1
- Heat treatment
- Integrated circuit fabrication
- Welding

- Uses a high-velocity stream of electrons focused on the work-piece surface to remove materia by melting and vaporization.

- Electrons are accelerated with voltages of approx. 150,000 V to create velocities over 200,000 km/s.

- K.E. is converted to thermal energy which vaporizes the mtrl.

- Lens can reduce the beam area to upto 0.025mm

2.7 Electron beam machining (EBM)

Limitations of EBM

- Process is limited to thin parts in the range from 0.2 to 6 mm thick
- need to perform the process in a vacuum
- high energy requirement
- expensive equipment

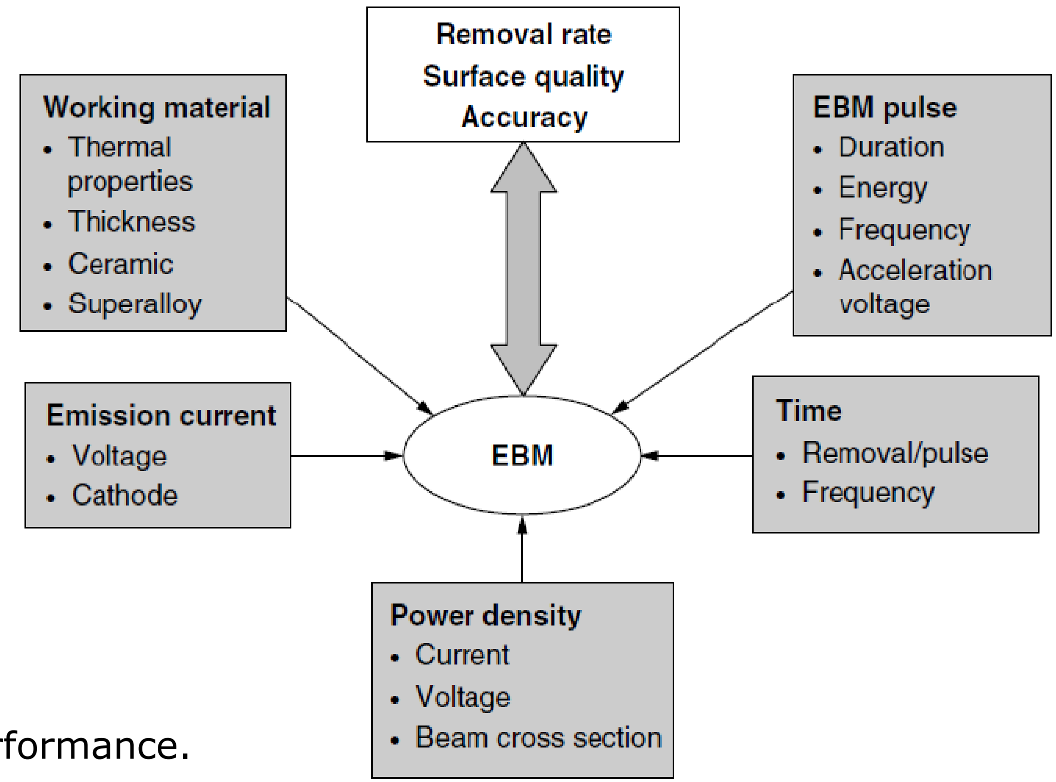


Figure 2.7.2: Parameters affecting EBM performance.

2.8 Plasma Beam Machining

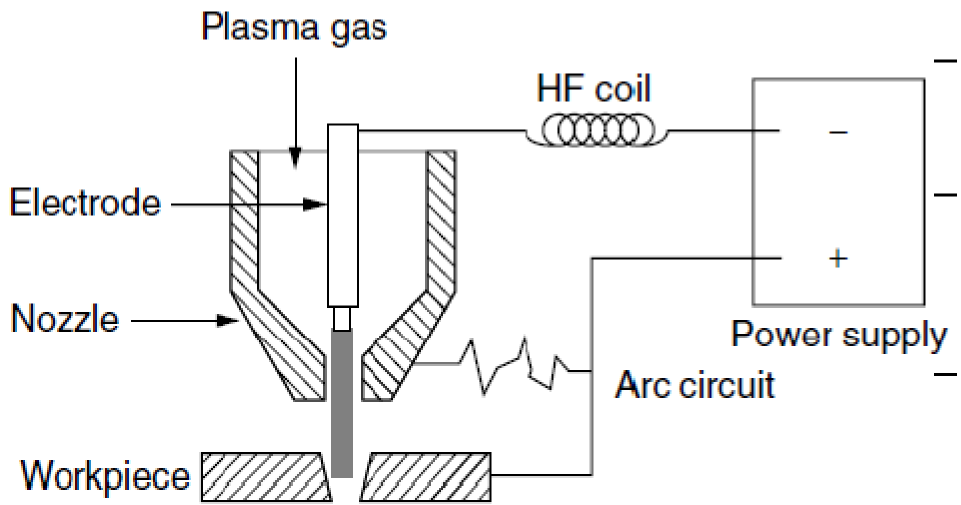


Figure 2.8.1: Transferred plasma arc system

– At 2000°C, gas molecules dissociate into atoms.

– At higher temperatures, 30,000°C, these atoms become ionized - plasma.

– A continuous arc is generated between a hot tungsten cathode and the water-cooled copper anode.

– A gas is introduced around the cathode and flows through the anode.

– The temperature, in the narrow orifice around the cathode, reaches 28,000 °C, producing a high-temperature plasma arc.

2.8.1 Applications

- Turning method for difficult-to-machine materials.
- Profile cutting of metals
- Can cut ut 1.5-mm-deep, 12.5-mm-wide grooves in stainless steel at 80 mm3/min,
- Recommended for parts that have subsequent welding operations
- High accurate underwater NC plasma cutting

Chapter 3: Welding and fabrication techniques

Def.: Welding is a process for joining two similar or dissimilar metals by fusion.

- It may apply pressure or the use of filler metal
- Fusion of metal takes place by means of heat (combustion of gases, electric arc, electric resistance, chemical reaction, frictional heat, or light energy.

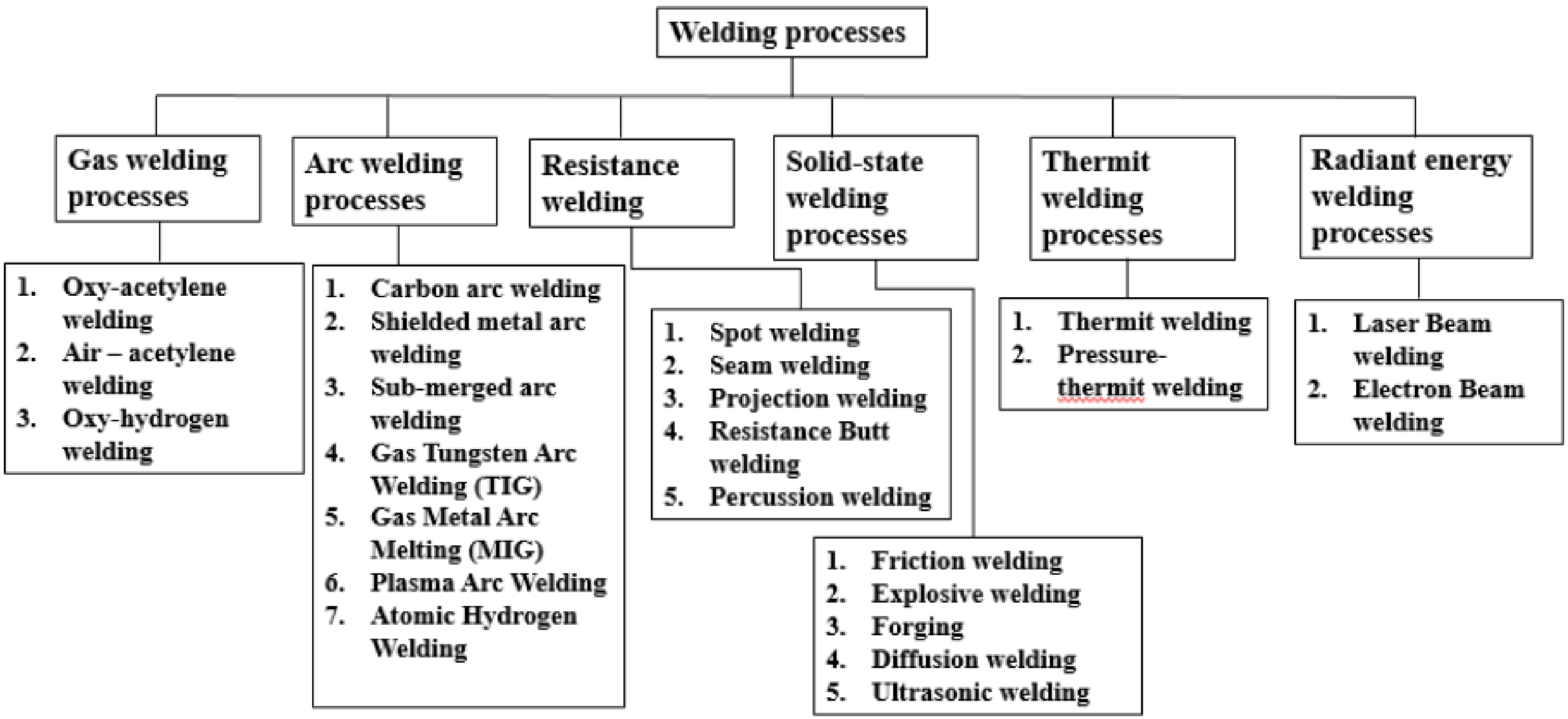


Figure 3.0.1: Welding processes

Chapter 3: Welding and fabrication techniques

3.1 Forge welding

Forge welding is a solid state welding process in which two pieces of metal are joined by heating them to a high temperature and then hammering them together.

3.1.1 Working

1. Work plates are heated together. The heating temperature is about 50-90% of its melting temp. Both the plates are coated with flux.

2. Manual hammering is then done by a hammer on an anvil for making a joint.

3. This process is repeated until a proper joint is created.

4. For welding large work pieces, mechanical hammering is used which is either driven by electric motor or by using hydraulic means.

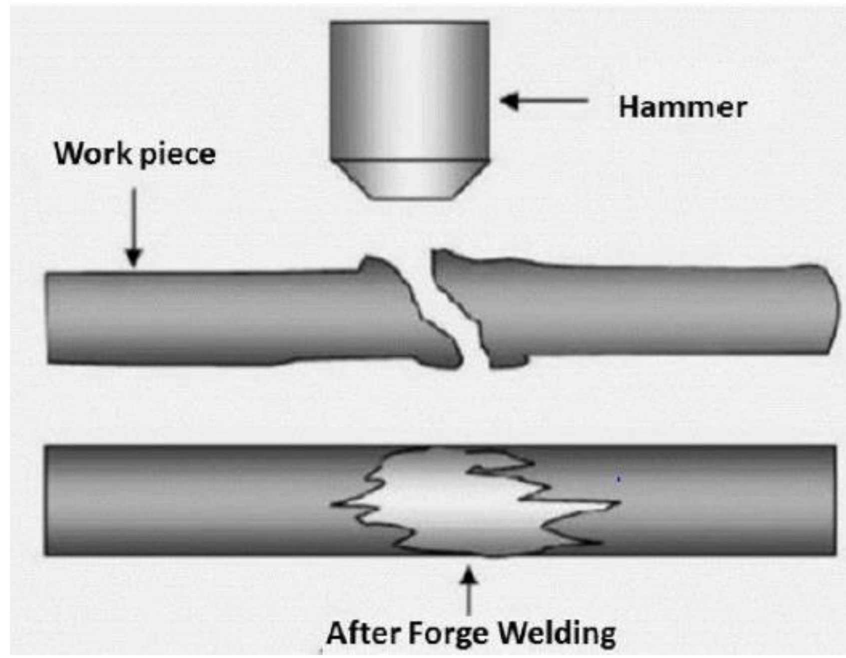


Figure 3.1.1: Schematic representation of forge welding using hammer

Chapter 3: Welding and fabrication techniques

3.1 Forge welding

3.1.2 Application

- It is used to join steel or iron.
- It is used to manufacture gates, prison cells etc.
- It is widely used in cookware.
- It was used to join boiler plates before introduction of other welding process.
- It was used to weld weapons like swords etc.
- Used to weld shotgun barrels.

Advantages

- It is a simple and easy joining process.
- It does not require any costly equipment for welding small pieces.
- It can weld both similar and dissimilar metals.
- Properties of weld joint are similar to those of the base material.
- No filler material is required.

Disadvantages

- Only small objects can be welded. Large objects will require large pressing machines and heating furnaces.
- High skill is required because excessive hammering can damage the welding plates.
- High welding defects involved.
- It is a slow welding process therefore not suitable for mass production.

3.2 Tungsten Inert Gas Welding

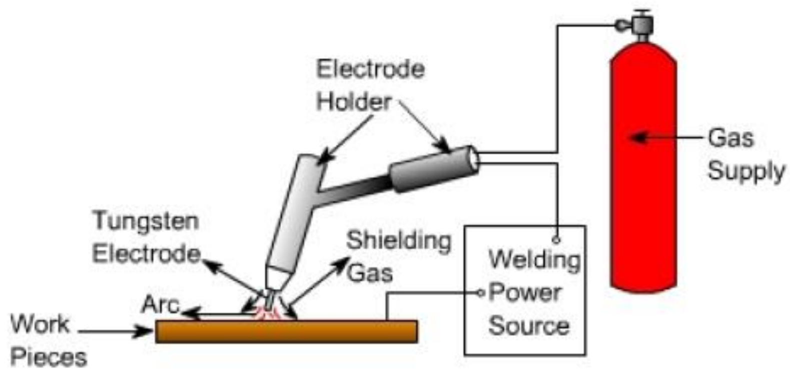


Figure 3.2.1: Schematic diagram of TIG welding system

- Arc is generated between non consumable tungsten electrode and work piece.
- The tungsten electrode and the weld pool are shielded by an inert gas normally argon and helium.
- Electrodes – tungsten and tungsten alloys.
- Electrode used only to generate an arc. The arc does not melt the tungsten, which has melting point above 3300 °C.
- Filler metal may or may not be used.
- The TIG process is used for welding aluminium and its alloy, stainless steel, magnesium alloy nickel base alloy, copper base alloy, carbon steel and low alloy steel.

3.2.1 Advantages of TIG

1. It produces high quality weld in nonferrous metals.
2. Practically no weld cleaning is necessary.
3. The arc and weld pool are clearly visible to the welder.

3.2.2 Disadvantages

1. Deposition rates are lower and hence completion time for weld joint is longer.
2. The welding cost is more because it uses argon gas for shielding.
3. Skill is required.

3.2.3 Application

1. The aerospace industry
2. For welding thin work pieces
3. Manufacture of space vehicles

3.3 Plasma Arc Welding

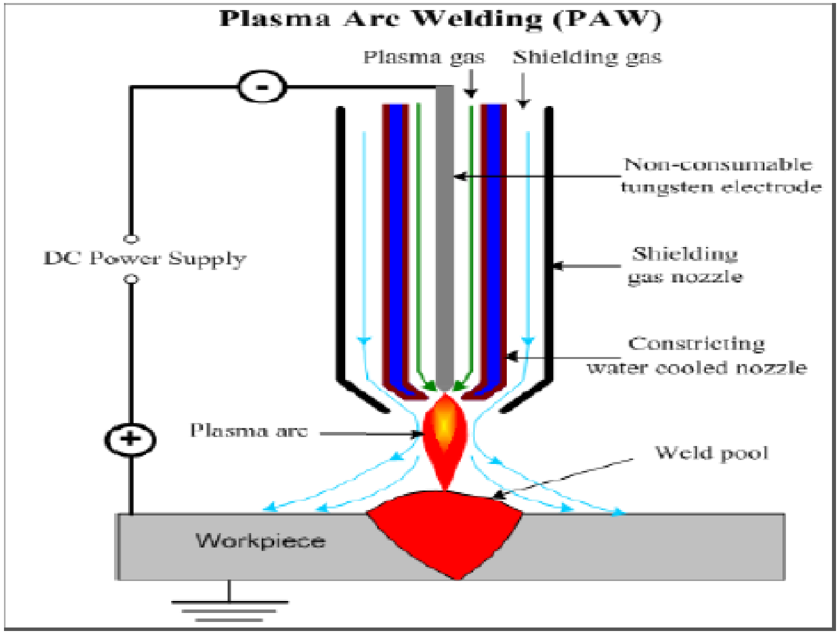


Figure 3.3.1: Schematic diagram of plasma arc welding system

- An arc welding process in which welding heat is obtained from a constricted arc set up between a tungsten electrode and the job.
- Employs two inert gases.

- Arc plasma temperature of the order of 11000°C

Types of PAW:

1. Non-transferred arc process
2. Transferred arc process:

Advantages of PAW

- Stability of arc
- Uniform penetration
- Simplified fixture
- Excellent weld quality
- Rewelding of the root of the joint saved

Disadvantages of PAW

- Welders need ear plugs
- Risk of electrical hazards
- Inert gas consumption is high
- Skilled welder required

Applications

- Tube mill application
- Welding of stainless steel tubes
- For welding high melting point metals

Chapter 3: Welding and fabrication techniques

3.4 Resistance Welding

– Pressure welding processes in which heavy current is passed for short time through the area of interface of metals to be joined.
– No fluxes are used, and filler metal rarely used
– The heat generated during resistance welding: $H = I^2RT$

3.4.1 Spot Welding

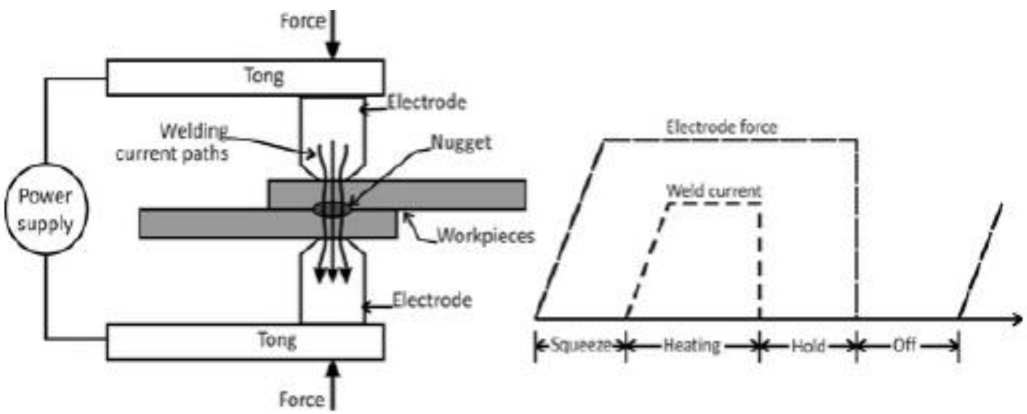


Figure 3.4.1: Schematic diagram of resistance spot welding system

- Overlapping sheet are joined at one or more spots by the heat generated by resistance
- Current range 3000 A - 40000 A
- Total thickness of 12 mm

Advantages

- High production rate
- Dissimilar metal can be welded
- High skill not required
- Most suitable for welding sheet metal

Disadvantages

- Suitable for thin sheet only
- High equipment cost

Applications of Spot Welding

- Automobile and aircraft industries.
- Containers and boxes frequently
- Spot welding of two 12.5 mm thick steel plates

3.5 Electron beam welding

- process in which the heat is generated when the electron beam impinges on work piece.
- High velocity electron beam - kinetic energy to thermal energy

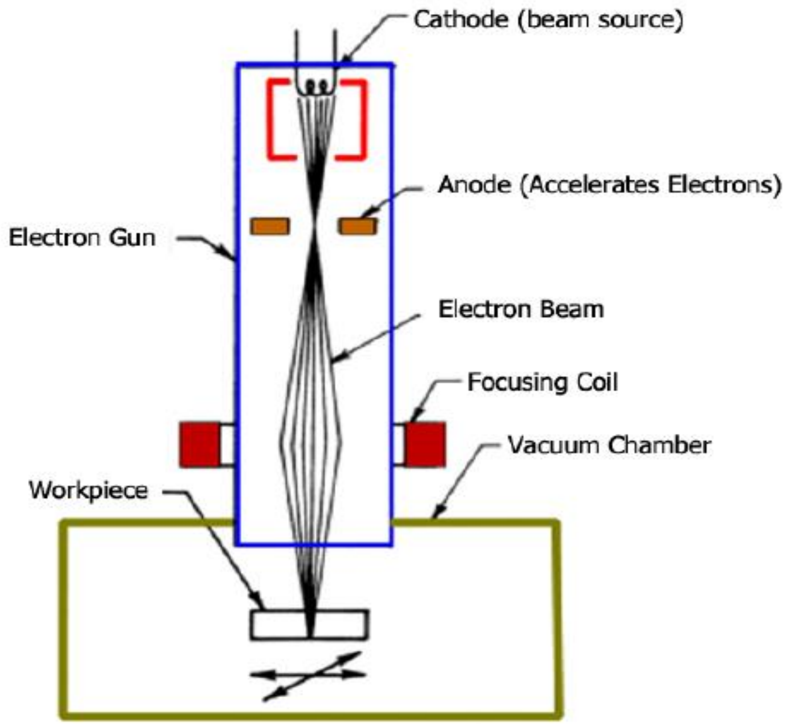


Figure 3.5.1: Schematic diagram of electron beam welding system

Advantages

- The penetration of the beam is high.
- Higher welding speeds btwn 125 & 200 mm/sec
- No filler metal or flux is required
- The heat affected zone is minimal
- Weld distortions are eliminated
- can weld any metal or ceramic, diamond, as thick as 150 mm.

Disadvantages

- High operating cost
- Expensive equipment
- Work size is limited by the size of the chamber

Applications:

Automobile, airplane, aerospace, farm and other type of equipment

3.6 Laser Beam Welding

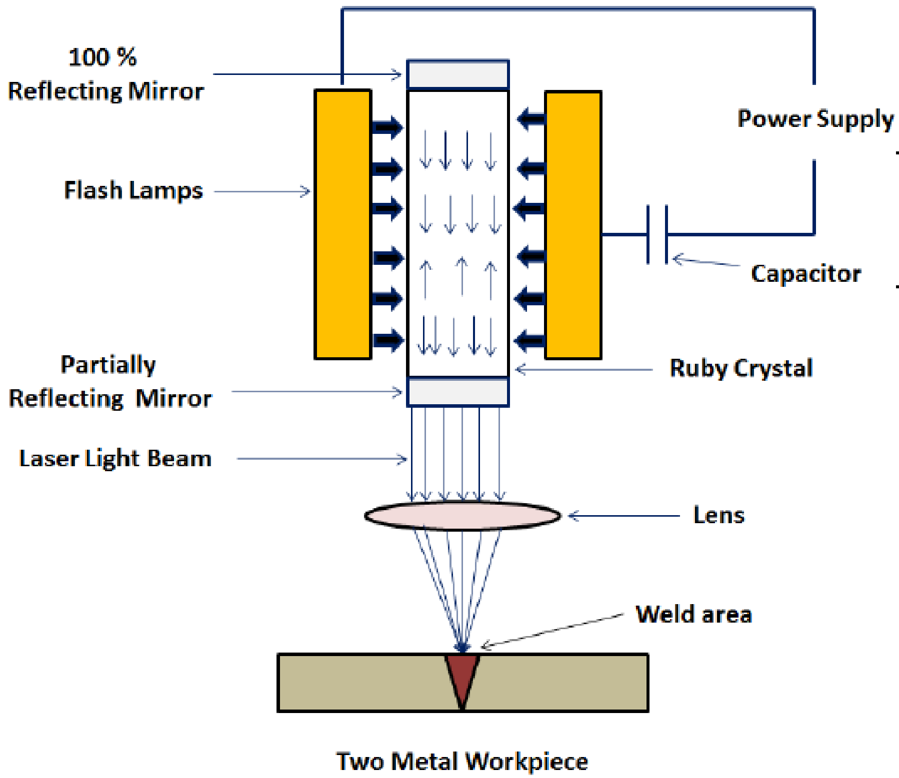


Figure 3.6.1: Schematic diagram of laser beam welding system

– The laser beam welding consist of: electrical storage unit, capacitor tank, triggering device, ash tube wrapped with a wire, focusing lens mechanism and work table.

– Capacitor bank is triggered, energy is injected into the wire that surrounds the flash tube.

– Flash tube or lamp emit thousands of flashes per second, thus converting electrical energy into light energy

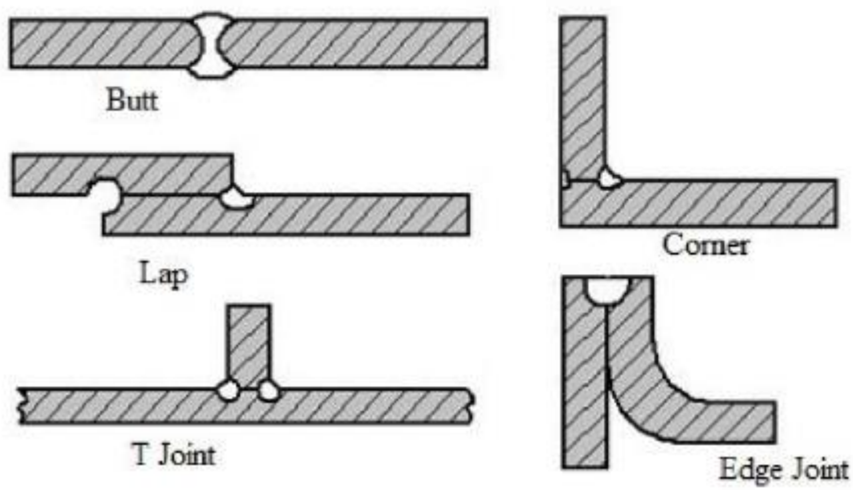
Advantages

- Used to weld dissimilar metals with varying physical properties.
- Minimal thermal distortion and shrinkage
- High production rate.
- High degree of precision

Disadvantages

- High energy losses
- Highly skilled operation
- High equipment cost
- Eye protection required

3.7 Design for welding: Design recommendations



- The most common classes of weld joints are: butt joints, lap joints, T-joints, corner joints, and edge joints

- butt, lap, T, and corner joints are shown with two fillets

Main welding aspects for consideration:

- Cost Reduction
- Minimizing Distortion
- Weld Strength

3.7.1 Cost Reduction

Some design recommendations to reduce costs:

- Welded assemblies should have few parts.
- Weld joints should have easy access of the welding nozzle
- Provide minimum amount of weld filler
- Welding should be done horizontally
- The designer should be aware of poor and good fit-up of parts
- Locating welds out of sight is better

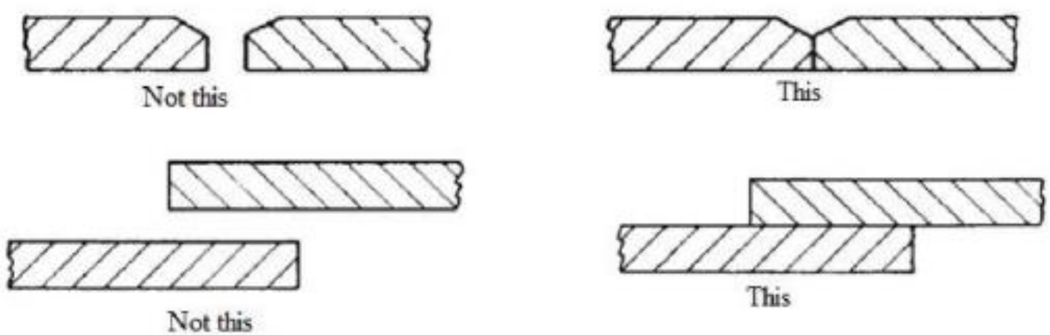


Figure 3.7.2: Poor and good fit-up of weld joints.

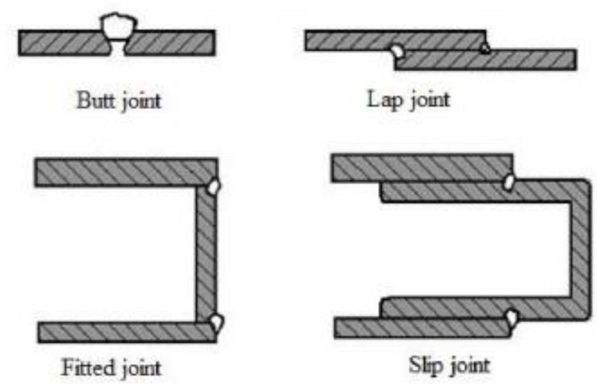
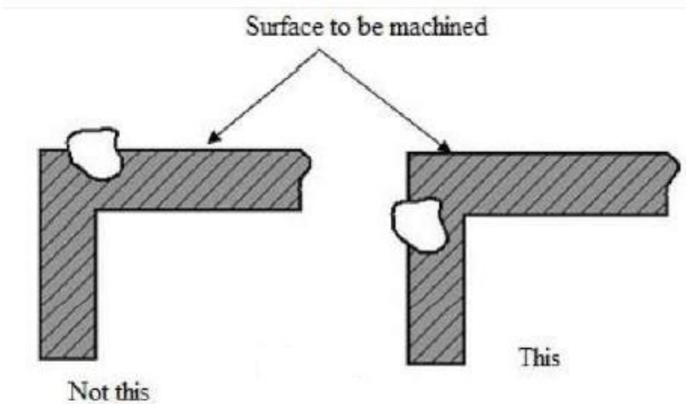


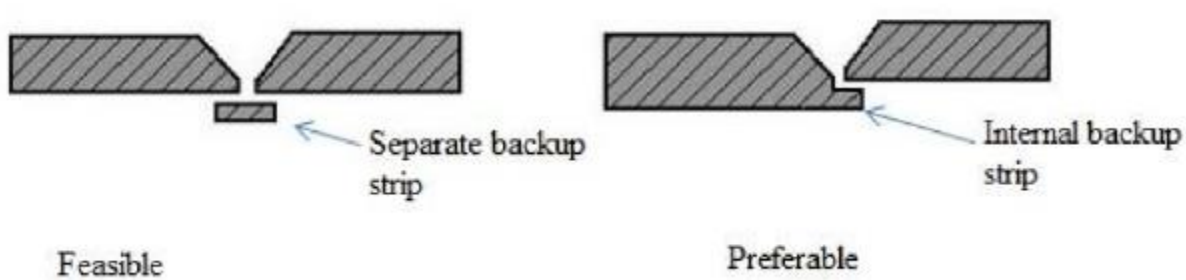
Figure 3.7.4: Joints on the right require less edge preparation

3.7.1 Cost Reduction

- The joint should require minimal edge preparation.
- Place welds away from parts to be machined



- Sometimes it is advantageous to include a weld backup strip as an integral part of one of the component to be welded.



3.7.2 Minimizing Distortion

Design recommendations for minimizing distortion:

- Good fit of parts minimizes welding time and controls the distortion. Figure 3.7.2
- Use thicker, rigid components to reduce distortion from welding
- Short flanged butt joints are preferable to join thin materials.

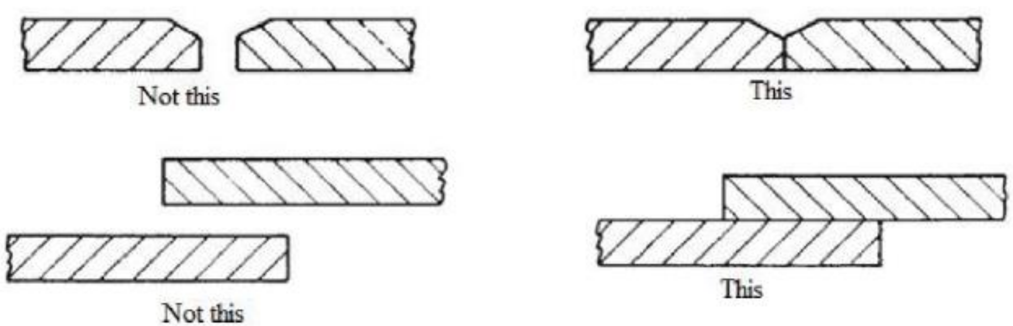


Figure 3.7.2: Poor and good fit-up of weld joints

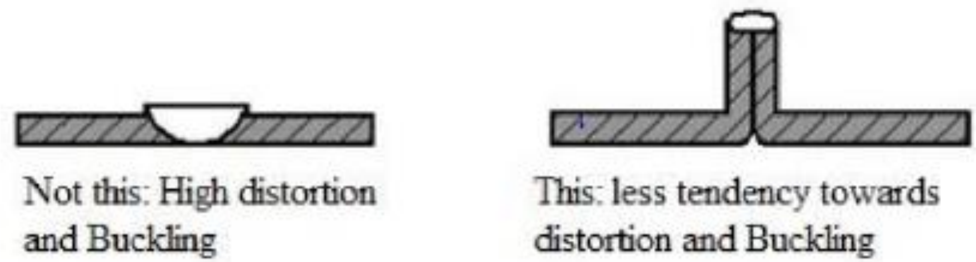


Figure 3.7.7: A short-flanged butt joint is often preferable for joining thin material

3.7.2 Minimizing Distortion

- Place welds opposite one another to reduce distortion, Figure 3.7.8.
- Consideration to shrinkage inherent in each weld while dimensioning welded assemblies.
- For sections of unequal thickness to be welded, distortion can be reduced by equalizing wall thickness at the joint, Figure 3.7.9.

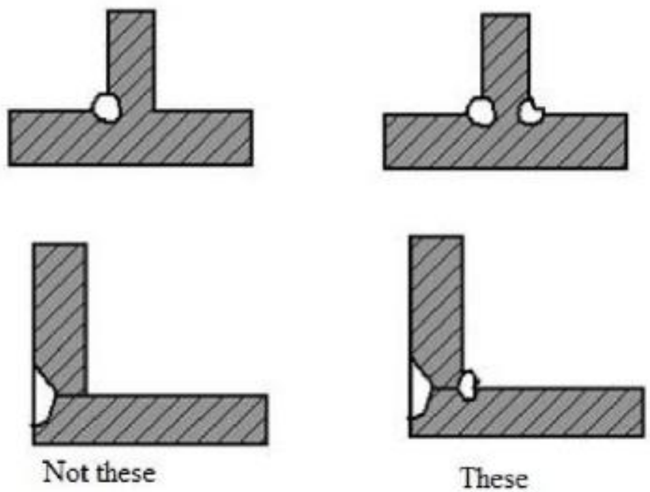


Figure 3.7.8: Use opposing welds to reduce angular distortion

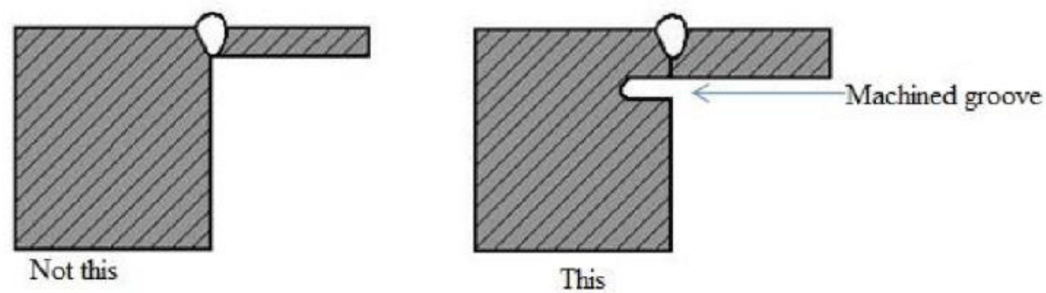


Figure 3.7.9: Use of a machined groove to equalize wall thickness to reduce distortion.

3.7.3 Weld Strength

- Butt joints are most efficient.

- Welds should be placed to minimise stress concentration in the fillet.

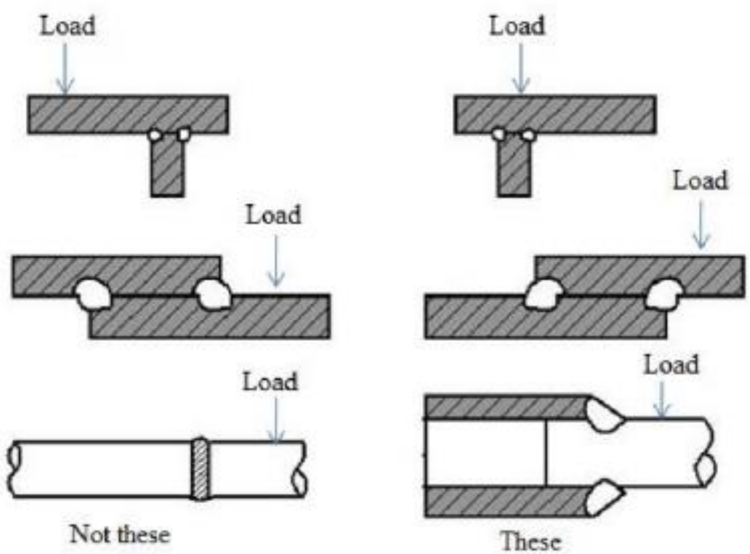


Figure 3.7.10: Design of weldments to minimize stress concentration in the weld fillet

Electron and Laser Beam Weldments

1. Butt joints are preferred to lap joints
2. Good fit up of the mating surface is essential because of the narrow beam.
3. Self-fixturing with minimum space occupancy.

Weldments and Heat Treatment

Rules concerning the use of heat treatment in weldments:

1. Carburized or hardened steels should not be welded.
2. Welding reduces the hardness of carburized or nitride mild (low-carbon) steels in the welded area.
3. Carbon in welded areas will affect the physical and chemical characteristics of the weld bead
4. Any straightening operation on carburized and hardened parts may result in some surface cracking in the welded area.

Thermit Welding: Process, Operation and Uses (With Diagram)

- Thermit welding is a chemical welding process in which an **exothermic chemical** reaction is used to supply the essential heat energy.
- That reaction involves the burning of **Thermit**, which is a mixture of fine aluminum powder and iron oxide in the ratio of about 1:3 by weight.

  The mixture reacts according to the chemical reaction:
  $8\ Al + 3\ Fe_3O_4 \rightarrow 9\ Fe + 4\ Al_2O_3$ + heat (3000˚C, 35 kJ/kg of mixture)

- Aluminum has greater affinity to react with oxygen
- Aluminum oxide floats on top of molten metal pool in the form of slag and pure iron (steel) settled below, because of large difference in densities.

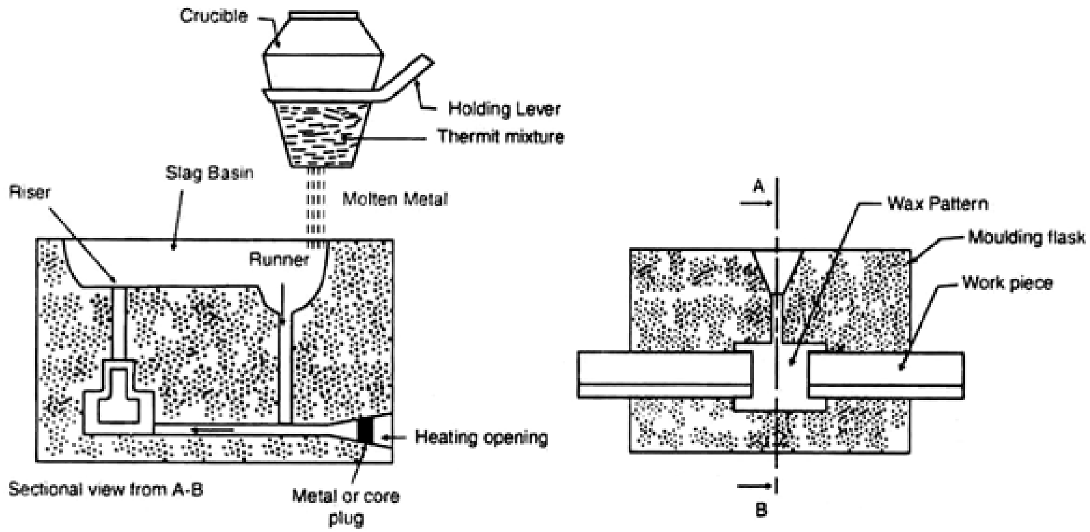


Fig. 7.40. Thermit welding.

Operation of Thermit Welding:

Thermit welding process is essentially a casting and foundry process, where the metal obtained by the Thermit reaction is poured into the refractory cavity made around the joint.

Chapter 3: Welding and fabrication techniques

The various steps involved in Thermit welding are:

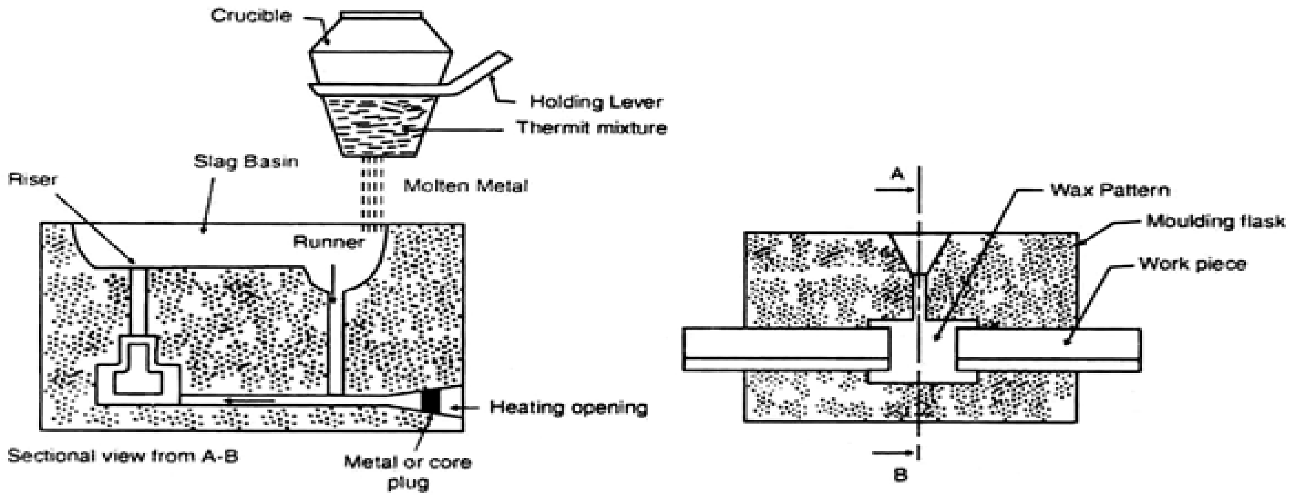


Fig. 7.40. Thermit welding.

1. The two pieces of metal to be joined are properly cleaned

2. The wax is poured into the joint so that a wax pattern is formed

3. A moulding box is kept around the joint and refractory sand is packed carefully around the wax pattern.

4. A bottom opening is provided to run off the molten wax. The wax is melted through this opening which is also used to preheat the joint. This makes it ready for welding.

Some applications are:

(i) Used for the welding of very thick and heavy plates.

(ii) Used in joining rail roads, pipes and thick steel sections.

(iii) Used in repairing heavy castings and gears.

(iv) Suitable to weld large sections such as locomotive rails, ship hulls etc.

(v) Used for welding cables made of copper.

Advantages of Thermit Welding:

1. It is a simple and fast process of joining similar or dissimilar metals.
2. This process is cheap, as no costly power supply is required.
3. This process can be used at the places where power supply is not available.

Disadvantages of Thermit Welding:

1. Itis essentially used for ferrous metal parts of heavy sections.

2. It is uneconomical for welding cheap metals and light parts

5. The Thermit is mixed in a crucible which is made of refractory material.

6. The igniter (normally barium peroxide or magnesium) is placed on top of the mixture and is lighted with a red hot metal rod or magnesium ribbon.

7. The reaction takes about 30 seconds and highly super-heated molten iron is allowed to flow into the prepared mould cavity around the part to be welded.

8. The super-heated molten metal fuses the parent metal and solidifies into a strong homogeneous weld.

9. The weld joint is allowed to cool slowly.

Chapter 4: Jigs and fixtures

Jigs and fixtures are production tools used to accurately manufacture duplicate and interchangeable parts.

4.1 Jigs

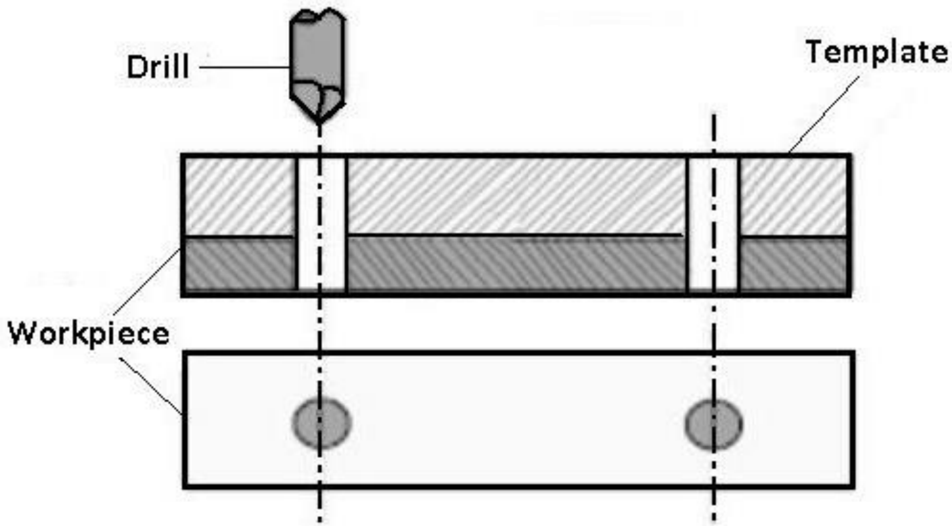
- A work holding device that **holds**, **supports** and **locates** the work piece and **guides** the cutting tool for a specific operation (drilling, boring, reaming or tapping holes).

- A jig is not fastened to the machine on which it is used.

- Jigs make it possible to drill, ream and tap holes at much greater speeds and with greater accuracy.

- Limit and control the path of the cutting tool with the help of bushings.

Types of Jigs



TEMPLATE JIG

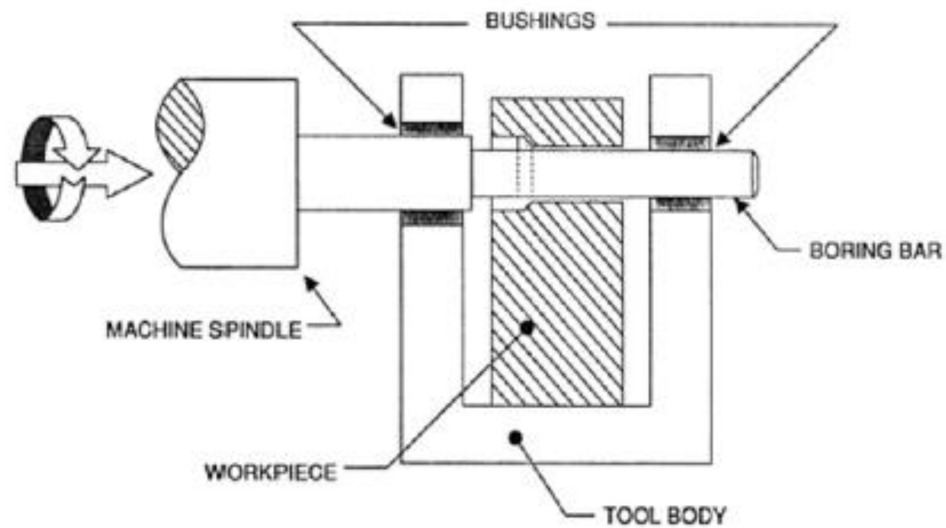


Figure 4.1.1: Boring jig

The plate, having two holes, acts as a template which is fixed on the component to be machined.

Chapter 4: Jigs and fixtures

Types of Jigs

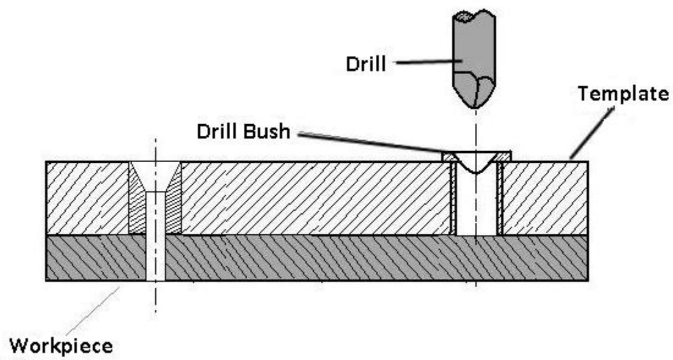
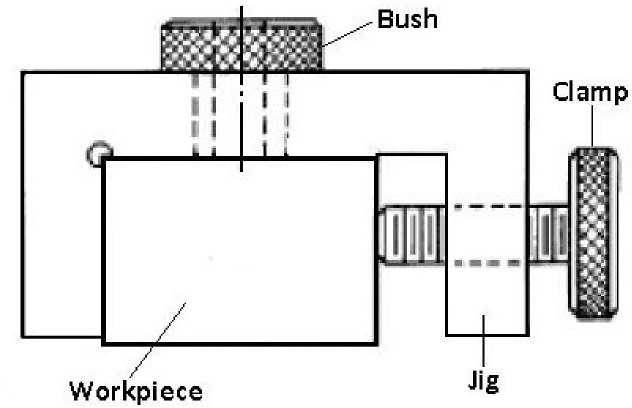


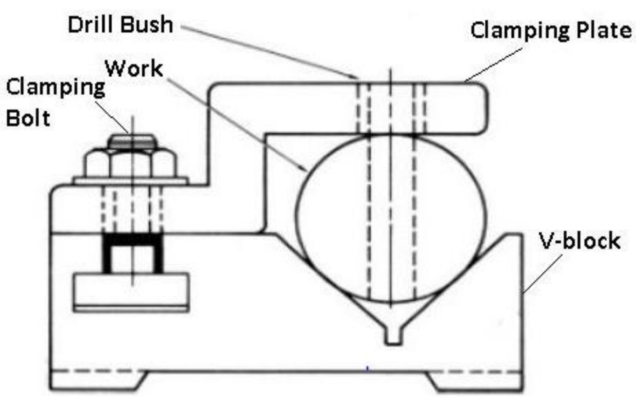
PLATE JIG

A plate jig is an improvement of the template jig by incorporating drill bushes on the template



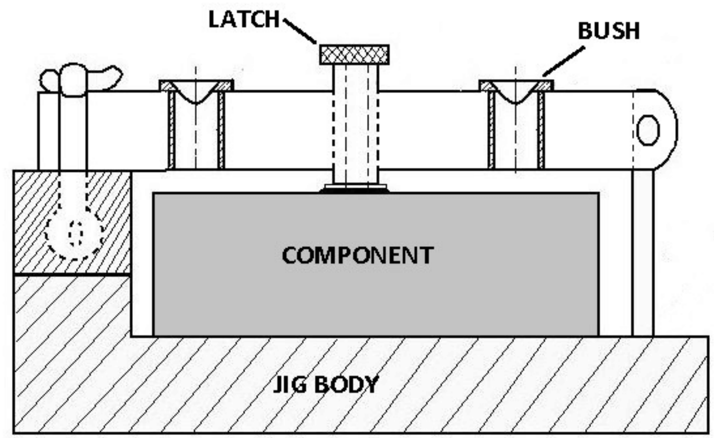
CHANNEL JIG

Channel Jig: Channel jig is a jig having a channel-like cross section.



DIAMETER JIG

Diameter jig is used to drill radial holes on a cylindrical or spherical workpiece.



LEAF JIG

4.2 Fixtures

- It is a work holding device that **holds**, **supports** and **locates** the work piece for a specific operation but **does not guide** the cutting tool.

- Fixtures are used for machining operations like milling, shaping, turning, broaching, etc.

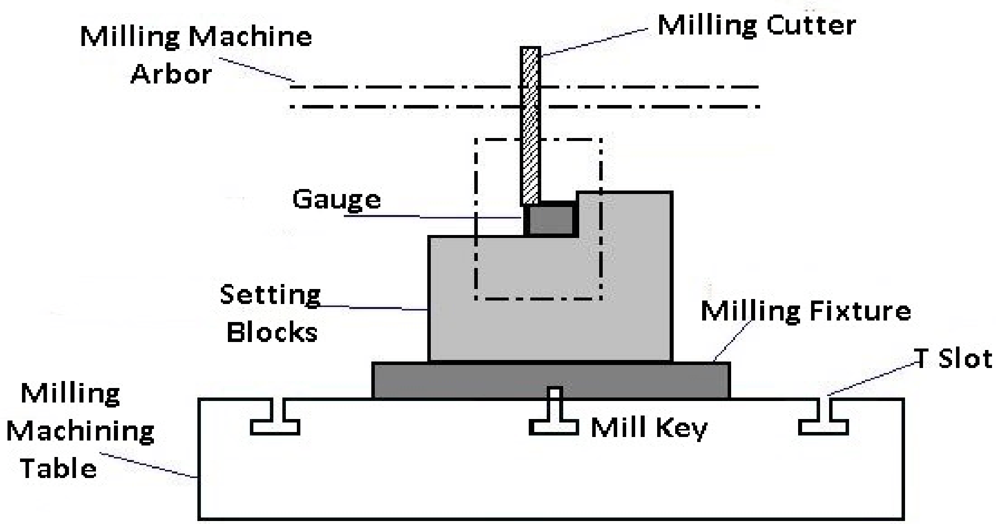
- A fixture is also fixed to the machine on which its is used.

- The accuracy of machining depends upon the operator and construction of machine tool.

- Examples: Vises, chucks

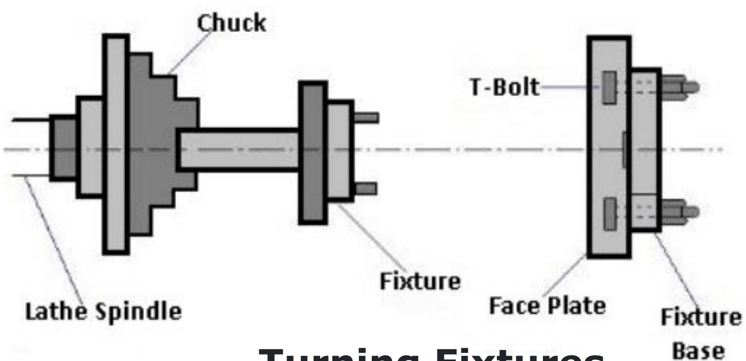
Chapter 4: Jigs and fixtures

Types of Fixtures



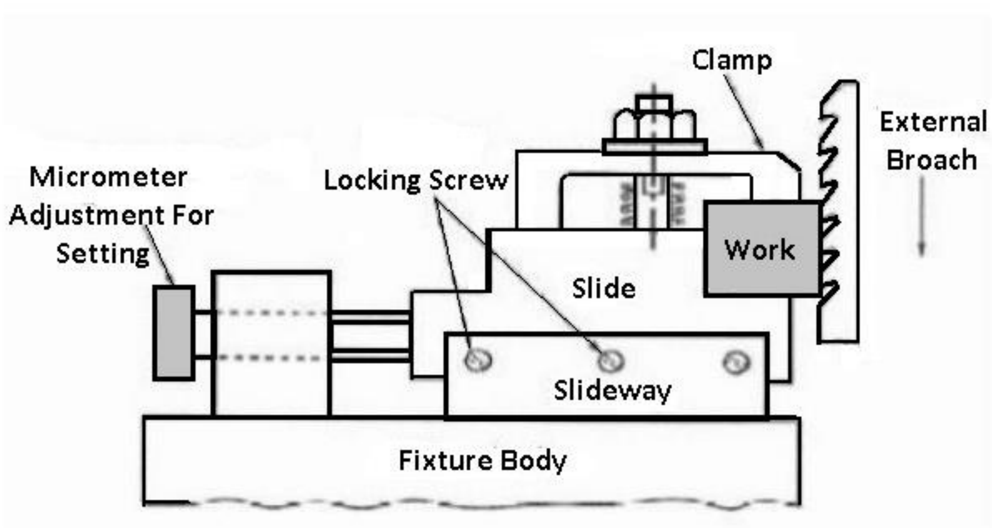
Milling Fixture

Figure 4.2.1: 4-jaw and 6-jaw chucks

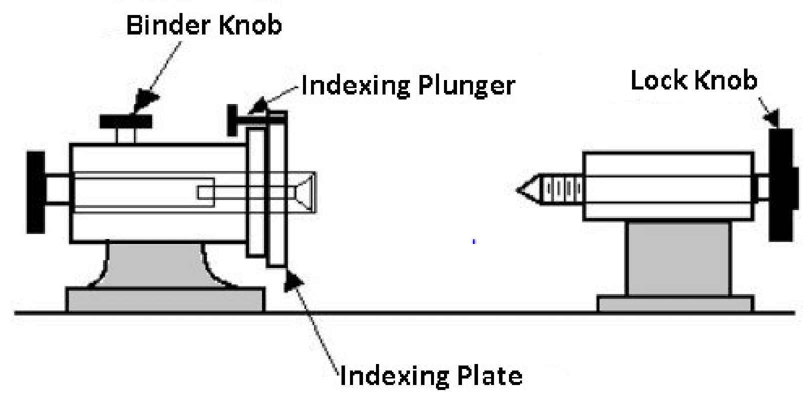


Turning Fixtures

4.2 Fixtures



Broaching Fixture



Indexing Fixture

Chapter 4: Jigs and fixtures

4.2.1 Differences between jigs and fixtures

JIGS	FIXTURES
1. It is a work holding device that holds, supports and locates the workpiece and guides the cutting tool for a specific operation	1. It is a work holding device that holds, supports and locates the workpiece for a specific operation but does not guide the cutting tool
2. Jigs are not clamped to the drill press table unless large diameters to be drilled and there is a necessity to move the jig to bring one each bush directly under the drill.	2. Fixtures should be securely clamped to the table of the machine upon which the work is done.
3. The jigs are special tools particularly in drilling, reaming, tapping and boring operation.	3. Fixtures are specific tools used particularly in milling machine, shapers and slotting machine.
4. Gauge blocks are not necessary.	4. Gauge blocks may be provided for effective handling.
5. Lighter in construction.	5. Heavier in construction.

Advantages of Jigs and fixtures

- Increased productivity
- Facilitate interchangeability and high quality products
- Skill reduction
- Cost reduction

Fundamental principles of jigs and fixtures design

- Locating points
- Fool Proof
- Reduction of idle time
- Weight of jigs and fixtures
- Jigs provided with feet
- Materials for jigs and fixtures: Hardened materials to avoid frequent damage and to resist wear. Example- MS, Cast iron, Diesteel, CS, HSS.
- Clamping device

Essential features of jigs and fixtures

- Reduction of idle time
- Cleanliness of machining process
- Replaceable part or standardization
- Provision for coolant
- Hardened surfaces
- Fool-proofing
- Economic soundness
- Easy manipulation
- Position of clamps
- Ejecting devices
- Safety

Materials used

- High speed steel
- Die steels
- Carbon steels
- Collet steels
- Non shrinking tool steels
- Nickel chrome steels
- High tensile steels
- Mild steel
- Cast iron
- Nylon and fiber
- Phospher bronze

- Sometimes referred to as post-processing

- The important applications include:

- Improving the hardness

- Improving the wear resistance

- Controlling friction, Reduction of adhesion, improving the lubrication, etc.

- Improving corrosion resistance

- Improving aesthetics

Chapter 5 : Decorative and protective surface treatment

- Mechanical hardening of the surface
- Case hardening
- Thermal spraying
- Vapour deposition
- Electroplating
- Electroless plating
- Anodizing
- Painting

5.1 Mechanical hardening of the surface

- Applies mechanical impulses (e.g. light hammering) on the surface of a metallic part.

- Examples of these processes include:

- **Shot peening** - uses tiny balls of metal or ceramic.

- **Water-jet peening** - uses a jet of water at high pressures, e.g. 400 MPa.

- **Laser peening** - surface is hit by tiny impulses from a laser an expensive process used to improve fatigue strength of jet fan blades and turbine impellers.

- **Explosive hardening** - a layer of explosive coated on the surface is blasted resulting in surface hardening. Used to harden the surface of train rails.

5.2 Case hardening

- Used to harden the outer surface of parts such as gear teeth, cams, shafts, bearings, fasteners, pins, tools, moulds, dies etc.

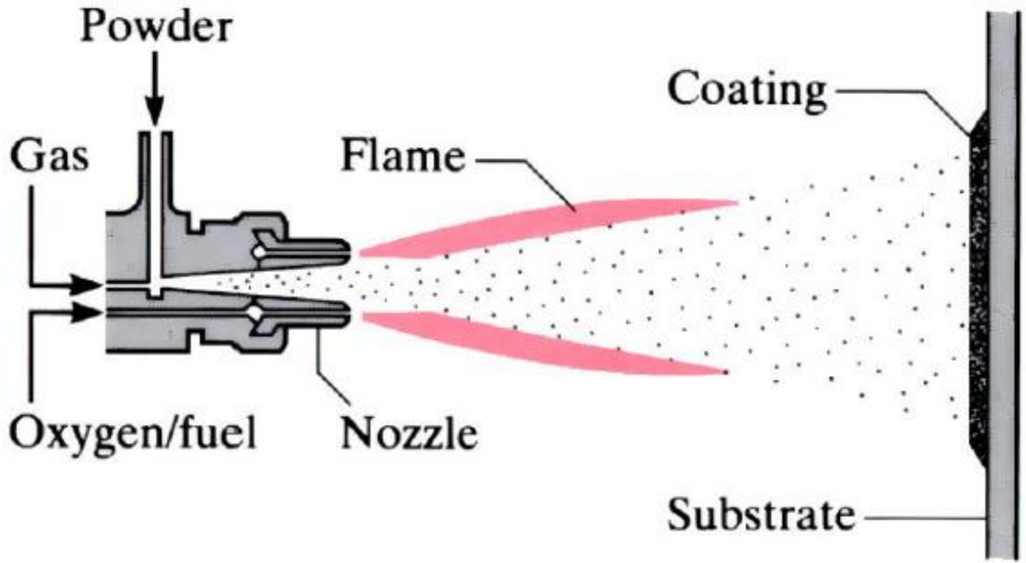
- Use of these components involves dynamic forces, occasional impacts, and constant friction.

- The chemical structure of the metal is changed by diffusing atoms of an alternate element which results in alterations to the micro-structure on the crystals on the surface.

- The metal parts are put in an oven, and heated with the atmosphere containing excess of a gaseous/liquid form of the doping substance.

- Used to case harden steel and other iron alloys, including low carbon steels, alloy steels, tool steels e.t.c.

5.3 Thermal spraying



Flame powder

- Metal is melted in a specially designed spray gun (using oxy-fuel, plasma, or other means to heat the sprayed metal till it melts).
- High pressure gas then sprays the liquid metal, depositing a layer on top of the part similar to a painting process.

5.4 Vapour deposition

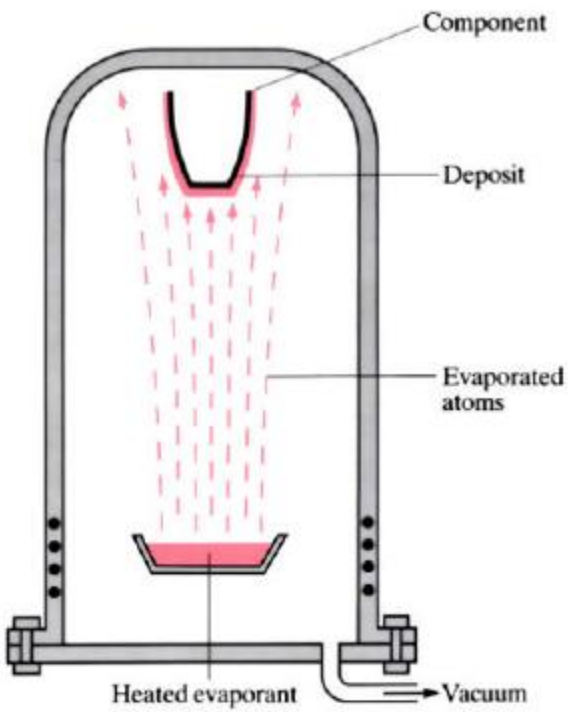
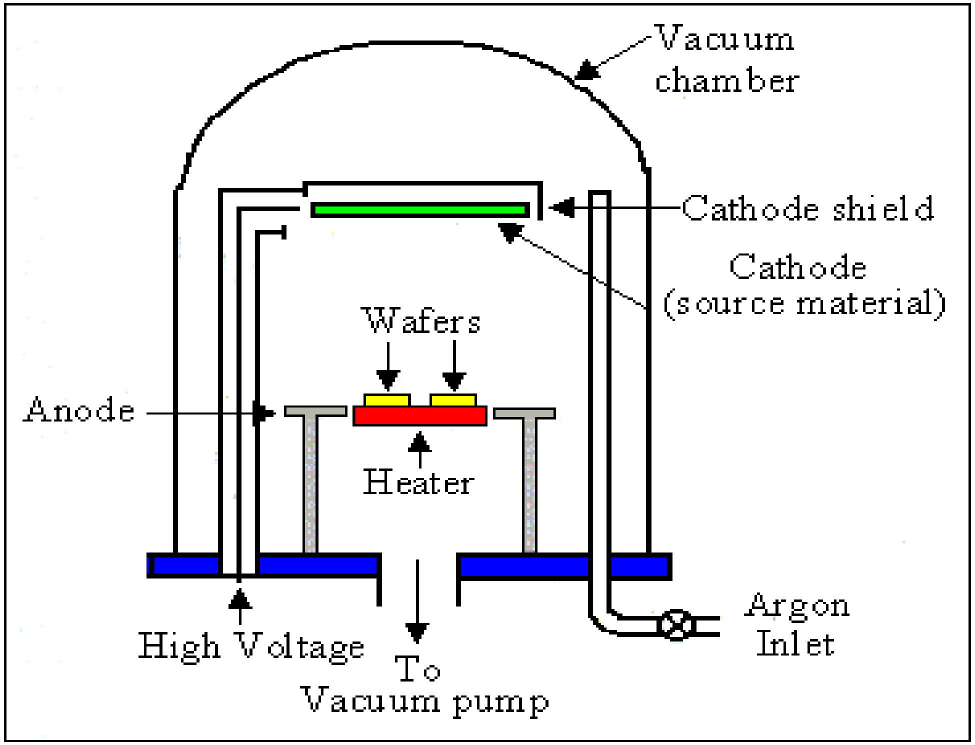


Figure 5.4.1: Physical vapour deposition

- The layer of deposited material is very thin only a few microns.
- Coating material - metals, carbides, nitrides, or ceramics.
- The metal to be deposited is heated in an enclosed oven at high temperature and very low pressure; some of the metal vapour deposits as a thin layer on the part.
- Typical applications include surface coating of cutting tools, e.g. drills, reamers, punches, dies etc.

5.4 Vapour deposition



Sputtering surface treatment process

- Used in production of electronic chips.
- An electric field ionizes an inert gas (e.g. Argon), and the ions are used to bombard the coating substance.
- Atoms of the coating material (on the cathode), when hit by the ions, are knocked out of the lattice, and later get deposited on the surface of the part by condensation.
- Aluminum sputtering is used to create most internal connections in VLSI chips in semiconductor manufacturing.

5.5 Electroplating

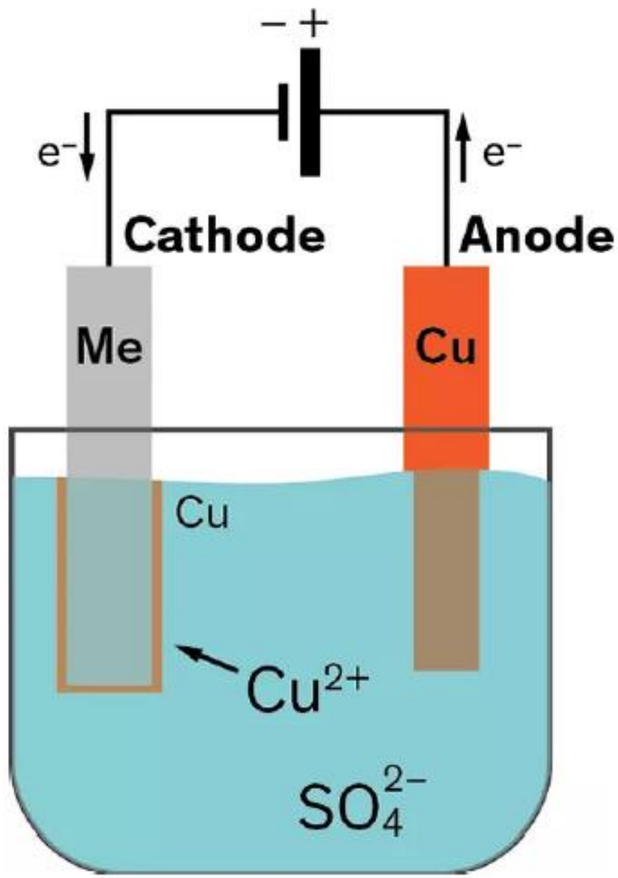


Figure 5.5.1: copper plating

- A thin layer of metal is deposited on the surface of an electrically conducting part.
- The part is used as a cathode, and the depositing material forms the anode.
- On the application of voltage, the metal from the anode is dissolved into the solution and deposited on the cathode – electrolysis.

5.6 Electroless plating

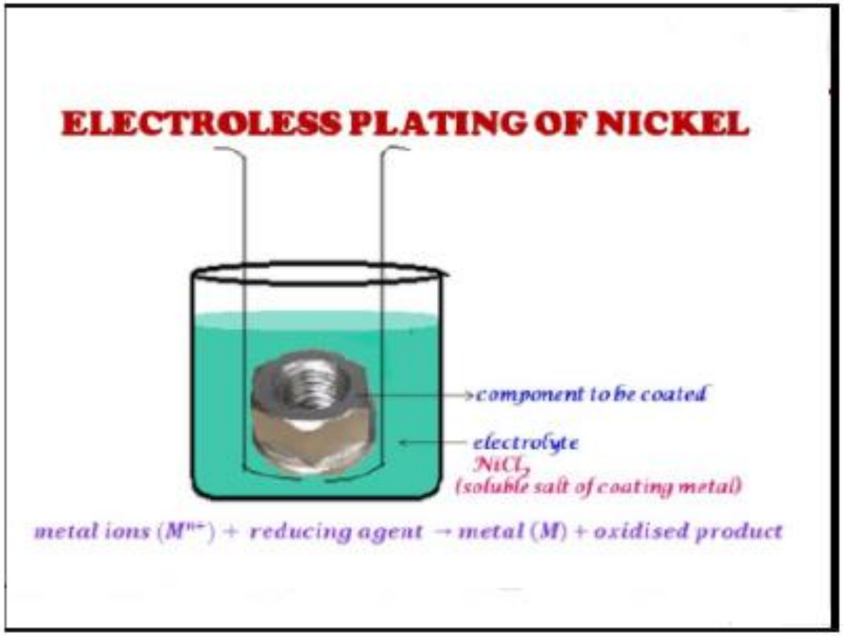


Figure 5.6.1: Nickel electroless plating

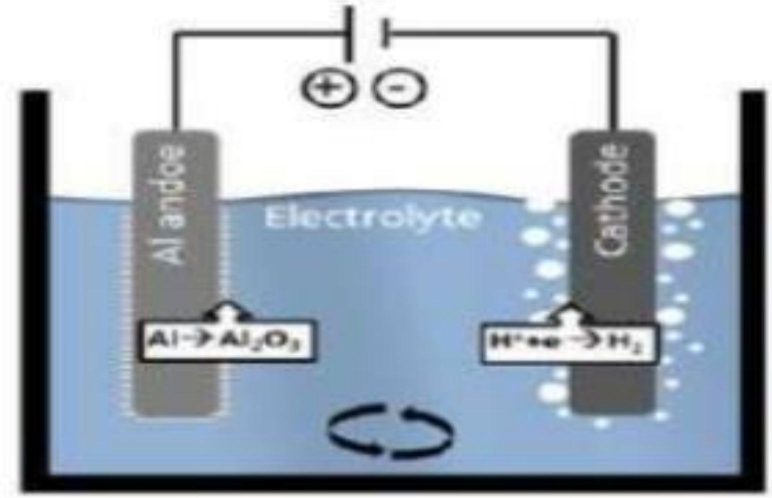
- The plating is achieved by a purely chemical reaction in the solution that causes the metal to be deposited.
- Used to plate non-conducting parts with a layer of metal.
- Example, the deposition of Nickel - the reduction of Nickel chloride in solution by Sodium hypophosphite, which causes Ni metal to be deposited on the part.
- Electroless nickel plating are used to provide protection from wear and abrasion, resistance against corrosion, and add hardness to parts of all conditions.
- It's commonly used in coating applications in engineering, aerospace, oil and gas, construction, electronics and several others.

5.7 Anodizing

- **Anodizing** is an electrochemical process that converts the metal surface into a decorative, durable, corrosion-resistant, **anodic oxide** finish.

- Aluminium is ideally suited to anodizing, although other nonferrous metals, such as magnesium and titanium, can be anodized.

- The process uses the metal part as an anode; using electrolytic process, a layer of hard metal oxide is formed at the anode (i.e. on the surface of the part).



- Common examples include aluminium parts, such as picture frames, car-body parts, door-knobs and other building fixtures, bathroom fixtures and racks, sporting goods, e.g. baseball bats, and so on.

5.8 Painting

Most common surface treatment is painting.

Examples of its functional value include:

(i) Car body paints: corrosion resistant
(ii) Boats painted: anti-corrosion paint with (toxic) chemicals to avoid growth of barnacles, seaweed etc.
(iii) Examples of aesthetic or decorative value are too numerous.

Paints are of three types:

(a.) **Enamel:** Oil-based paints that produce a smooth surface and glossy appearance

(b.) **Lacquers:** These are resin based paints that dry to a thin coat after the solvent evaporates out. Common examples are varnish used in painting wood.

(c.) **Water-based paints:** common examples include several wall paints and home-interior paints.

5.8 Painting

The most common methods of paint application include:

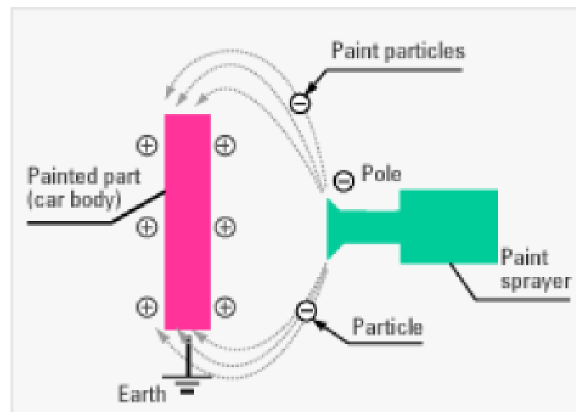
(i) Dip coating

(ii) Spray coating

(iii) Electrostatic spraying

(iv) Silk-screening

Figure 5.8.2: Automated spray painting of a car body in a BMW plant



8.1: Schematic of an Electrostatic Spray Painting process

Mass production is the manufacturing of ***large quantities*** of ***standardized products***, often using ***assembly lines*** or ***automation technology***.

The main characteristics of mass production are:
- Specialized machines
- Interchangeable parts
- Division of labour

An early example of mass production is Henry Ford's - first moving assembly line in 1913.

- Assembly line broken into 84 steps
- In 1914, a mechanized belt was added
- Production time reduced from over 12 hours to 2.5 hours

Fords Model T (1908 – 1927)

Advantages of mass production

1. Increased productivity
2. Uniformity in products
3. Lower production cost leading to lower prices for products
4. Higher quality of life
5. Faster production
6. Less error
7. Increased worker safety
8. Job specialities

Disadvantages of mass production

1. High initial costs
2. Less flexibility
3. High energy consumption
4. Pollution
5. Affects employees' well-being
6. Lack of product uniqueness
7. Unhealthy habits
8. Inventory build-up
9. Loss of jobs for unskilled workers

6.1 Machining Centers

- A machining center is an advance machine tool capable of turning, milling and drilling a work piece, usually metal, in a single operation.

- As an example, machining centers in the automobile industry are used for efficient grinding and drilling of engine parts as well as for making dies for body components.

- Feature a computerized automatic tool change function, that automatically retrieves and exchanges tools from a tool magazine.

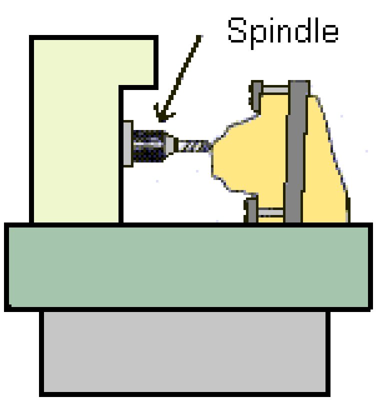
- Machining centers can continuously perform several types of machining at the same time on different surfaces of a workpiece, greatly improving production efficiency.

6.1.1 General Structure and Types of Machining Centers

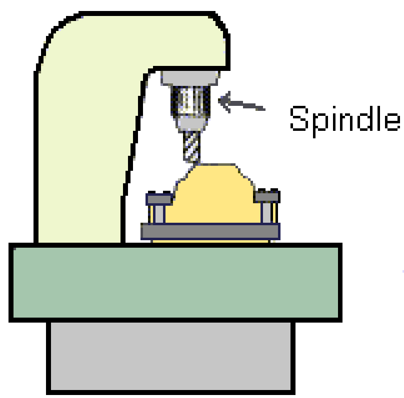
Three types based on their structure: horizontal, vertical, and gantry types.

- The **horizontal type** - the 1st to be developed can be defined as a machine where the spindle to which the cutting tool is attached, is mounted horizontally (parallel to the floor).
- **Vertical types** have the spindle set upright.

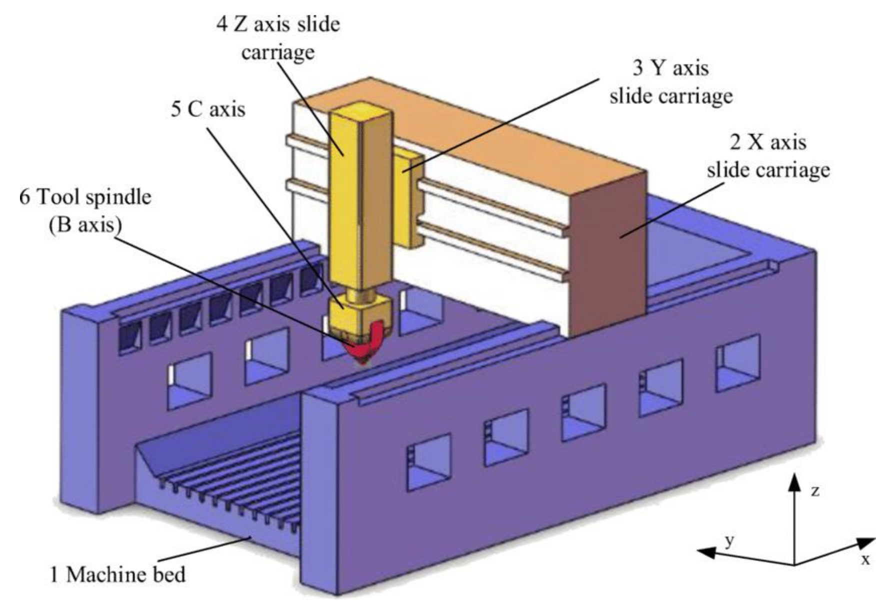
- **Gantry types** have a gate – like structure with the spindle mounted on the ceiling of the gate, facing downward.



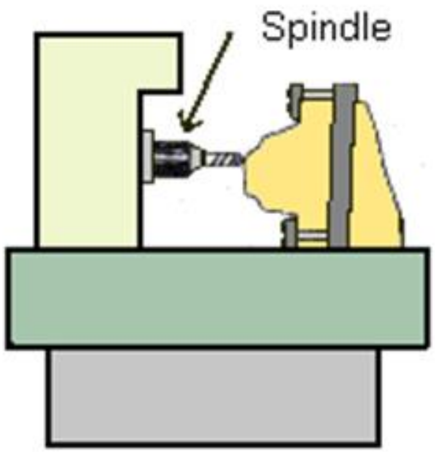
Horizontal type



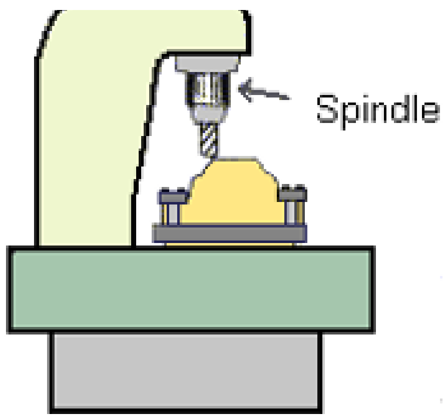
Vertical type



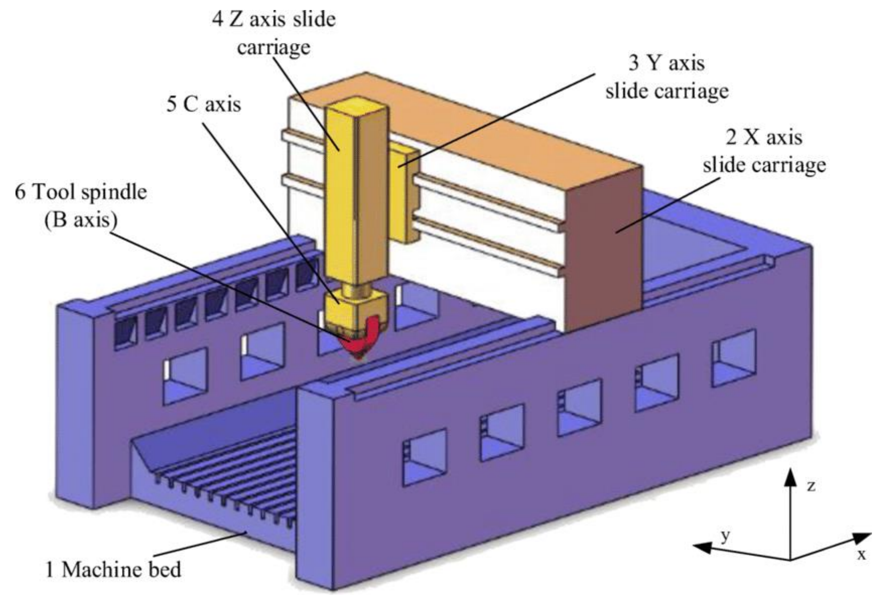
Gantry type



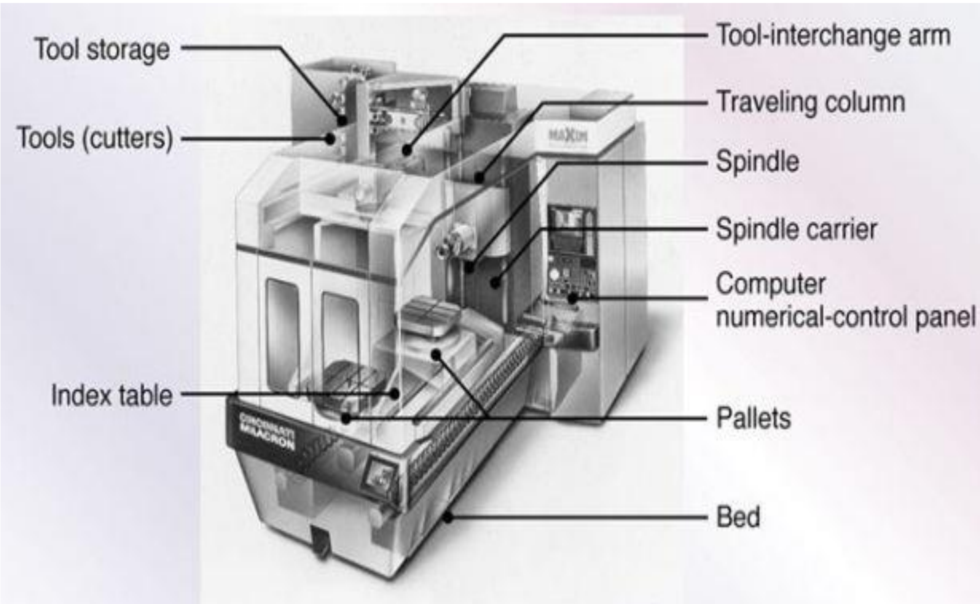
Horizontal type



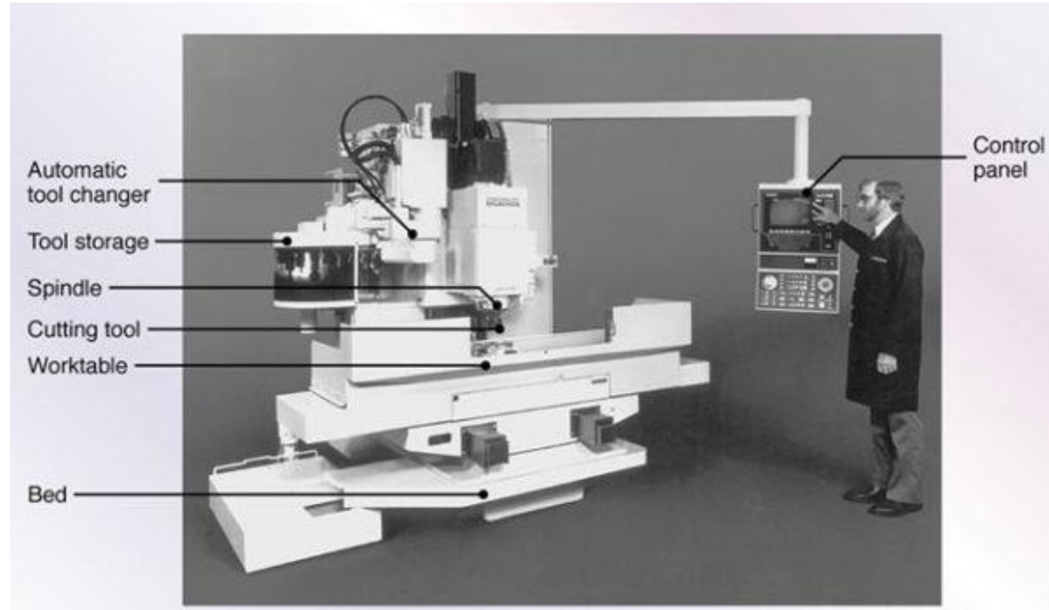
Vertical type



6.1.1 General Structure and Types of Machining Centers



A horizontal-spindle machining center equipped with an automatic tool changer.



A vertical-spindle machining center.

The general structure of a machining center consists of:

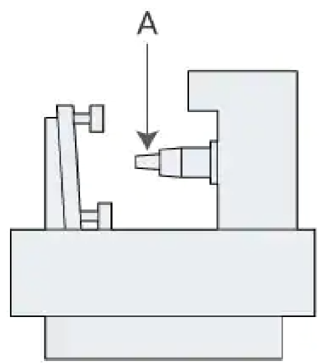
- a base part called a bed at the bottom
- a saddle that moves on the bed
- a table attached on top of the saddle for placing the raw material
- a column installed perpendicularly to the bed
- a spindle head where the cutting tools are attached (tool storage)
- automatic tool changer

6.1.1 General Structure and Types of Machining Centers

Differences Between Horizontal and Vertical Types

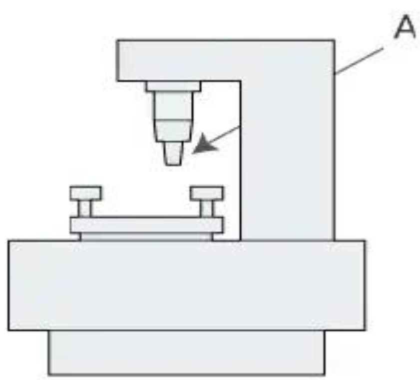
Horizontal machining center

Cutting tool is horizontal



Vertical machining center

Cutting tool is vertical



Horizontal machining centers

- Machines in the horizontal direction.
- The column moves along the X axis, the saddle along the Y axis, and table along the Z axis, and this combination enables 3D machining.
- A B-axis that rotates the table horizontally, enabling machining using a total of four axes.
- Can machine four surfaces of a work piece all at once. eliminates manually switching of the workpiece, contributes to higher machining precision.
- Horizontal machining allows chips to fall down

Vertical machining centers

- Take up less installation space, making them a popular choice.
- Machining from above the workpiece allows operators to work while comparing the machining to the design drawings.
- However, machining on the top of the workpiece causes chips to accumulate on the workpiece.

6.2 Job Production

– Job production (one-off production) is where ***one single item*** is designed and made at a time.
– Associated with high quality parts, customized orders and unique items.
– Examples: satellites for scientific discovery, customized cars, designer clothes, special machine parts, prototypes for marketing and quality testing, hand-made furniture, jewellery, wedding cakes.
– Suitable for smaller establishments

Advantages

- Each piece is made to the exact customer requirements.
- Job satisfaction for workers is high
- Quality of products is very high

Disadvantages

- The products are very expensive
- The work is very time consuming

6.3 Batch Production

− Used where several of the same product are made

− When the required number has been produced, production stops

− Another batch of the same product can be made later if there’s demand

Examples: Electrical goods, Clothing, Baked goods, Books/ newspapers, Pharmaceuticals, Fast food

Advantages

- Workers may specialise to some degree
- Labour costs are reduced resulting in cheaper products
- Production is faster

Disadvantages

- The work is less interesting and repetitive
- More space required for working and storage
- Quantities of raw material must be stored

6.4 Lean Production

- Lean is about doing more with less: less time, inventory, space, labor, and money.
- A commitment to eliminating waste, simplifying procedures and speeding up production.
- Lean Manufacturing (Toyota Production System) is, in its most basic form, the systematic elimination of waste. 21st century production system

Five areas that drive lean manufacturing/production:

1. cost
2. quality
3. delivery
4. safety, and
5. morale

Benefits of Lean Production

- Waste reduction
- Production cost reduction
- Manufacturing cycle times decreased
- Labor reduction while maintaining or increasing throughput
- Inventory reduction while increasing customer service levels
- Capacity increase in current facilities
- Higher quality
- Higher profits
- Higher system flexibility improved.
- More strategic focus
- Improved cash flow

6.4 Lean Production

Removal of waste activities:

In Lean Manufacturing, waste is any activity that consumes time, resources, or space but does not add any value to the product or service.

The seven wastes to be eliminated:

1. Overproduction and early production
2. Waiting time delays, idle time
3. Transportation
4. Inventory
5. Motion
6. Over-processing
7. Defective units

Difference between Lean Production and Mass Production

Mass Production	Lean Production
Focuses on manufacturing in large-sized lots.	Focuses on producing as per the latest market demand.
Requires the company to stock the manufactured products in a warehouse	Generally supplies direct to the customer.
Planning is complex and requires enterprise-level tools	Easy to plan because it is based on market demand
The manufacturing cycle and the sales cycle are separate issues	The two are closely intertwined because the products are manufactured based on the latest demand numbers.
A push type of process - push the products to the market.	A pull process - let the customer pull the product based on its demand.
Mass production is supply-oriented,	Lean production is demand-oriented

Difference between Lean Production and Mass Production

Mass Production	Lean Production
Huge volume of waste is generated	A lean production facility produces minimal waste
Facilities are equipped with heavy machinery.	Facilities may not be equipped with bulky machinery. Machinery used in lean production is compact and movable, and can be easily set up.

6.5 Total Productive Maintenance as one of the tools of Lean Production

– TPM (Total Productive Maintenance) - holistic approach to equipment maintenance that strives to achieve perfect production:

- No Breakdowns
- No Small Stops or Slow Running
- No Defects
- No Accidents

– It emphasizes proactive and preventative maintenance to maximize the operational efficiency of equipment.

– Places a strong emphasis on empowering operators to help maintain their equipment.

– It creates a shared responsibility for equipment that encourages greater involvement by plant floor workers.

– This can be very effective in improving productivity

6.5.1 The Traditional TPM Model

TPM was developed in the 1960s and consists of 5S as a foundation and eight supporting activities

a. The eight pillars

6.5.1 The Traditional TPM Model

b. The "5S" foundation

- Before any of the eight pillars of TPM can be put in place, a "5S" foundation must be built.

- The purpose of laying this foundation is to introduce standardization and continuous improvement processes into every TPM activity.

Sort - Determine which items are used frequently and which are not. The ones used frequently should be kept close by, others should be stored further away.

Systemize - Each item should have one place—and one place only—to be stored.

Shine - The workplace needs to be clean. Without it, problems will be more difficult to identify, and quality maintenance will be more difficult to perform.

Standardize - The workplace should be standardized and labelled. This often means creating processes where none existed previously.

Sustain - Efforts should be made to continually perform each of the other steps at all times.

6.5.1 The Traditional TPM Model

TPM The eight pillars

Pillar 1: Autonomous maintenance

Places responsibility for routine maintenance, such as cleaning, lubricating, and inspection, in the hands of operators.

Pillar 2: Planned Maintenance

Schedules maintenance tasks based on predicted and/or measured failure rates.

Pillar 3: Quality integration / maintenance

Involves integrating manufacturing performance, quality assurance, design error detection and prevention into the production process. Aims to improve quality management by removing the root causes of defects and understanding why they occur.

Pillar 4: Focused improvement

Have small groups of employees work together proactively to achieve regular, incremental improvements in equipment operation.

6.5.1 The Traditional TPM Model

TPM The eight pillars

Pillar 5: Early Equipment Management:
Directs practical knowledge and understanding of manufacturing equipment gained through TPM towards improving the design of new equipment.

Pillar 6: Training and education
The training and education pillar of TPM principles focuses on making sure the maintenance team has the knowledge and skills necessary to carry out TPM across an entire facility.

Pillar 7: Safety, health, environment
Focuses on building a safe and healthy facility environment and eliminating any conditions that could be risky or harmful to facility workers' well-being.

Pillar 8: Administrative TPM
Involves encouraging people in administrative or supportive roles (such as purchasing) to apply TPM learnings and principles in their own work processes so that TPM implementation is truly cross-functional.

Chapter 7: Recent advances in production technology

7.1 Micro and nano manufacturing

Def.

- **Micro-manufacturing** concerns manufacturing methods, technologies, equipment, organizational strategies and systems for the manufacture of products and/or features that have at least two dimensions that are within sub-millimeter ranges.

- Manufacture of micro-products/features with scaled-down conventional technologies/processes, such as micro-machining (mechanical, thermal, electric-chemical,electric discharge methods), micro-forming/replication,
- micro-additive (rapid methods, electro-forming, injection molding, etc.) and joining.

- The technologies relating to design and fabrication of these micro-systems are sometimes referred to either as **micro-system technology (MST)** or **MEMS techniques**

Micro-machining processes

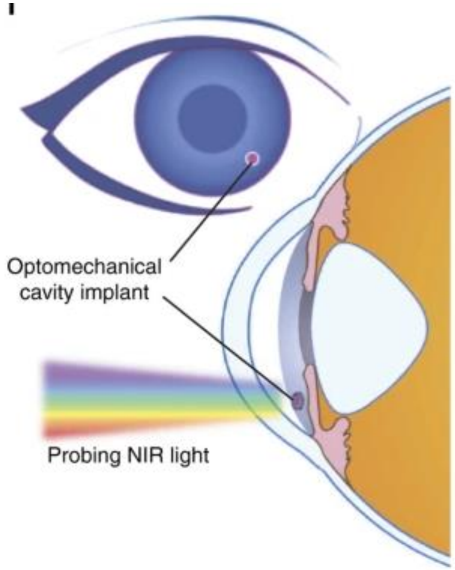
- Micro-EDM
- Micro-electrochemical Machining (MECM)
- Micro-forming
- Laser Technology such as laser-assisted chemical vapor deposition (LCVD), laser guided direct write (LGDW)
- Replication techniques like LIGA, micro- injection molding, micro-casting and micro-embossing
- etc

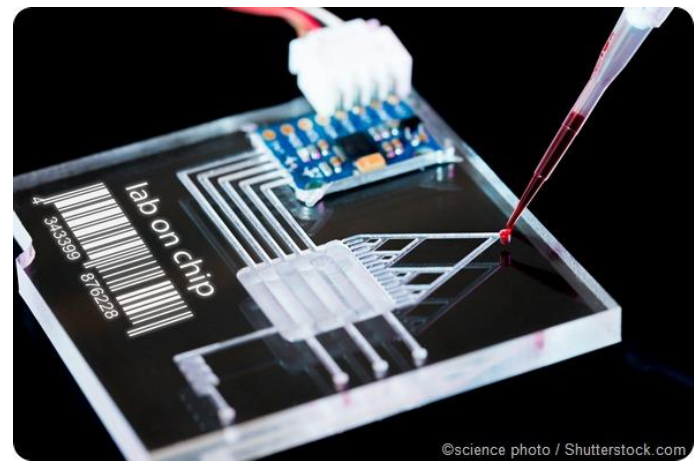
Chapter 7: Recent advances in production technology

7.1 Micro and nano manufacturing

– Sectors such as electronics, optics, medicine, biotechnology and automotive.

Examples of applications include medical implants, diagnostic devices, micro fluidic systems, micro nozzles and micro moulds.

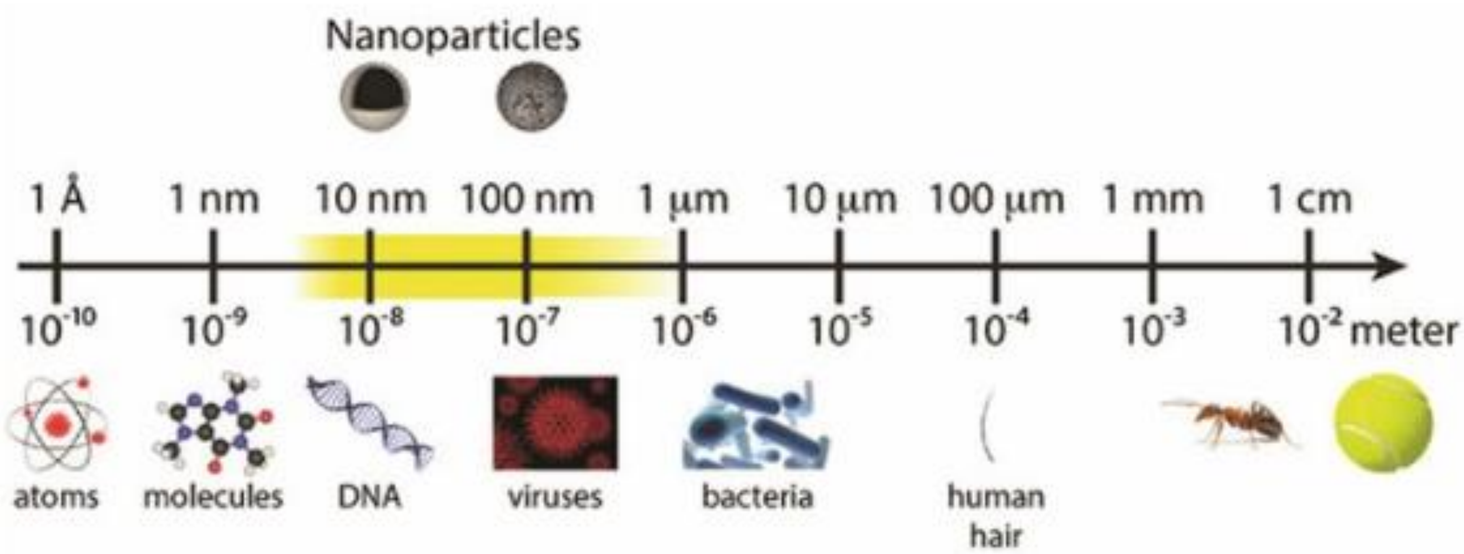




– Micro electromechanical systems (MEMS) fabrication technologies are used.

Nano manufacturing

Nano manufacturing is a set of industrial processes based on nanotechnology, where products are developed at the nanoscale.



Nano manufacturing

Some applications:

Nano-engineered materials have brought about the following improvements:

- Polymer nanocomposite parts
- Rechargeable battery systems
- Thermoelectric materials for temperature control
- Lower rolling-resistance tires
- Fuel additives

Nano manufacturing

- Wrinkle resistance using anti-wrinkle nanoparticles
- Stain resistance
- Antimicrobial - Resistance to fungal development

Nano manufacturing

Common products that have benefited from nanotechnology include the following:

- Ceramic glazes e.g. crockery
- Paints
- Skincare products
- Sunscreen lotion

7.2 Rapid Prototyping (Additive Manufacturing)

Synonyms: 3D printing, additive fabrication, additive process, additive techniques, additive layer manufacturing, layer manufacturing, and freeform fabrication

- Additive manufacturing (AM) refers to a group of technologies that build physical objects directly from three dimensional CAD data.
- AM adds **liquid, sheet, wire or powdered materials**, layer by layer, to form component parts with little or no subsequent processing requirements.
- The range of AM technologies is classified into several categories: binder jetting, material jetting, direct energy deposition, sheet laminations, material extrusion, powder bed fusion, and vat photo-polymerization.
- All of them share the principle used for the selective modelling of the layers.

7.2.1 Additive Manufacturing technologies

A. Material Extrusion

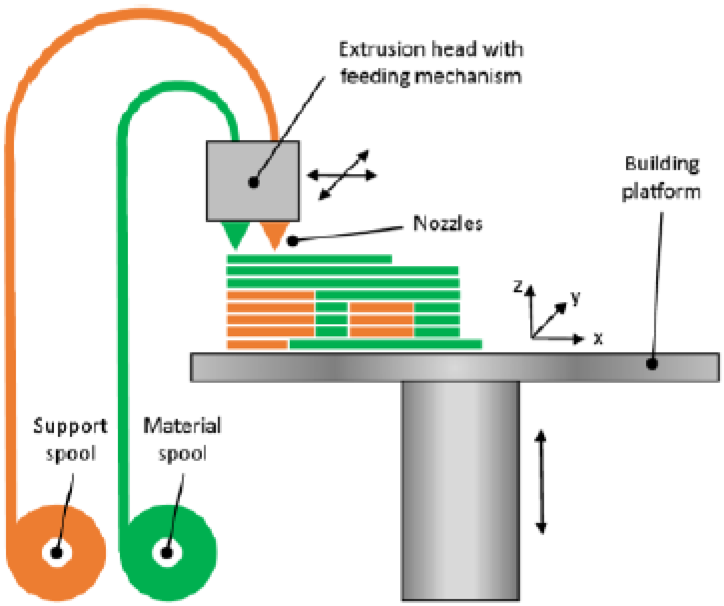


Figure 7.2.1: Scheme of the FDM process.

- FDM is classified under the category of Material Extrusion processes.
- Consists of the extrusion and subsequent deposition of a molten filament of polymeric material.
- A filament of polymeric material is softened and melted with the aid of heat and is extruded, i.e., pushed and forced through a nozzle of reduced diameter and then deposited layer by layer on the building platform

B. Material Jetting

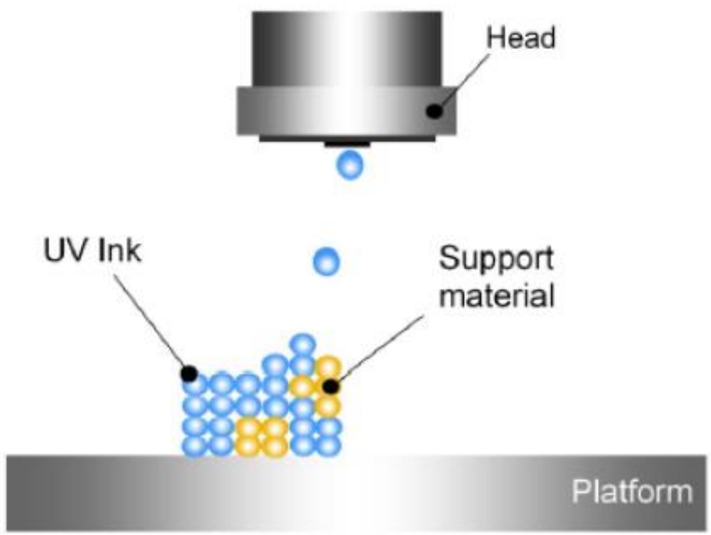


Figure 7.2.2: Scheme of the material jetting process.

- The 3D models are created through the use of movable inkjet print heads that jet photopolymer onto a build platform.

- The **drop-on-demand technique** is used to eject the drop, which obtains a high accuracy in the positioning, low waste, small droplet size and wider availability of material.

- The material deposited is cured by using UV (ultraviolet) light.

- Substances used in material jetting are typically materials having a viscous nature capable of forming the drops as photopolymers or wax-like materials.

C. Vat polymerization (SLA)

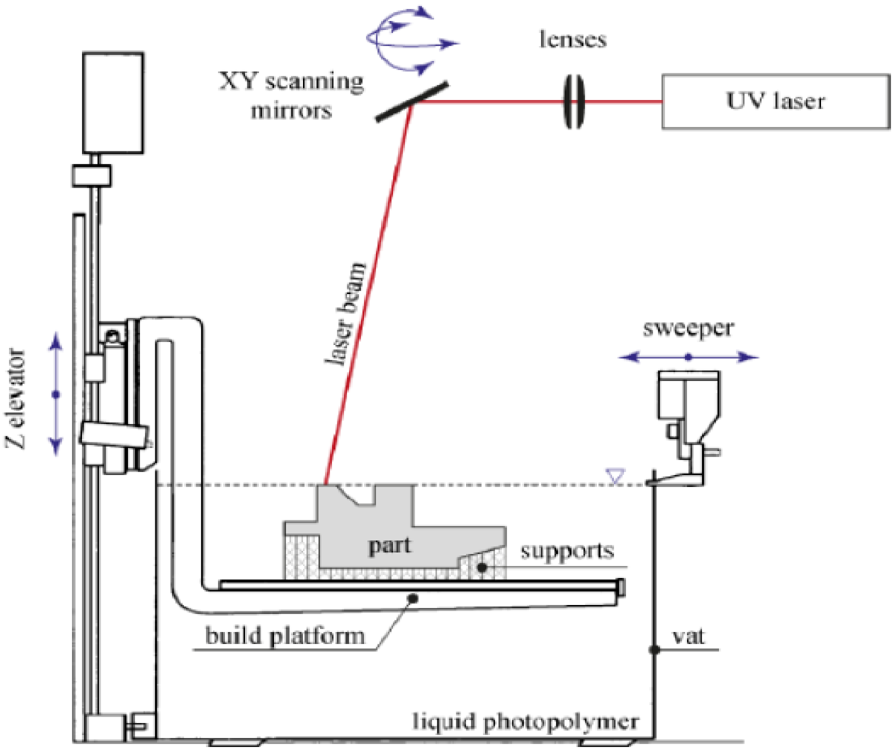


Figure 7.2.3: Vat photopolymerization process.

Produces parts by selectively curing liquid photo-reactive polymers.

D. Binder jetting

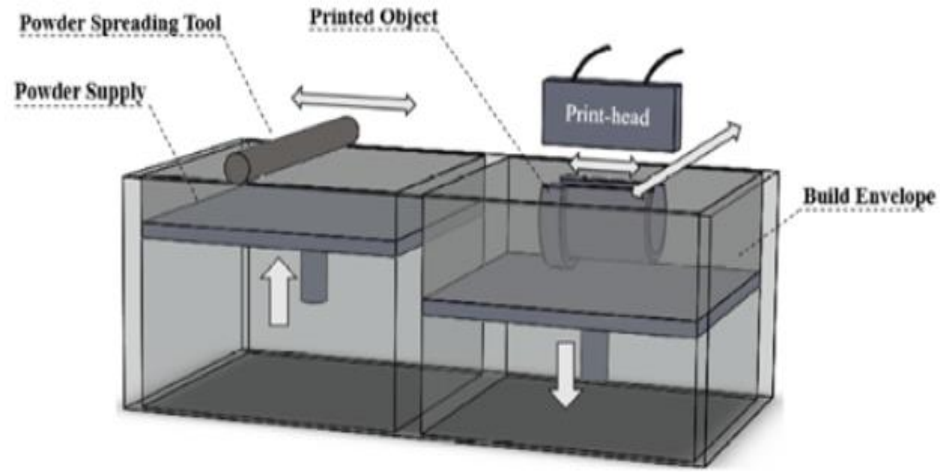


Figure 7.2.4: Schematic of the binder jetting process

A liquid binding agent is distributed on a selected region on the powder bed based on component geometry to form a structure layer by layer

E. Powder bed fusion

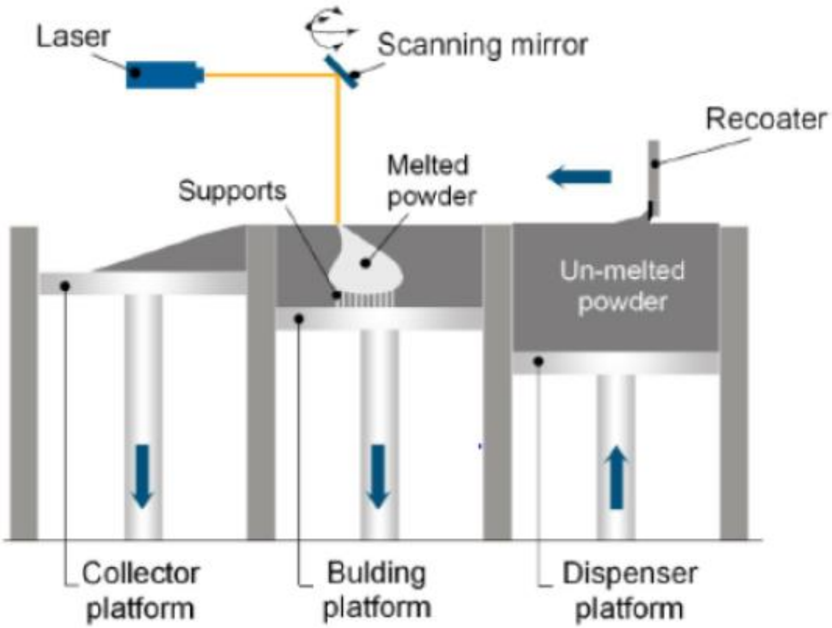


Figure 7.2.5: Schematic of the selective laser melting process

- Thermal energy, laser or electron beam, is used to bind the powder instead of use of a binder as in binder jetting technique.

- SLS and SLM are some of the processes in PBF

F. Direct energy deposition techniques

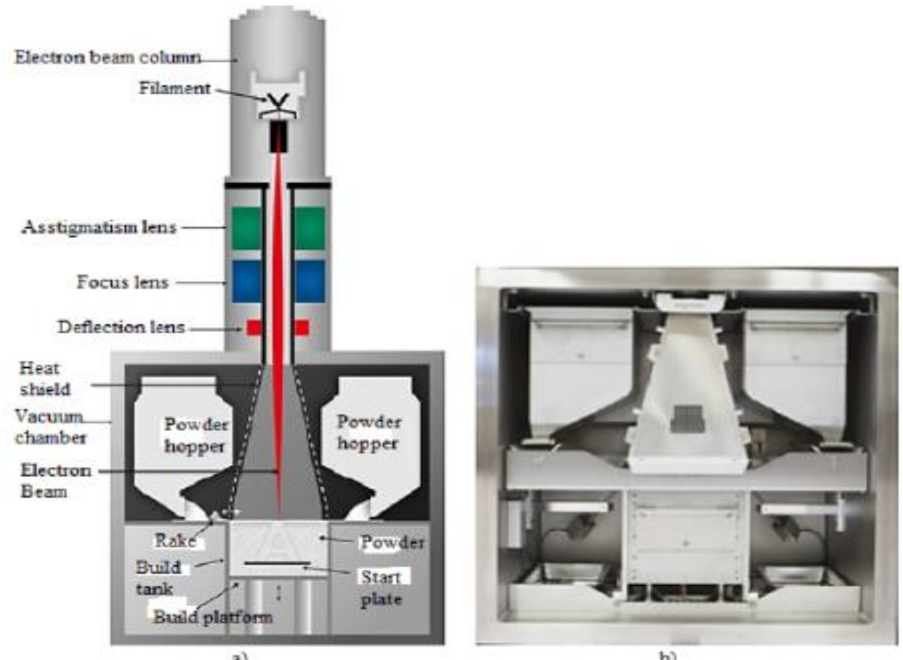


Figure 7.2.6: EBDM A2X system. (a) Schematic and (b) Picture of the interior

- A direct energy source such as a laser or electron beam is used to deposit, melt and solidify the material which is fed as a powder, filament or wire.
- LDD and EBDM are some of the processes

Applications of AM Technologies and Markets

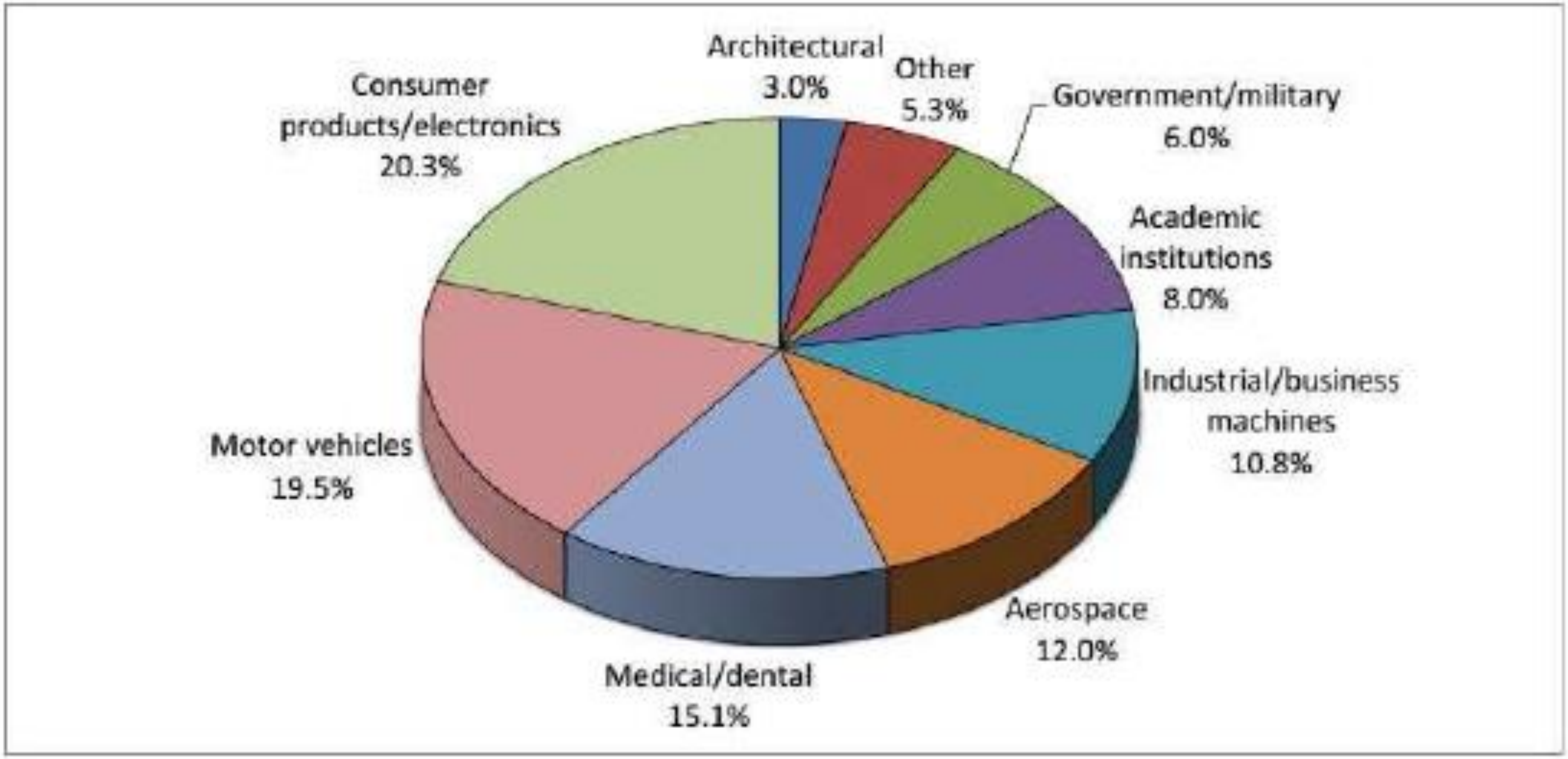


Figure 7.2.7: Industries being served and their revenues by percentage

Chapter 7: Recent advances in production technology

Applications of AM Technologies and Markets

a) Consumer Products

– Toys, games, home furnishings, fashion items, sports equipment

Figure 7.2.8: Consumer goods

b) Electronics

– Deposition of conductive materials onto conformal surfaces.
– Passive circuit components such as resistors, capacitors and inductors, as well as diodes, and circuit interconnections

Figure 7.2.9: Electronics Equipment by AM Technologies

Applications of AM Technologies and Markets

c) Motor Vehicles

Figure 7.2.10: Some of motor vehicle and its component by AM Technologies

Car manufacturers are using the benefits of AM in the production of concept cars.

d) Medical and Dental

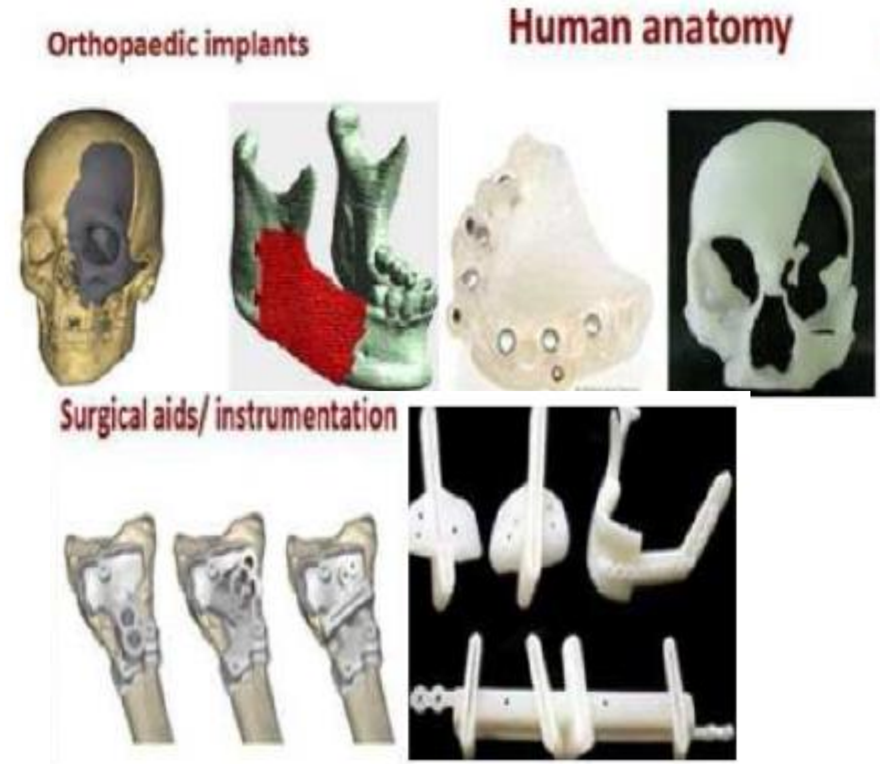


Figure 7.2.11: Medical and Dental

Assistive, surgical and prosthetic devices, surgical implants, and scaffolds for tissue engineering

Applications of AM Technologies and Markets

e) Aerospace

Crown Panel Skin Lay Up
Source: Airbus

f) Architecture

Figure 7.2.13: 3D Printed Sport Stadiums

Architecture model printed in colour

ADVANTAGES OF AM

- Industrial efficiency
- Mass customization
- On-demand manufacturing
- Decentralized manufacturing
- Component manufacturing
- Printing complete systems
- Quality improvement
- Modifications and redesigns without penalties
- Increased supply chain proficiency
- Sustainable manufacturing initiatives

CHALLENGES IN AM

- Process Control
- Tolerances
- Finish
- Bias toward conventional manufacturing
- Economic/cost difficulties
- Intellectual property protection
- Educational challenges
- Materials capacity

Thank you for your attention.