lecture 1
safety & measurments

Production is:
process followed in a factory for converting semi-finished products or raw material into finished products

product is:
an item that has a value added to it during production process

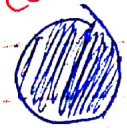
Manufacturing :
Latein word : Manufactus → made by hand

Industrial revolutions.

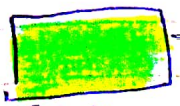
Mechanization	Industrialization	Automated Production	Smart factory 4.0
18th	19th	20th	21st
Britain	Britain, USA, germany		
>steam engine >railways >forging >metal forming	>automobile & planes >electricity, machines >telegraph, telephone	>nuclear energy >Electronics >robots	>Internet >digitalization >virtual world steering physic world.

Safety Signs

①  red → Prohibition → The thing drawn in the circle is prohibited

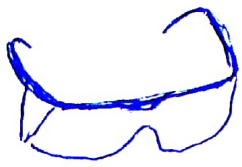
②  → mandatory action → You have to do what is drawn in the circle

③  → Warning

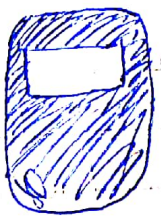
④  green → information about safe condition → Escape route / exit

⑤  → fire safety → ex. fire extinguisher.

Eye protection
- safety glasses
  - Turning
  - milling
  - drilling
  - grinding



- Safety goggles / mask
  - Welding
  - metal casting



Hearing protection
- Ear plugs
  85-90 dB
- Ear muffs
  >90dB

respiratory protection
- face mask → Nanoparticles dust
- respirator → chemicals / toxic gases

Hand protection
- friction
- chemical
- Thermal

foot protection
- safety shoes
  - Crushing
  - puncture
- Safety rubber boots
  - slips / falls
  - chemicals

Standerization
- ISO
  International Standard Orginization
- BSI
  British Standard Institution
- DIN
  Deutches Institut für Normung
- ANSI
  American National Standards Institute

difference between Accuracy and Precision.

Accuracy: closeness of a measurment to a standard or known value

Precision: closeness of 2 or more measurments to each other.

Callibration: it is the procedure in which a measuring instrument is measured against a known standard

measurment

Direct: by measuring tools only, no calculations are needed

Indirect: mathmatical relations and calculations are needed.

Lecture two:

Foundry: the place where the casting process takes place.

Casting

- Expandable molds
  - sand
  - investment
  - shell
- permanent molds
  - die
  - Continuous
  - centrifugal

Steps of sand Casting

- preperation of mold & cavity
- Melting and pouring liquified metal
- Solidification and cooling
- defects and inspection.

types of defects

1. mismatch
   - Caused by misalignment between Cope and drag.
2. Misrun / incomplete mould filling
   - happens when liquid is too cold (higher viscosity)
3. flashes
   - thin random layer of metal that forms outside mold cavity.
4. Blow holes.
   - bec of nonexistance of riser to discharge air, excessive moisture in moulding sand
5. Inclusions:
   - impurities, or sand is loose.
   - first to be detected.

Applications on Sand casting.

- machine tool beds
- manhole covers
- Pistons
- mill rolls
- wheels
- housing.

Advantages:

1. price effective for custom prods
2. Can produce large products
3. Almost all types of materials can be used in Sand Casting

disadvantages:

1. poor Surface finish due to Sand grains
2. dimentional accuracy of cast parts is low due to → shrinkage, → poor Surface finish
3. alot of metals are loosted in sprue, riser, gating system.

folbw: expandable molds

investment casting

1) very expensive 2) used for making complex shaped component
3) better surface finish. 4) pattern is made of wax
shell is ceramic

Applications:

① jewelry ② surgical implants ③ aerospace ④ military tools
⑤ special automotive parts.

Advantges

① products of small size and very thin walls can be produced
② relefivaly complex shapes can be produced
③ high dimensional accuracy can be achieved
④ better surface finish
⑤ suitable for very hard metals

disadvantages -

① very high cost process
② requires skilled worker
③ only small products can be achieved
④ large and expensive setup
⑤ not all geometries and designs can be produced

shell mold casting

the mold is a thin walled shell created from applying a sand-resin mixture around a pattern. The sand is high quality fine grain to provid better surface.

Applications:
> cylinder heads
> Bearing housings

Advantages:

① Very useful for mass production as it can be fully automated

② Excellent surface finish.

③ very high dimensional accuracy

④ Can produce hollow structure

⑤ low possibility of casting defects

disadvantages:

① Very high cost equipments

② Sand & materials are expensive

③ high cycle time

④ limited product weight

⑤ gatting system must be part of the pattern.

Die Casting

- quick - reliable - Cost effective

applications:

> Automotive parts
> Aerospace casting
> pump parts
> pressure Cookers
> electric motors housings.

Advantages

① lower costs
② high dimensional accuracy
③ economical
④ high surface finish quality
⑤ thin walled and small sized products can be formed

disadvantages

① Complex and very expensive equipments.
② large capital investments for initial set up
③ inflexible.
④ less suited to limited production runs or individual Casting.

- Centrifugal Casting :-
  form cylindrical parts by centrifugal force.

- Applications:-
  Axi-symmetric parts such as cylinders and discs which are hollow for aerospace, industrial, marine and power transmission applications.

- products:-
  > pipes / tubes
  > pressure vessels.
  > bearings, bushings.
  > coils
  > wheels
  > rings
  > rolls
  > pulleys
  > piston rings

Advantages:-
1. can form large parts
2. low equipment cost
3. low labor cost
4. little scrap generated
5. can form very large parts
6. good surface finish and accuracy

disadvantages:-
1. long process time
2. limited to cylindrical parts
3. secondry machining is often required for inner diameter

Continuous Casting:-
Biggest casting method for steel production for its high level of productivity.

Applications:-
products are in form of blooms, billets, sheets, blocks, bars any shape of uniform cross sectional area
> production of steel, Aluminum and copper billets, bleek & bars

Advantages:
1. cost effective
2. easily automated
3. unlimited length restrictions
4. easy to cast hollow products
5. fast process.

disadvantages:
1. only simple geometries
2. very poor geometrical tolerance

Bulk metal forming :-

- large set of manufactoring processes in which the material is deformed plastically to take the shape of die geo.
The tools used are called: die, punch or rolls

The main hot working sub-processes under bulk forming namely:

>forging
>rolling
>extrusion

* the metal work is forced / compressed to flow through a die hole to produce a desired cross-sectional shape.

>Applications:
tubes, hollow pipes, frams, doors and window profile.

*forging :
→ the work peice is compressed between 2 dies using impact loading to plastically deform it.

→ cause deformation and ellongation of the grains leading to enhancing strength and toughness of the forged metal.
this is due to the alignement of the deformed grains to form a chain like structure along the work piece.

i.e. : forging increases the metal durability and strength.

Grain flow

Machining

* discontinued grain flow line due to the machining tool cutting action

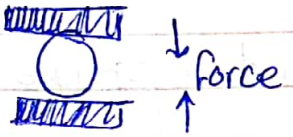
forming

* Continued grain flow line which is only deformed according to the shape retains the strength & durability of product.

forging

Open die forging
* metal is pressed between 2 flat surfaces only with no restrictions on the sides.

ex: rotor



Closed die forging
* metal is enclosed in a confined shape while applying pressure

ex: heavy duty bolt, conneting rod

> Advantages:

Forged products are charachteized by:
1- High strength
2- Toughness
3- Reliability for critical and highly stressed applications.

> Applications:
1- crank shaft
2- rotors for large turbines
3- heavy load gears
4- heavy load bolts
5- knives
6- Hand tools
7- Houses and gardens "Black smith hand-work"

Rolling

flat rolling
> The thickness of workpiece is reduced by compressive forces by 2 rolls rotating in opp. direction

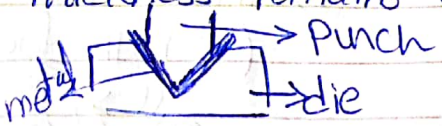
Shape rolling
> used to shape the workpiece by passing it through a set of opp rolls that have matching grooves w.r.t the desired shape
> bars, structural beams, rails, heavy duty threads

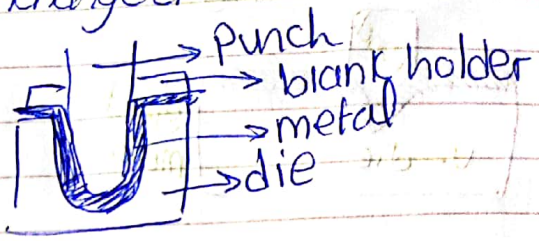
Thread rolling
> Heavy duty screws and threads.

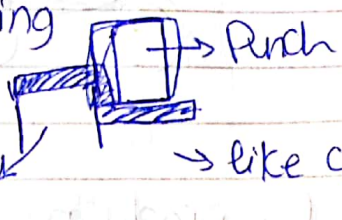
Metal Sheet working

* Involves plastic deformation of sheets to change their shape while thickness remains unchanged

- Bending
- deep drawing
- sheering







→ like cutting with scissors.

Special close fit is the blanking / punching

Blanking

> is a cutting process in which a large piece of sheet metal is removed from a larger piece. The piece removed - called blank - is the desired part

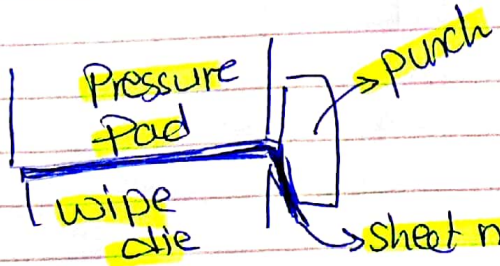
> clearance is given to the die

Punching

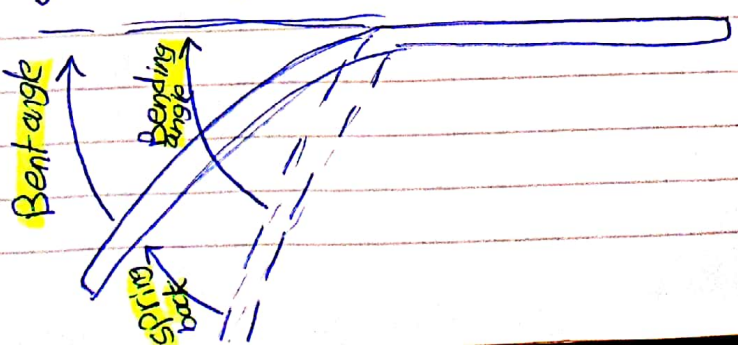
> in which a small material is removed from a piece of sheet metal. the product is the sheet metal and the removed part is scrap.

> clearance is given to the punch

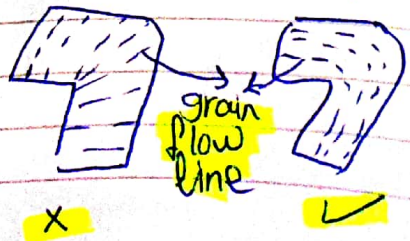
In **Bending**:



spring back effect should be considered

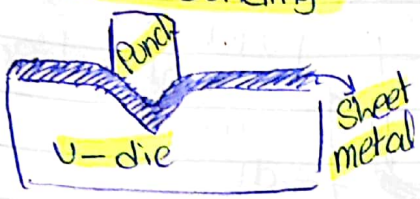


Also we have to consider the bending axis which has to lie ⊥ to the grain flow lines to avoid initiation of cracks and defects

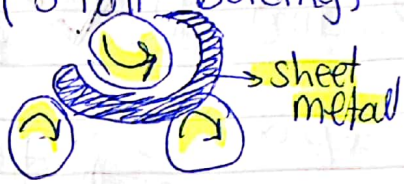


types of bending:

1) V-bending

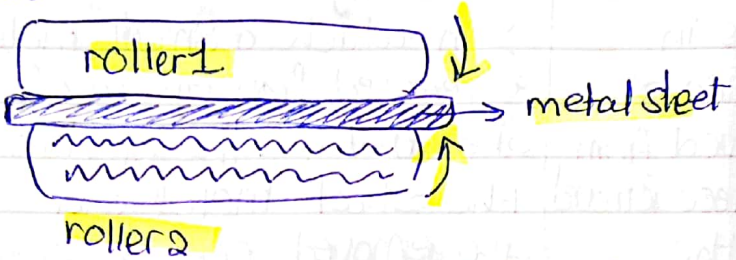


2) Circular roll bending (3 roll bending)



embossing:

> A metal forming process for producing raised or sunken designs or relief in sheet material by means of matched dies with no change in metal thickness



Applications:
assembling components for high production volume
- Automotive
- electronics

Welding:-

"The act of joining two metals by applying high energy and in some cases pressure"

→ Type of welding vary due to the source of energy.

Types:

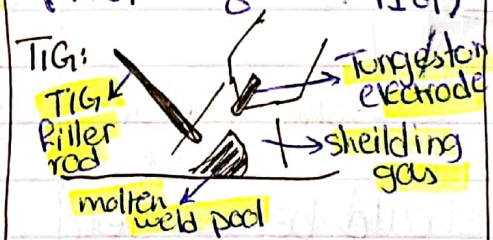
① Oxyfuel gas welding

→ Acetylene is a flammable fuel gas while oxygen helps burning so they create a 3500°C flame.

→ a filler material is essential.

→ The filler rod is covered with a crust layer called flux which when heated forms fumes cloud. to prevent air from oxidizing the hot metal.

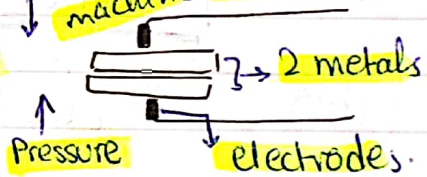
② Arc welding (TIG & MIG)



Applications: sections welding aerospace industry, welding thin tubes and pipes.

By increasing the O_2 to max and decreasing the acetylene to min. The flame can be used to cut.

③ Resistance Spot welding.



Source of energy:
heat generated from the resistance to the flow of the current passing between the 2 parts held together under pressure.

★ Arc welding - MIG
"metal inert gas welding"
→ very similar to TIG but in this case, the electrode is consumable and has 2 functions
1] Induces the arc
2] provides the filler material
→ The process is automated.
→ it is very suitable for joining massive and bulky structure

Applications:
- Automotive repair
- petroleum pipes
- Reinforcing worn out metal structures

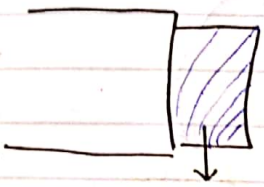
★ oxyacetelene flame:

Applications

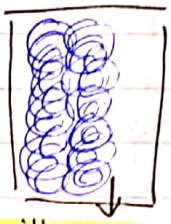
> welding thin walled workpiece
> joining most ferrous and non ferrous metals
> automotive and aircraft industries.
> Joining materials require slow rates of heating and cooling.

Lecture three :

- The best product quality has the least obvious machining marks



Turning ~~machine~~ operation marks



milling operations mark

What is machining ?
Machining is the act of removing a thin layer of metal called chip by a wedge shaped tool of a harder material
The tool can be:

- Single point tool : have only one wedge
- multi point tool : have several wedges together.
- random point tool : several cutting particles without a defined orientation.

Machining can be done on
- Cylindrical workpiece
- rectangular work piece.

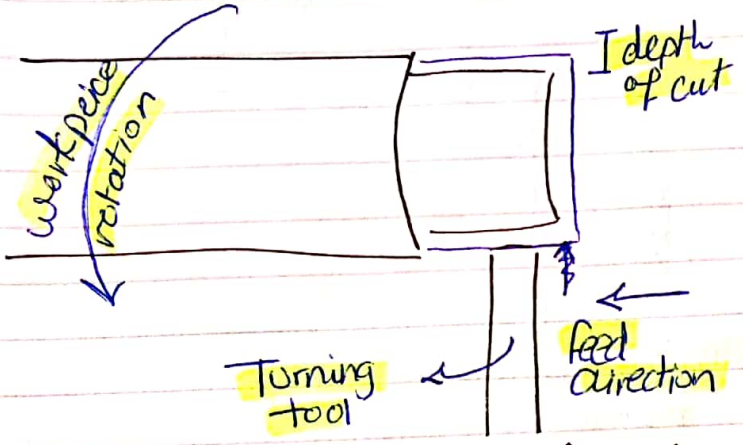
To control process of cutting, several factors should be balanced together: "Parameters"

1) Relative motion between tool and workpeice:

Feed: it is the rate at which the tool moved into the part or the part into the tool. It is measured by mm/revolution (in case of rotational motion - Turning operation) or mm/min (in linear motion - milling operation)

Speed: rate of rotation of object taking the cutting motion. Unit: revolution/min (RPMs)

Depth of cut: measurment in (mm) of how wide and deep the tool cuts into the workpiece.



$$\text{Depth of cut} = \frac{D_o - D_f}{2}$$

D_o → original diameter

D_f → final diameter

→ The adjustement of motion and force at the cutting interface influences:

① quality ② tool life ③ productivity.

$$\text{Speed} = N \pi D_o \quad \text{m/min}$$

N → Spindle rotation (rpm)

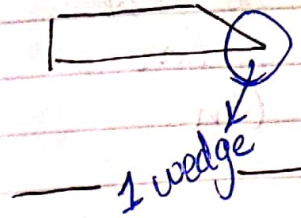
D_o → Outer diameter (m)

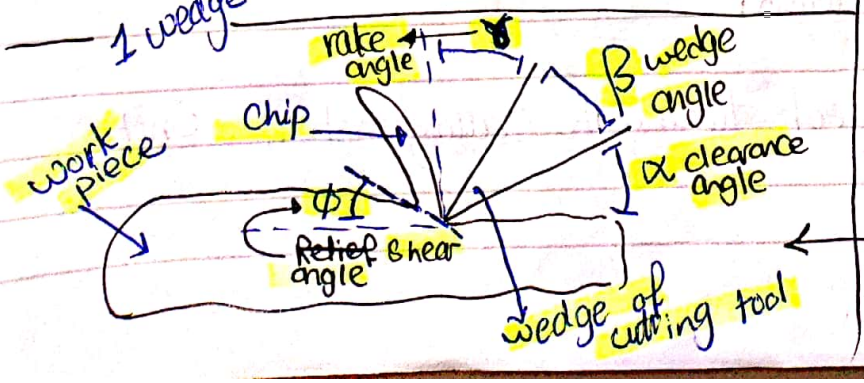
2) Shape of Cutting tool:

Single point → Knife

multipoint

random point → Sand paper





In order to have a clean cut, the friction between the cutting edge and the workpeice has to be minimum, this achieved by adjusting some angles in the cutting tool

$$\gamma + \beta + \alpha = 90^\circ$$

positive Rake:

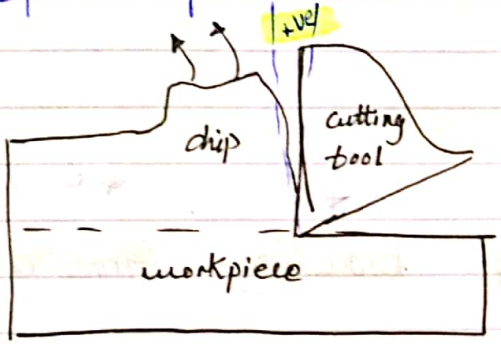
↳ ~~less than 90° "acute"~~

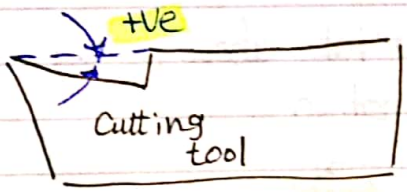
→ Sharp, pointed tool

→ HSS are given +ve rake angle

→ Low strength material

→ Not preferred for high speed operations.





+ve rake angle

negative Rake:

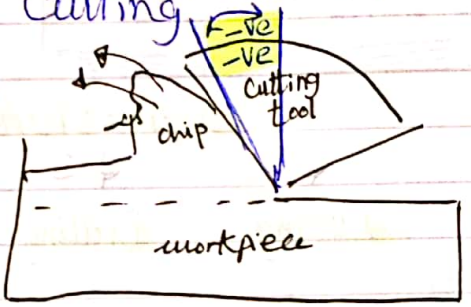
↳ ~~"more the 90°"~~ obtuse

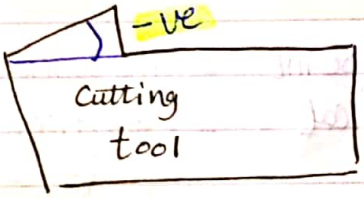
→ Greater tool strength

→ Enhances surface finish

→ Carbide tools are given -ve rake angles.

→ Usually for high speed cutting





-ve rake angle

3) Material of cutting tool w.r.t material of workpiece:

→ To perform the cutting action, the material of the cutting tool has to be stronger than the material of the workpiece.

→ also not all tools withstand high cutting speeds

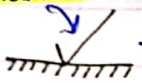
Carbon Steel → low speeds

High Speed Steel (HSS) → medium to high speed

Carbide → very high speed

Surface roughness:

number



→ Symbol indicates surface roughness

→ Surface require metal removal

→ Surface doesn't require metal removal "leave it as cast"

Chip formation

- **Tear** ↓ : there is no movement of the workpiece material over the tool face
- **Shear** ↓ : There is general movement of the chip over tool face.

operations:

1 Turning | 2 Milling | 3 Drilling | 4 Boring | 5 Broaching | 6 Grinding.

1 Turning :-

Cutting tool: Single point
Workpiece: Cylindrical

- The workpiece is fixed & rotates about its axis
- Cutting tool takes feed motion
  - Longitudinal
  - Cross

Operations:

A Facing
- First step to be performed on any new workpiece
- type of feed: Cross feed

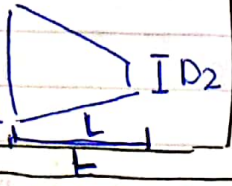
B Contour
- type of feed: Longitudinal

C Drilling
- opening a new hole in the centre of workpiece
- Feed: Longitudinal

D Boring
- Enlarging an existing hole
- type: Longitudinal feed

E Form turning
- very efficient in producing many part of the same quality
- type: longitudinal
- i.e: making screw nails

F Tapering
- giving inclination angle to the axis
- feed: longitudenal
- Taper angle: $\tan\alpha = \frac{D_1 - D_2}{2L}$



G Threading
- longitudeal feed
- make a thread on the external surface, or on the internal surface of a bored hole

Same is H chamfering

I Undercutting
- Cross feed

J Cut-off
- Cross feed
- cutting apart of the workpiece

K Knurling: Cross feed
The tool is pressed firmly against the workpiece and leaves crossed impressions on it

[2] Milling:

- metal removal by multi point rotary Cutter
- The material is fixed, The cutting tool is the one moving
- Milling is typically used to produce products with assymetric axis and have many feutes
- The cutter takes the cutting motion and the workpiece usually takes the feed motion.

Types of milling:

① **Face Milling**
- only on vertical milling machine.
- for surfaces which are at right angle to the axis of the cutter

② **Plain Milling**
- only on Horizontal milling machine
- for surfaces which are Parallel to the axis of the Cutter

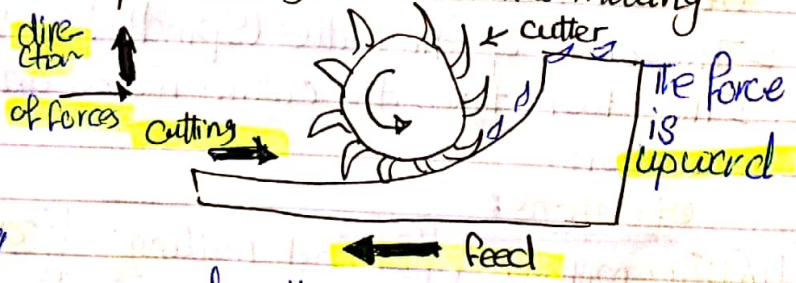
③ **Angular Milling**
- machining flat surfaces which are at an inclination angle with the cutter

④ **Form Milling.**
- for surfaces with irregular outline

Horizontal milling:
→ The axis of the cutter lies horizontally (called Arbour)

Cutters used for it:
- Cylindrical cutter for plain milling and facing operation.
- Concave cutters to produce round corners in the workpiece.
- Convex cutters which cut a curved slot
- side and face cuter for slotting "making rectangular grooves"
- Single angle cutters used for chamfering
- equal angle cutters to cut V-shaped slots

Up milling: "convertional milling"



when the direction of cutting is opposite to that of the feed.

Down milling: "climb milling"

cutting direction as the same as the feed.
Suitable for difficult to clamp and thin work piece

more differences between up milling & down milling:-

Down "Climb"	Up "Conventional"
- The width of the chip starts at a maximum and decreases	- The width of the chip starts from zero and increases
- The tooth meats the workpiece at the top of the cut	- The tooth meat the work piece at the bottom of the cut
- chips are dropped behind the cutter	- chips are dropped infront of the cutter
- less power required	- more power required
	- surface finish is worse

→ more differences on Slide 54 Lec 3

Applications:
Gears, slots, grooves, facing of large workpeice at low cost

Vertical Milling Machine:
> The axis of the cutter (Spindle) is vertical.
> The tool takes the cutting motion and workpiece take the feed motion

Operations:

[A] Face milling: provide a smooth finish workpiece ⊥ to the axis of the cutter.

[B] End milling: cuts, contour pocket and slots into the workpiece

[C] Drilling: cutting a hole

[D] Boring:

[E] Counter Boring: enlarging the top portion of an existing hole

[F] Countersinking: enlarging the top portion of an existing hole to a cone shaped opening

[G] Reaming: To obtain more accurate diameter and a smoother interal finish to the top of an existing hole

[H] Tapping: Cutting interal threads into an existing hole

3| Drilling:

The drilling machine can Peform boring, Tapping, Counter boring, reeming, Canter sinking using the correct tools

→ The feed and the cutting motion are both given by the tool, the work-piece doesn't move

4| Broaching:

using a toothed tool to remove material in a consistent and accurate way by only axial motion. (No rotation of either tool nor workplace)

used for producing custom complex cuts at high production volume and high accuracy.

5| Grinding:

removing a thin layer of the workpiece surface by a random point tool in a form of wheel called grinding wheel

The grinding wheel takes the cutting motion and the workpiece takes the feed motion. →

dimential dimensional tolerance < 1 μm

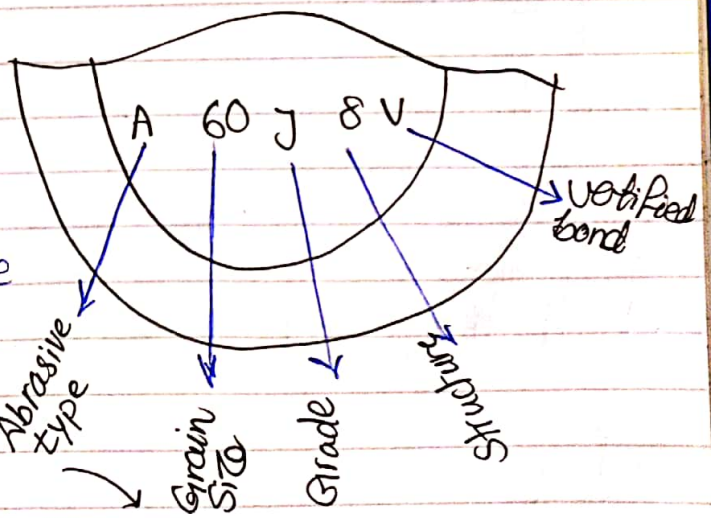
Surface roughness up to 0.025 μm

→ finishing operation

→ obtain smooth shiny metallic surface.

→ abonding material is added to to bind the particles together.

→ filler material is also added to reduce the cost of the grinding wheel as usually the abrasive particles are very expressive.



Surface grinding
For ~~curved~~ surfaces
Flat

Cylindrical grinding
For curved surfaces.

Lecture 4: CNC Machining

levels of production

No of products	Type of production	Example
- 1-10	prototype	any product
- 10-4999	Small batch	Aircrafts
- 5000-100,000	high volume / batch production	Agriculture machinary
- >100,000	Mass production	Automotive.

Automation:

Greek word → Automatos (self-acting)

it is achieved by:

- monitoring all aspects of manufactoring operations
- Making decisions Concerning in-process changes

it is implemented in the following areas:

- Manufactoring processes
- Material handling
- Inspection
- Assembly
- packaging.

Product Guidlinese :-

- Cost - affordable
- Quality - good quality
- Time - should be produced in the right time before other compititors

CAE → Computer-aided Engineering
CAD → " " Drawing
CAM → " " Manufactoring → CAPP → Computer aided production planning
CIM → " Integrated "
↳ all mg CNC machine cells are connected togetter with a network and Connected to the Computer which perform the CAD, CAM and CAPP

CAP → Computer aided planning

CAQ → Computer aided quality ~~Control~~

PPS → process planing and steering

Adaptive Control "a type of Numerical Control"

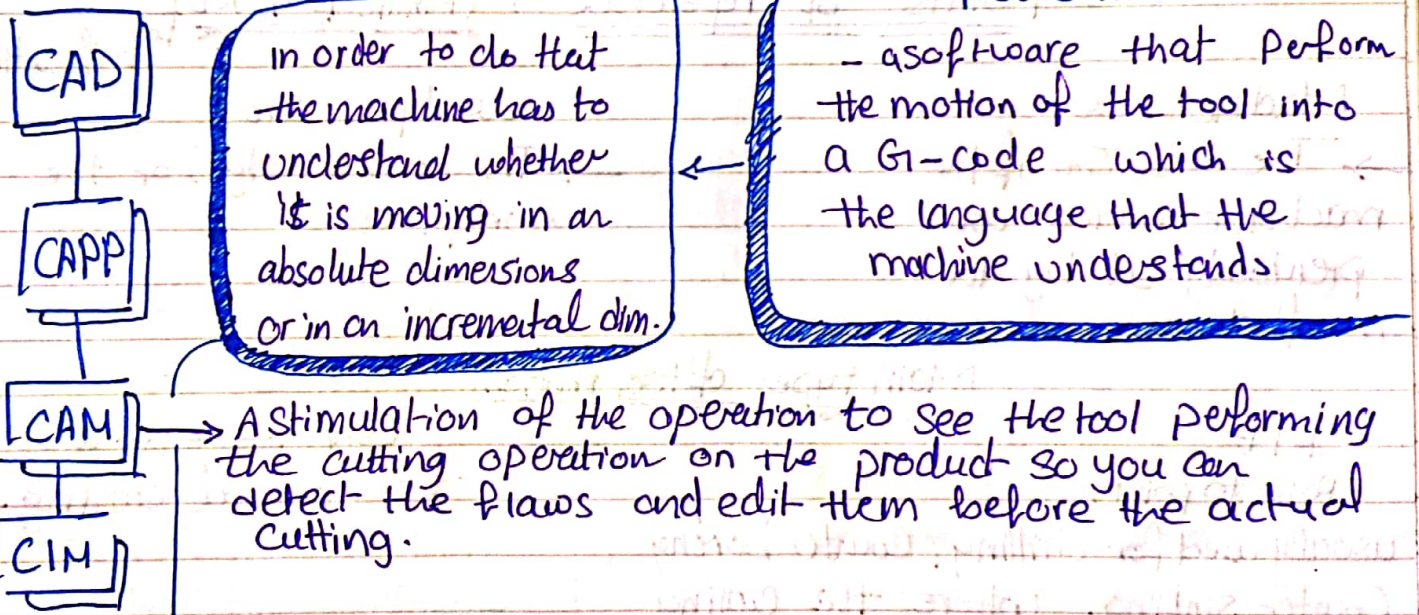
↳ The system is adapting to the enviroment in order to keep the parameters at the set parameters.

↳ it saves alot of time and tool work

Advantages:

1] optimized production rate
2] Optimized product Quality
3] Minimized production Cost

product programming process chain:



CAM → A stimulation of the operation to see the tool performing the cutting operation on the product so you can detect the flaws and edit them before the actual cutting.

① absolute dimension → always refering to the Zero point, each motion or measurment I take is always refered to the zero point

② Incremental positioning → refers to the last position the machine was standing on.

3D coordinate System:

	CNC milling machine	CNC lathe machine
X-Axis	Table movement (transverse)	Cross motion of cutting tool
Y-Axis	Table movement (Longitudinal)	—
Z-Axis	vertical movement of Spindle	Carriage movement

↓ it is considered a 5-axis machine as it has two rotating axis

↓ considered a 2 axis machine

Points of reference : (Minute 32 VOD) for clarification-

Machine Zero:
→ The own Zero of the machine which was previously set by the manufacturer.

workpiece Zero:
→ The corner (edge) of the workpiece.

Main types of tool motion:

PTP (Point to point)
usually used for drilling, Counter boring Counter sinking. where the cutting operation happen by the Z-axis.
- rapid motion.

Continuous Path
the normal cutting.

The G-Codes:

G → preparatory function
M → Miscellaneous function
X, Y, Z, A, B, C → The axis
S → Spindle speed
T → Tool Call
H → Tool Height offset
D → Tool diameter
F → feed rate
N → sequence number
P → dwell time

Safe start:

G00 → rapid mode (no cutting, only motion)
G90 / G91 → Absolute position / Incremental position
G17 → XY plane
G54 → fixture offset 1
G40 → Cutter compensation (tool diameter) cancel
G49 → Length offset cancel
G80 → Canned cycle cancel.

M3 → spindle rotation clock-wise
M30 → Program end and rewind

Lecture 5 : Plastics manufacturing

POC → proof of concept, trying the idea with simple materials to see its functionality.
prototype → stimulate the whole system
Pilote → a product which is identical to final product. for the audience.
production → final step

→ The main advantage of additive manufacturing over the subtractive manufacturing is the limited amount of waste. and the resources preservation.

Advantages of 3D printing:

① Time/Speed ② Cost ③ Confidentiality
④ Creativity / Complexity and design freedom ⑤ Customization
⑥ Ease of access ⑦ resources Sustainability ⑧ Single step manufacture

Applications for 3D printing

→ Surgical learning tools
→ surgical guides and tools.
→ Implants
→ Prosthetics
→ Hearing aids
→ product developments
→ Architecture

Steps of 3D printing:

Translates CAD into dimensions. Sets the printer speed and Layer thickness

3D CAD file
• STL format
→ CAM - SLICIGN
• GCODE file format
→ 3D Printing
↓
generating cross sectional layer (x-y) and joining the layer with the next one (z)
→ final Physical object

3D Printing techniques:

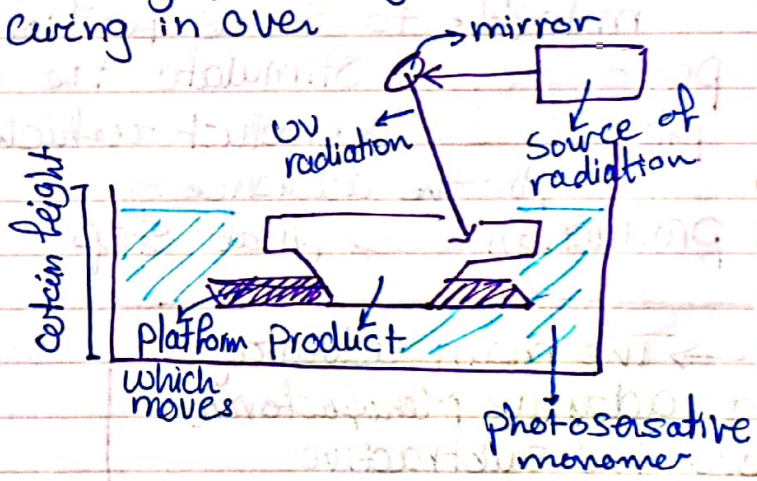
1 - (SLA) Stereolithography.

→ Generation from aliquid phase.

→ Solidification of liquid material by photopolymerization using UV radiation, then post curing in over

→ Material: photosensitive monomer

→ disadvantge: The product can't exceed a certain hieght.
↓
which is solved by revesing the design of the machine



→ Products:
products with fine details and gives a smooth surface finish
> Jewelry → detal and medical applications

2- Selective Laser Sintering (SLS)

→ II - Gereration from solid phase
→ Melting by laser beam and solidification of the surface powder layer arranged in a powder bed
→ Material :
plastic powder, metal - polymer powder
Metal - Metal powder.
→ products :
have high mechanical properties. They are often used to manufacture end products
> Printed furniture > T-Hawk (micro air vehicles)
> Prosthetic fairings.

*Both SLA and SLS need a further step after the part is printed.

↓	↓
post curing to make sure it solidified	post curing to make sure all the powder is fused together

3- Binder Jetting (BJ)
→ Gereration from solid phase.
→ Similar to SLS but instead of fusing the powde together using laser beams, we glue them together.
→ Material: Sand, Sandstone, Gypsum + Binding material + Infiltrant (post curing)
→ products :
parts can have every large sizes and various colours in comparison to othe 3D printers. Products are usually for demonstration purposes with low mechanical properties
> sand Cast molds & cores > full color models
> Complex low cost models > Custom metalic parts

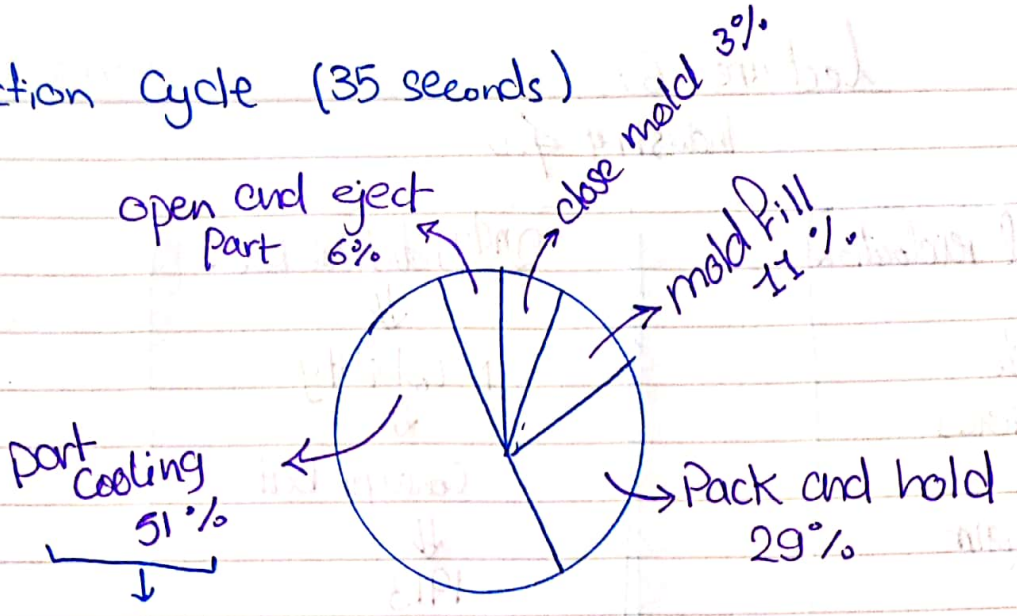
4- HP metal jet
5- Fused deposition modeling (FDM)
→ Generation from solid phase
→ The most popular 3D printing technique
→ Very fast
→ Materials:
Plastics (PLA, Nylon, ABS)
polymer Composites (PLA/wood, HIPS/CF)
→ works like the glue gun (same method)
a solid coire or semi molten materials are heated in a nozzle and deposited geometrically onto a defined structure
→ There is usually a cooling fan to help the 1st layer solidify before the second layer
→ products:
the surface finish is of limited quality due to the thickness of layer.
>High peformance prototypes
>functional parts (enviromental control systems ECS Ducts)
>Customized jigs and fixtures
>Concept design

Injection molding

Advantages:
>mass production
> low labor cost
>large range of pure and composite materials
> High precision products at low cost
> Flexible design for complex products
>very good surface finish

Materials:
>Plastics (Polypropylene [PP], Polyethylene [PE], polyethylene tetra phthalate [PET], polyamide [PA], Polylactide [PLA])
> compounds → plastics + fillers
> Rubbers

Injection Cycle (35 seconds)



The most Consuming part.

Mold design:

→ single cavity mold → multi cavity mold

Types of molds:

→ 2 plate mold
"requires afurther step to seperate the products"

→ 3 plate mold
"the extra plate is a stripper plate to seperate the sprew and the reamner from the part"

How to distinguish aproduct made with injection molding?

> seperation line mark (Parting)
> Injection gate mark
> ejection pins marks

Defects:

> weld lines
> Flashes
> Sink marks
> Burn marks
> Short shot
> warpage