CBCS SCHEME

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15ME82

Eighth Semester B.E. Degree Examination, Aug./Sept.2020
Additive Manufacturing

Time: 3 hrs. Max. Marks: 80

Note: i) For Regular Students: Answer any FIVE full questions irrespective of modules.
ii) For Arrear Students : Answer any FIVE full questions, choosing ONE full question from each module.

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-1

1 a. Explain Additive Manufacturing Process Chain with a neat block diagram. **(06 Marks)**
b. Explain stereolithography process with a neat sketch. Write its merits, demerits and applications. **(10 Marks)**

2 a. Distinguish between stereolithography and selective laser sintering processes. **(06 Marks)**
b. Explain with a neat sketch, Fused Deposition Modeling Process. What are its advantages, disadvantages and applications? **(10 Marks)**

Module-2

3 a. Explain the types of D.C. motors with field coils with neat sketches. **(08 Marks)**
b. Explain briefly with neat diagrams the following:
(i) Thyristors (ii) Triacs **(08 Marks)**

4 a. Compare hydraulic and pneumatic systems. **(06 Marks)**
b. Write a note on shape memory alloys. **(10 Marks)**

Module-3

5 a. Explain with a neat sketch polymer processing by wet spinning. **(08 Marks)**
b. Explain in detail the liquid phase sintering. **(08 Marks)**

6 a. Explain with a neat sketch Dry Spinning Method for additive manufacturing. **(08 Marks)**
b. Explain with a neat sketch powder production by vacuum atomization technique. **(08 Marks)**

Module-4

7 a. Explain with a neat sketch the sol-gel process. **(06 Marks)**
b. Explain the principle of Scanning Electron Microscopy (SEM) with a neat sketch. What are its applications? **(10 Marks)**

8 a. Explain with a neat sketch, flame assisted ultrasonic spray pyrolysis. **(08 Marks)**
b. Explain with a neat sketch the salient features of Atomic Force Microscopy (AFM). **(08 Marks)**

Module-5

9 a. Write a note on NC, CNC and DNC machine tools. **(06 Marks)**
b. Explain briefly the various strategies for automation and process improvement. **(10 Marks)**

10 a. Explain with a block diagram the levels of automation. **(10 Marks)**
b. Distinguish between continuous control in process industries and discrete control in manufacturing industries. **(06 Marks)**

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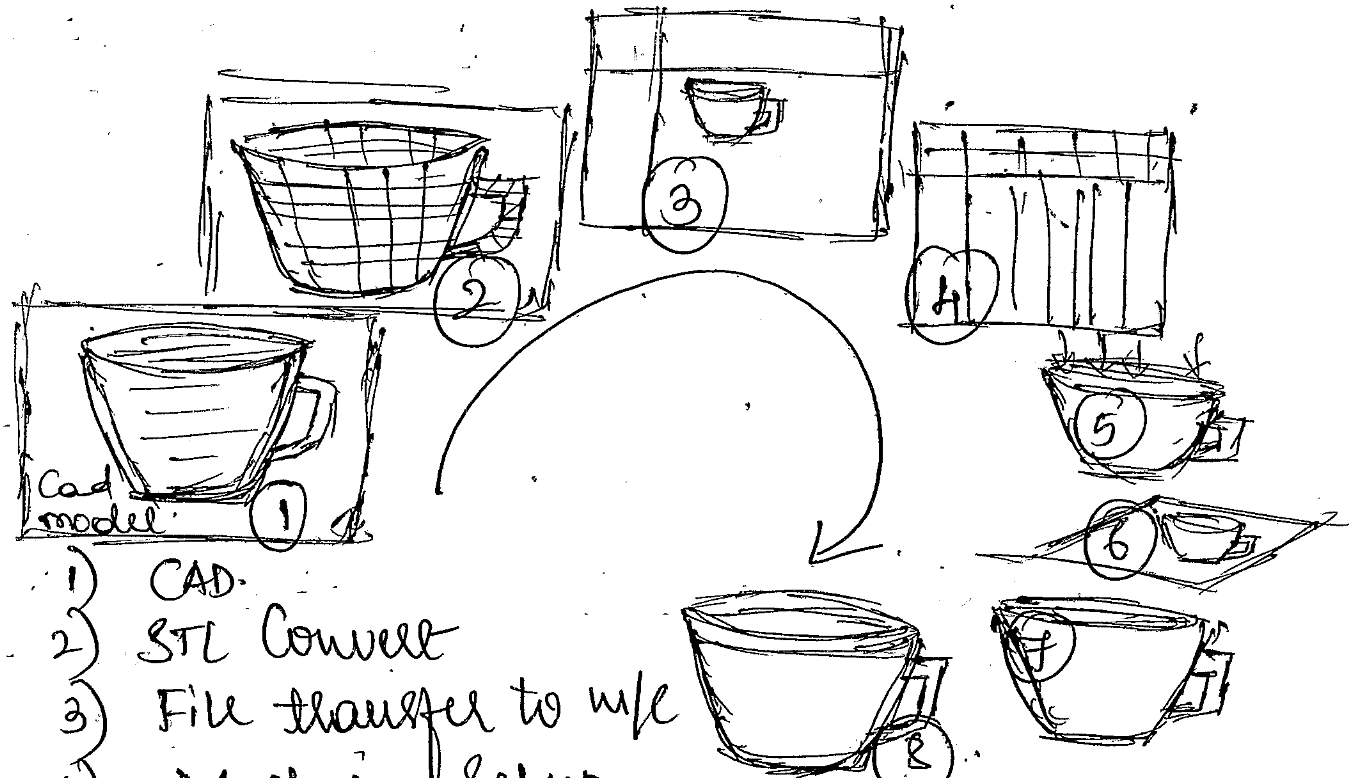
1 a Explain additive manufacturing process chain with a neat block diagram

AM process chain contains 8-9 steps as shown below.



1) CAD.
2) STL Convert
3) File transfer to m/c
4) Machine Setup.
5) Build
6) Remove
7) Post process
8) Application

Step 1:- Conceptualization & Computer aided design (CAD) model.

* in any product design process the first step is to imagine & conceptualize the function & appearance of the product.
* in general the AM process chain start with 3D CAD modeling.
* in this step the designer using any design software; builts the CAD model.

Step 2:- Conversion to Stereolithography (STL) format

* AM technology available today uses the Stereolithography (STL) file format to convert CAD model into AM machine acceptable format

* The STL format of a 3D CAD model captures all the surfaces of the 3D model by means of stitching triangles of various sizes on its surfaces

Step 3:- Transfer (file) to AM machine

* Once a correct STL file is available, STL file is first imported into a software that allows repairing & manipulating of the file as well as the generation of support, & the slicing of the part & support models.

Step 4:- STL file manipulation & Machine set up

* Once imported, the dimensions can be modified if needed, once the errors have been repaired, a proper orientation of the 3D model with respect to build platform is then decided

* Machine preparation can roughly be divided into groups of tasks. Machine hardware setup & process control

* Hardware Setup entails cleaning of build Chamber from previous build, loading of powder material.
* Process control task group allow an AM system to accept & process the build files, start the build & Preparing the machine for finished part extraction, & unloading of material

Step 5 :- Build

* Once the STL file has processed & machine specific information to allow placement of material unit into the desired location in a controlled manner to construct the physical model layer by layer.
* Once the first layer is build the platform is lowered by distance equal to the thickness of layer
* Then the laser beam scans the next cross section. The cycle is repeated till the top most layer of the object is generated

Step 6 :- Removal & Clean up

* Removal of finished part from the build plate typically involves the use of cutting tools such as band saws or wire EDM for higher fidelity & flexibility.

* The unpacking process typically involves raising the platform in the build Chamber & removing loose powder at the same time.
* Once the loose powder is removed from the finished part, the build is ready for post-process.

Step 7:- Post processing

* The minimum required processing is removal of built part from build plate & the removal of support structure from the built part.
* A thermal annealing process can be used to relieve the thermal stresses in the built part.

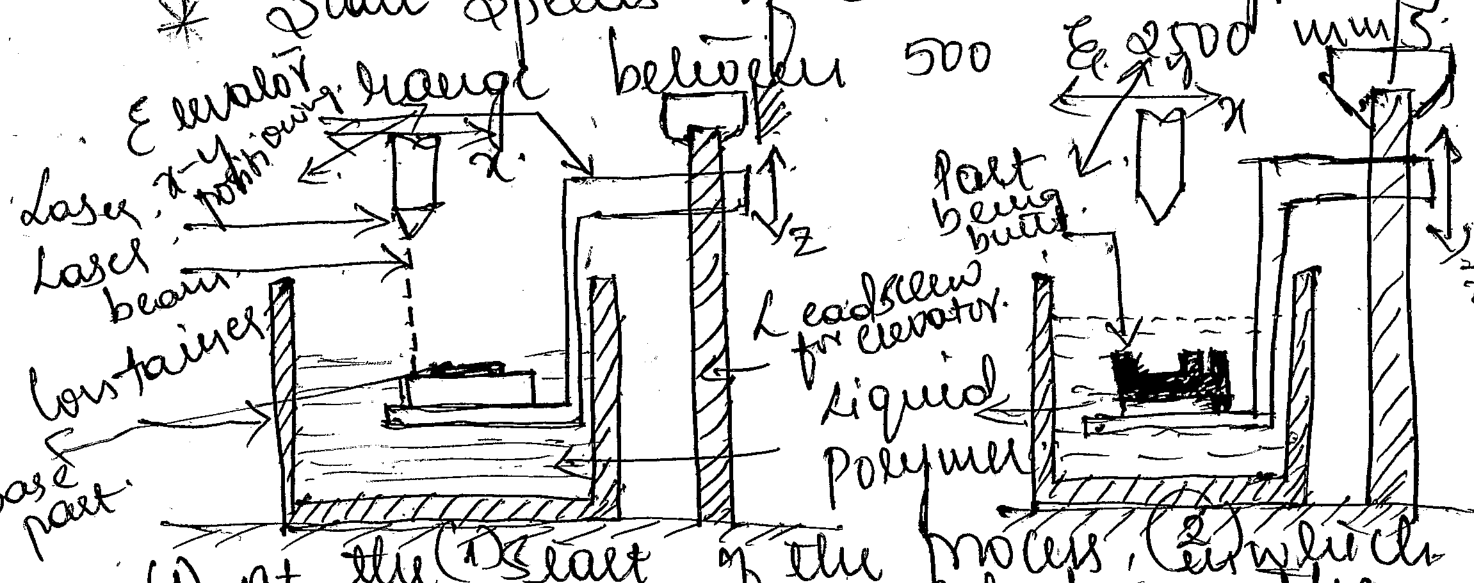
Step 8:- Application

* Following post-processing, parts are ready for use.
* Some process may cause the material to degrade during build or for material not to bond well, or crystallize in an optimum way.

1.b Explain Stereo lithography process with a neat sketch. Write its merit, demerits & application.

* Stereo lithography was the first material addition RP technology dating from about 1988 & introduced by 3D systems inc.
* Stereolithography (STL) is a process for fabricating a solid plastic part out of a photosensitive liquid polymer using a directed laser beam to solidify the polymer.
* The process starts with a model in a CAD software & then it is translated to a STL file in which the pieces are "cut in slices" containing the information for each layer.
* The general setup for the process is illustrated in figure below. Part fabrication is accomplished as a series of layers, in which one layer is added onto the previous layer to gradually build the desired three dimensional geometry.
* The stereo lithography apparatus consists of (1) a platform that can be moved vertically inside a vessel containing the photosensitive polymer & (2) a laser whose beam can be controlled in the x-y direction

* The action of the laser is to harden the photosensitive polymer where the beam strikes the liquid, forming a solid layer of plastic that adheres to the platform.
* When the initial layer is completed, the platform is lowered by a distance equal to the layer thickness & second layer is formed on top of the first by the laser & so on.
* Each layer consists of it's own area shape, so that the succession of layer, one on top of the previous, creates the solid part shape.
* Polymerization occurs upon exposure to ultraviolet light produced by helium-cadmium or argon ion laser.
* Scan speeds of STL laser typically range between 500 & 2500 mm/s.



(1) at the start of the process, in which the initial layer is added to the platform.
(2) after several layer have been added so that the part geometry gradually take from elevator

Merits

* Good user Support
* Good Accuracy
* Accurate Surface finish

Demerits

* Requires post-curing: it needed to cure the object Completely and the integrity of the Structure.
* Requires Post Processing: it involves removal of Supports which is tedious time consuming & can damage the model.

Application of SLA

* Pattern for investment Casting, Sand Casting & moulding.
* Tools for fixture, tooling design & production tooling.

Q.a. Distinguish between Stereo lithography (SLA) & Selective laser Sintering (SLS) processes

Property	(SLS)	(SLA)
Build/Bed volume	200x250x330 mm	145x145x175 mm
Layer thickness	0.06 mm to 0.12mm	0.05mm to 0.15mm
Accuracy	± 100 microns	± 50 microns
Minimum wall thickness	1mm	5 mm

Laser type	UV laser beam	CO_2 laser
Sensitivity	Long exposure to UV light damage the object	High brightness
Surface finish	very rough surface finish	Smooth surface finish
Build material	Powdered nylon resin	Liquid photo-Polymer, Photosensitive resins
Post processing	Dusting & possible Sanding	UV baking & removing Support structure
Applications	Functional prototypes, Short run, bridge or Custom manufacturing	Pattern moulds, dental & jewellery application

Q.b. Explain with a neat sketch, fused deposition modeling process. What are it advantages, disadvantages & application?

Working Principle of FDM

* The Principle of the FDM is based on Surface Chemistry, thermal energy, & layer manufacturing technology.

* The material in filament (spool) form is melted in a specially designed head which extrudes on the model. The schematic representation of FDM setup shown in Fig a) & Data processing (Fig b)

* As it is extruded, it is cooled & thus solidifies to form the model. The model is built layer by layer, like the other RP system.

* Parameters which affect performance & functionalities of the system are material column strength, material flexural modulus, viscosity, tip diameter, envelop temperature, & part geometry

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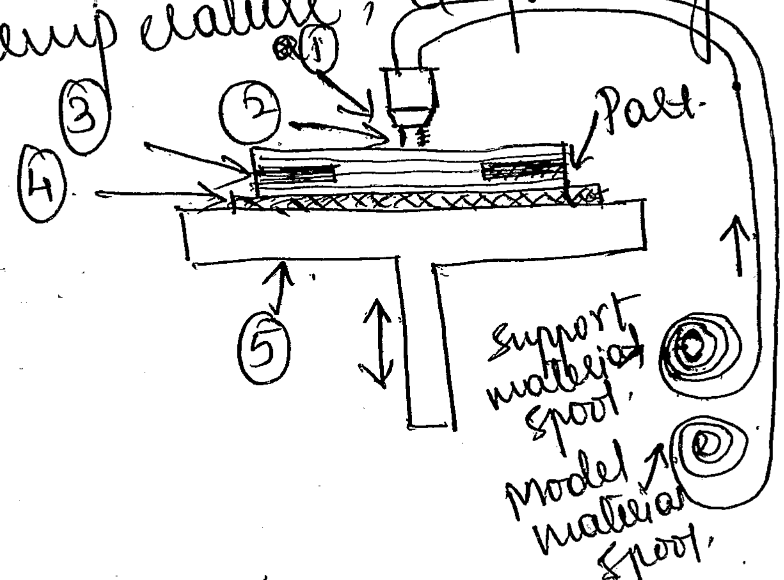


1) Liquifier (moves in x & y direction)
2) Extrusion nozzles
3) Supports
4) Foundation sheet
5) Build platform

Advantages

1) Fabrication of functional parts
2) Minimal wastage
3) Ease of support removal
4) Ease of material change

Disadvantages

1) Restricted accuracy
2) Slow process
3) unpredictable shrinkage

Applications

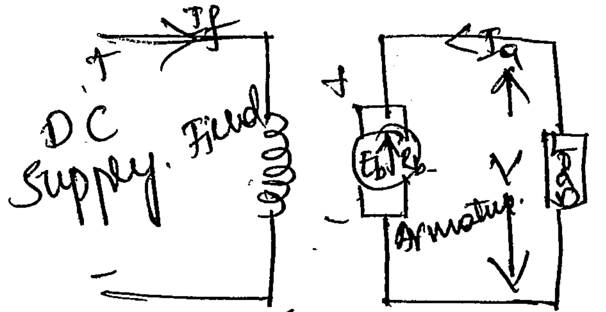
1) Models for conceptualization & presentation.
2) Prototypes for design, analysis & functional (design) testing
3) Pattern & masters for tooling.

3.a. Explain the type of DC Motors with field coils with neat sketches.

A direct current motor, DC is named according to the connection of the field winding with the armature. There are mainly two types of DC motors.
Separately Excited DC Motor.
Self-excited DC motor.

Separately Excited DC motor

As the name signifies, the field coils or field windings are energised by a separate DC source as shown



Separately Excited DC motor

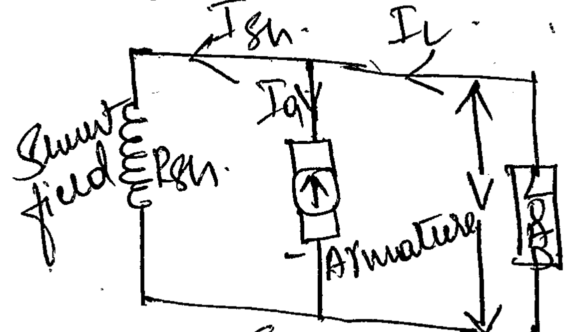
Self Excited DC Motor

As the name implies self-excited, hence in this type of motor, the current is the windings is supplied by the machine or motor itself.

It is further divided into shunt wound, & series wound motor.

Shunt wound motor

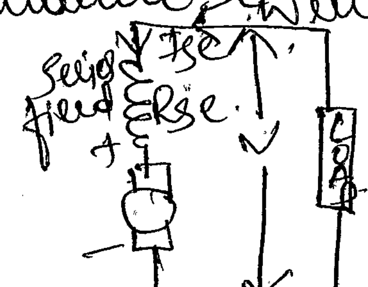
This is the most common type of DC motor. Here the field winding is connected in parallel with the armature as shown in the figure.



Shunt wound DC motor

Series wound motor

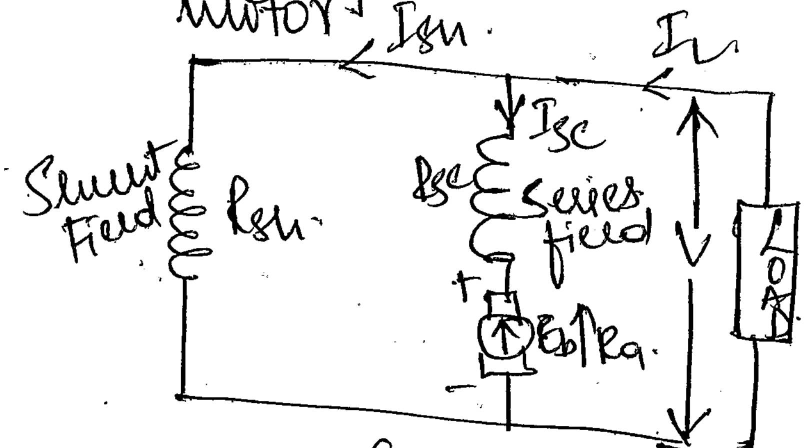
in the series motor, the field winding is connected in series with the armature winding.



Series wound motor.

Compound wound motor

A DC motor having both Shunt & Series field winding is called a Compound motor.



Compound motor

3b. Explain briefly with neat diagram the following
i) Thyristors ii) Triacs

Thyristors

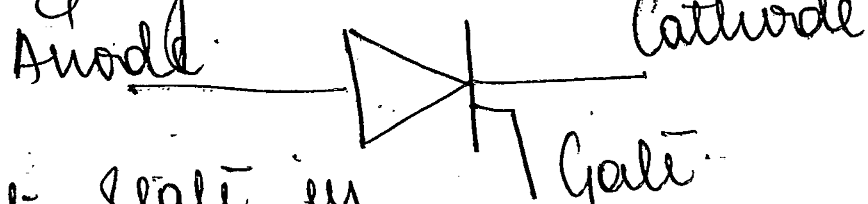
Thyristors is a small device which can control large amounts of voltage & power.

Thyristors are used as current reversal to turn off the device.

* A thyristors is a four-layer solid-state semiconductor device with P & N type material.
* when never a gate receives a triggering current.
* it starts's conducting until the voltage across the thyristor device is under forward bias.

Thyristor Circuit Symbol

It has three terminals Anode, Cathode & gate.



Different state in a thyristor
- Reverse blocking mode
- Forward blocking mode
- Forward Conducting mode

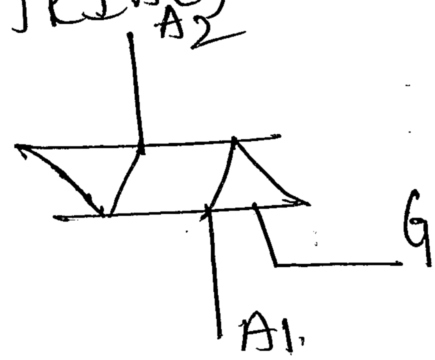
Application

* variable speed motor drives
* High power inverters & traction.

Triacs

Triode for alternating current (TRIAC)

* Triac can conduct current in either direction & formally called bidirectional triode thyristor



* closely related to SCR
* Difference between Triac & SCR

* Triac is bidirectional devices while SCR is unidirectional devices force Commutation by reversed biasing Cannot be employed
* TRIACs can be triggered by either a positive or a negative current applied to its gate electrode while SCR can only triggered when a positive current apply to the gate terminal.
* In order to create a triggering current, a positive or negative voltage has to be applied to be gate with respect to the terminal.

Application of TRIAC:
TRIACs are used in numerous application such as light dimmers, speed controls for electric fans.

4. a) Compare hydraulic & pneumatic System.

Hydraulic System	Pneumatic System
* The working fluid is hydraulic oil.	working fluid is compressed air.

* As oil is incompressible, oil can be pressurized to very high pressure.	* Air is compressible; hence air can be pressurized to lesser pressure.
* Since pressure is high, the force developed is also very high.	* Since pressure is very less, the force developed is very less.
* Leakage of oil results in dirty & slippery surrounding that may lead to accidents.	* The very clean & dry surrounding is maintained.
* Application: CNC machine tools, earth-moving m/cs, automobiles, aviation etc.	* Application: Material handling system, hand tools, mining works.

4b. Write a note on shape memory alloys.

* A shape memory alloys are metal alloys that can be deformed at one temperature but when heated or cooled, return to their "original" shape.

* The alloy appears to have a memory.

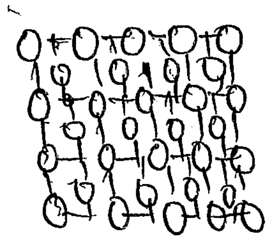
* The most effective & widely used alloys are NiTi, CuZnAl, & CuAlNi.

* SMA also exhibits superelastic behaviour

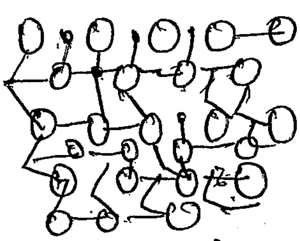
Basic working principle
* SMA's have two stable phases.
  * The high temperature phase called Austenite Ef.
  * The low temperature phase called Martensite.
* The martensite can be in one of two forms.
  * Twinned / * Detwinned.

* A phase transformation which occurs between these two phases upon heating / cooling is the basis for the unique properties of the SMA's.

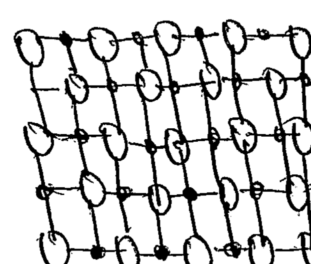
Austenite
* High temperature phase
* Cubic crystal structure



Martensite
* Low temperature phase
* Monoclinic crystal structure



Twinned martensite



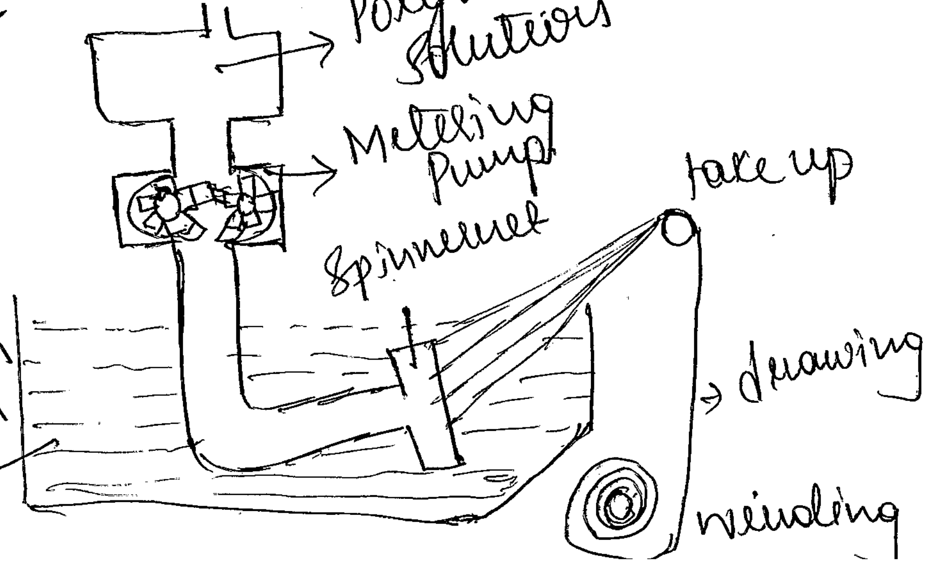
Detwinned martensite

Biological applications of SMA's
* Bone plates
* Surgical anchor
* Clot filter
* Eye glasses

Flexible nitinol wires.
* Wires have the ability to flex the robotic muscles according to electric pulses sent through the wire.

5a. Explain with a neat sketch polymer Processing by wet spinning.

<u>Wet spinning</u>
This is the oldest, most complex & also the most expensive method of man-made yarn manufacture. This type of spinning is applied to polymers which do not melt & dissolve only in non-volatile or thermal unstable solvents.



Spinning process

1) In wet spinning, a non-volatile solvent is used to convert the raw material into a solution.

2) The solvent is extruded through the spinneret either by simply washing is out

3) After extrusion, the solvent is removed in a liquid coagulation medium

4) Finally the filament yarn either is immediately wound onto bobbins or is further treated for certain characteristics or end desired use

Example:- Wet spinning is used in the production of aramid. Lyocell, PVC

5.b Explain in detail the liquid phase sintering.

Liquid phase sintering (LPS) is a process for forming high performance multiple phase components from powders. It involves sintering under conditions where solid grains co-exist with a wetting liquid.

* During liquid phase sintering a liquid phase co-exists with a particulate solid at the sintering temperature.

* The wetting liquid provides a capillary force that pulls the solid particles

together & induces particle re-arrangement.

* The second phase chosen has lower meltin temperature than the main constituent.
* The sintering temperature is set just above the melting point of the added phase so that during sintering it forms a liquid phase that wets the solid particles.
* The pores in the compact are largely surrounded by the liquid phase & the driving force for sintering is liquid surface energy.
* with high liquid fraction, full density can be achieved almost entirely by rearrangement.

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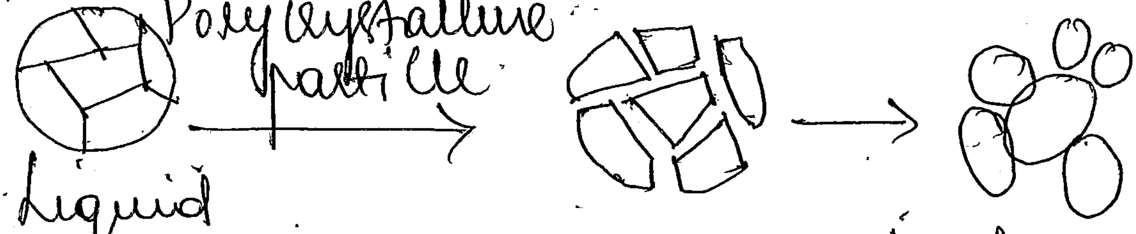
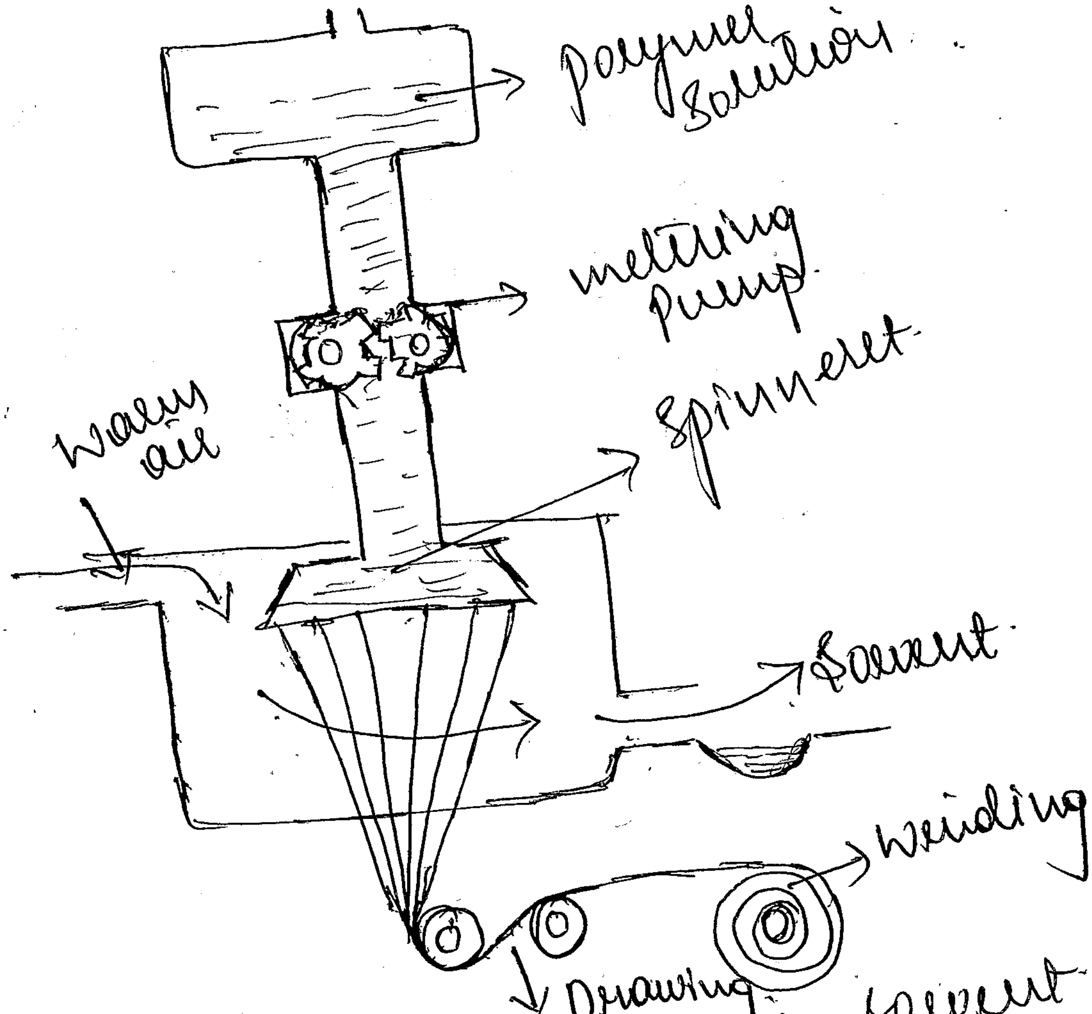


Wetting is a very important phenomenon which is happening during LPS.

6a. Explain with a neat sketch. Dry spinning method for AM.

Dry spinning is used for polymers that need to be dissolved in a solvent. Solvent spinning are used by 30% of the fibers.



1) In dry spinning, a volatile solvent is used to dissolve the raw material and form a solution.

2) Then the solution is purified by filter

3) The solution is extruded through a spinneret into a warm air chamber where the solvent evaporates, solidifying the fine filaments

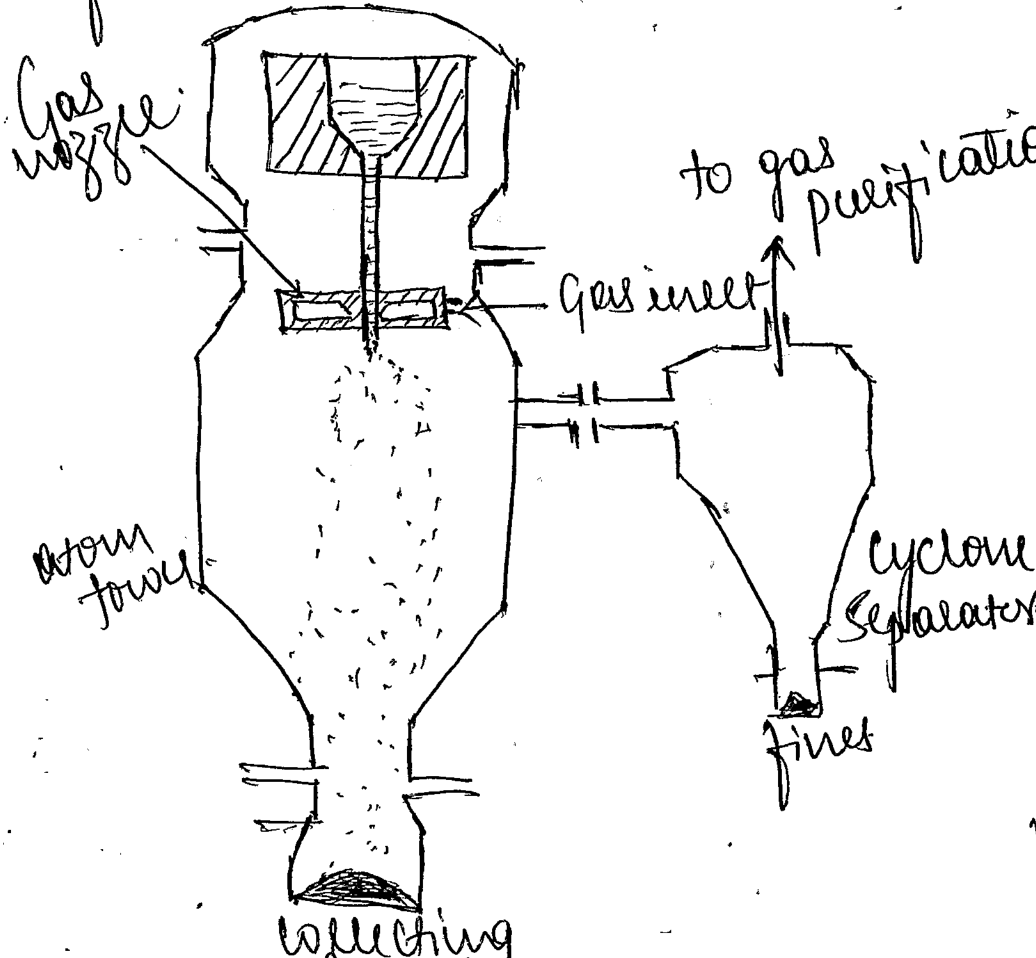
4) Finally the filament yarn either is immediately wound onto bobbi

Ex- Dry spinning is used in the production of acetate.

6b. Explain with a neat sketch powder production by vacuum atomization technique.

Vaccum gas atomization is one one of the leading powder-making processes for production of large volumes of spheri high-grade powders.

Here, melted initial material is collapse with the gas within the Chamber. Hea is transferred from the liquid droplet to the surrounding gas & liquid solidifies.



Atomization unit.

Atomization can be undertaken either in vertical or horizontal unit

Production of fine particles

* a high velocity of the atomizing fluid
* small melt stream diameter
* High density, & low viscosity & surface tension of the melt

The mean particle size of gas atomiz powders is in the range of 20 - 300 um.

7a. Explain with a neat sketch the sol-gel process

Wet chemical synthesis of nano-materials sol-gel process

Wet chemical technique produce high purity & homogeneous nano materials particularly metal oxide nanoparticles

Starting material from a chemical solution leads to the formation of colloidal suspensions known as SOL

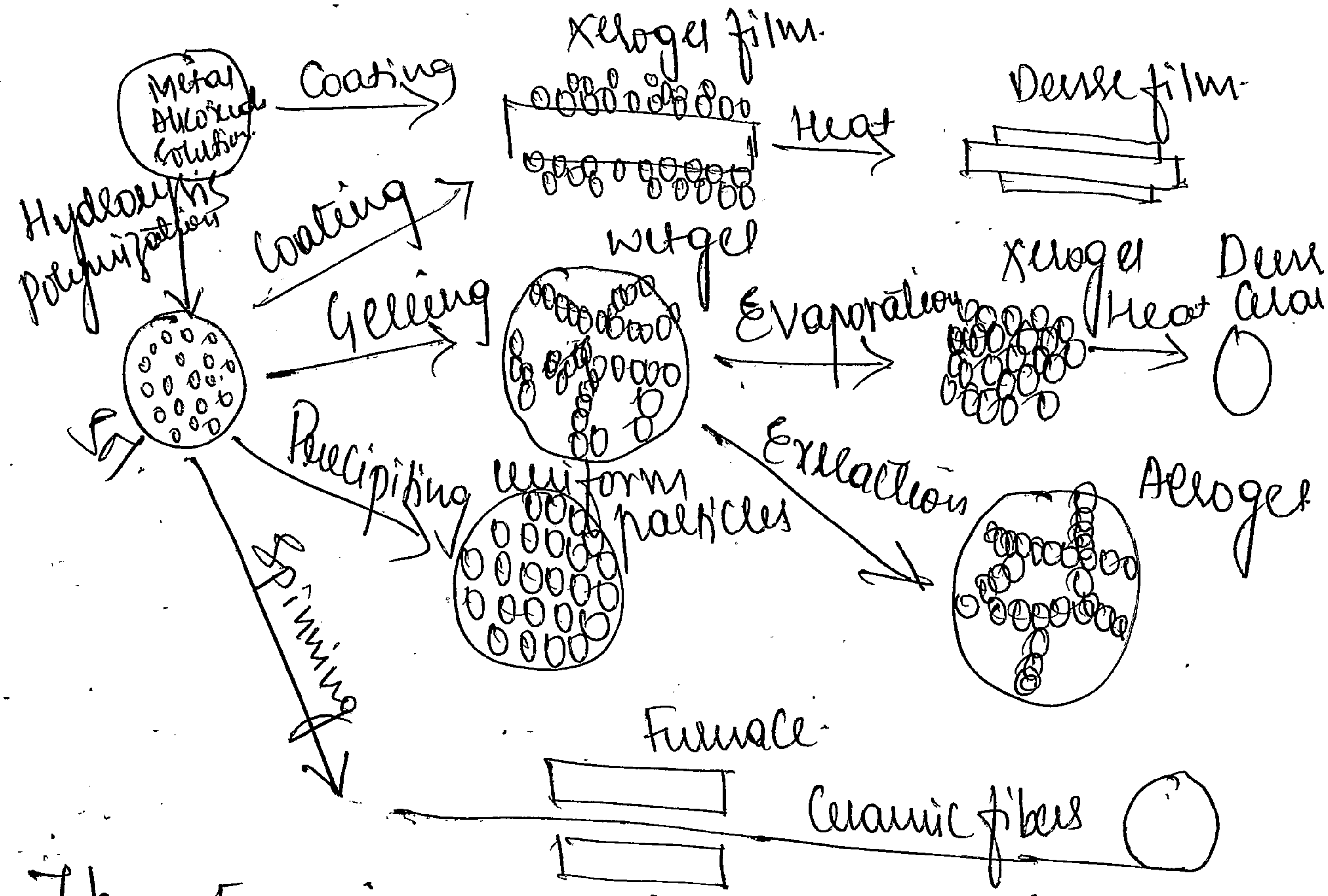
The SOL evolve towards the formation of inorganic network containing a liquid phase called the GEL

The particle size & shape are controlled by the Sol/Gel transitions.

The thermal treatment of the gel leads further polycondensation reaction & enhances the mechanical properties of the products (i.e) oxide nanoparticles

In essence, the sol-gel process usually consists of 4 steps:

1) The desired colloidal particles once dispersed in a liquid to form a sol.
2) The deposition of sol solution produce the coating on the substrate by spraying, dipping or spinning.
3) The particles in sol are polymerized through the removal of the stabilizing components & produce a gel in a state of a continuous network.
4) The final heat treatment pyrolyze the remaining organic or inorganic components & form an amorphous or crystalline coating.



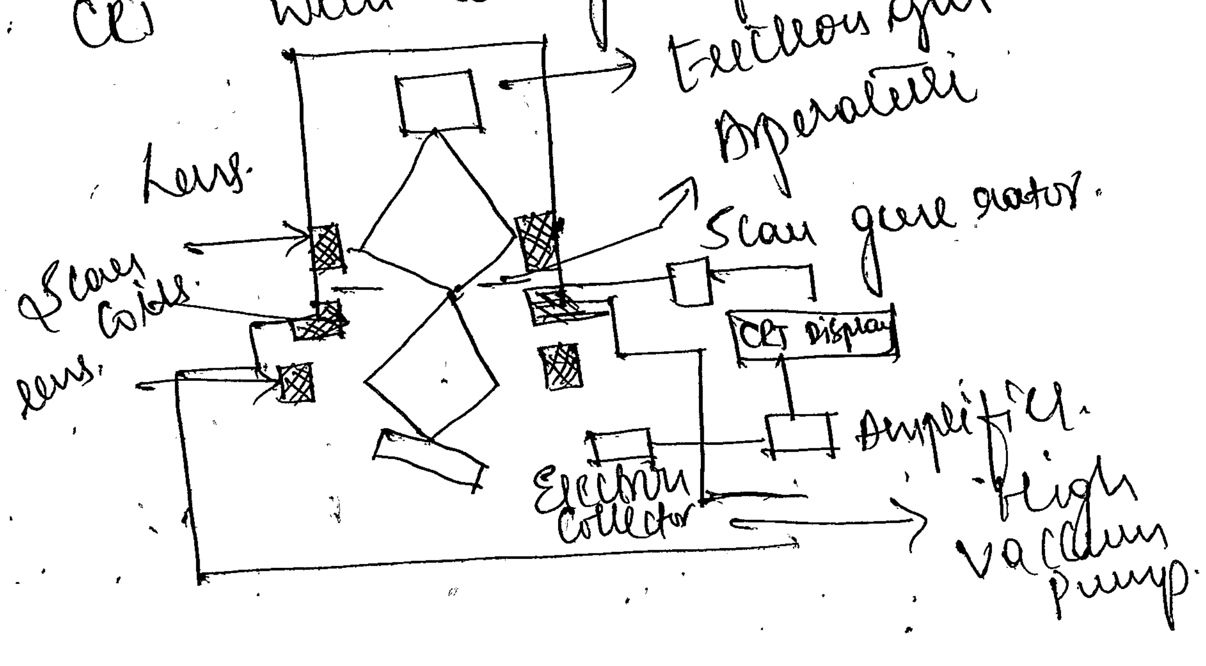
7.b. Explain the Principle of Scanning Electron microscopy (SEM) with a neat Sketch. What are it's applications?

Scanning Electron microscope produces images of a sample, ~~produ~~ by scanning it with a focused beam of electrons.

The electrons interact with atoms in the sample, producing various signals that contain information about the sample's surface topography & composition.

7.b <u>Principle</u> An electron beam is focused onto the sample surface kept in a vacuum by electro magnetic lenses. The beam is scanned over the surface of the samples. The scattered electrons from the sample is then fed to the detector from the sample is then fed to the detector & then to a cathode ray tube through an amplifier where the images are formed, which gives the information on the surface of the sample.

Instrumentation - Heated filament as a source of electron beam.
Condenser lenses. Evacuated chambers, Electron detector. Amplifier CRT with image forming electronics.



SEM Application

* Characterization of Solid materials. Topographical, morphological & Compositional information.
* Sem can detect & analyse surface fracture provide information in micro structure.
* Provide Qualitative chemical analysis
* Identify crystalline Structures.

8.a Explain with neat sketch, flame assisted ultrasonic spray pyrolysis.

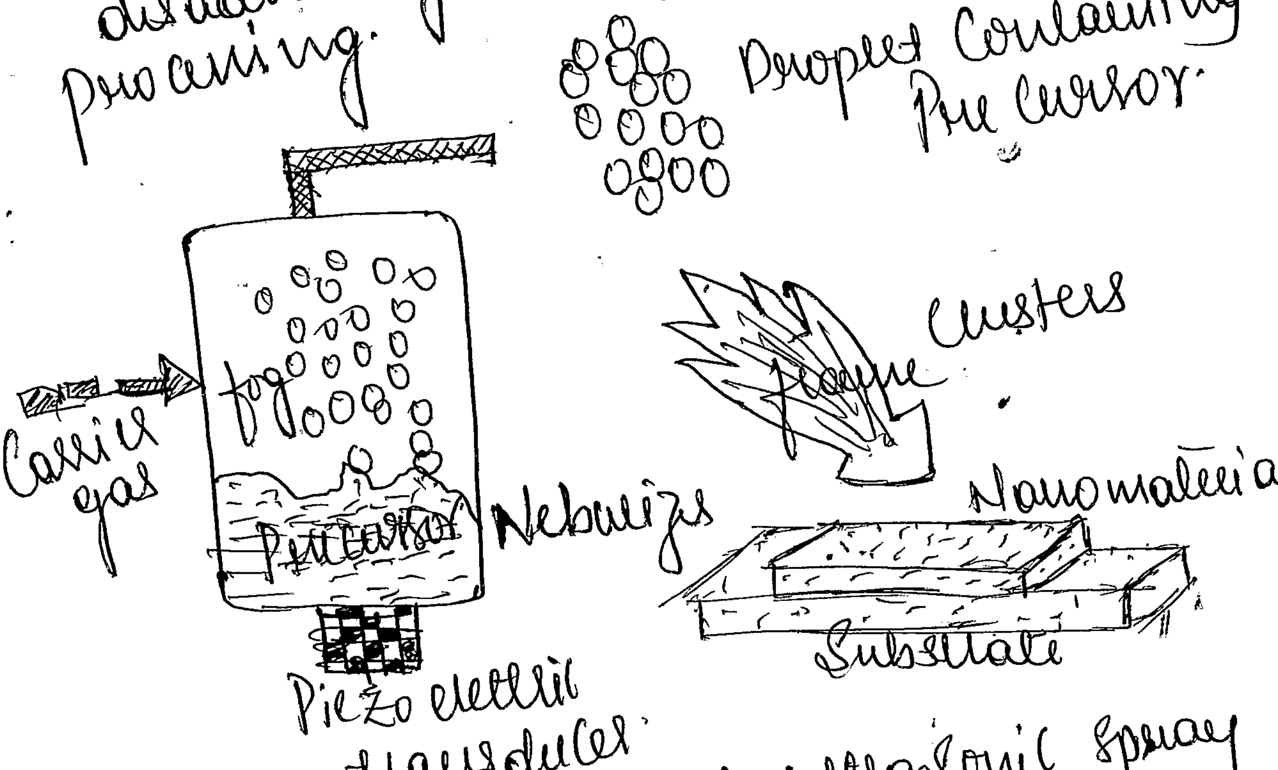
In this process, precursors are nebulized & then unwanted components are burnt in a flame to get the required material, Eg:- ZrO_2 has been obtained by this method from a precursor of $Zr(CH_3CH_2CH_2O)_4$

Flame hydrolysis that is a variant of this process is used for the manufacture of fused silica.

The resulting white amorphous powder consists of spherical particles with sizes in the range 7-40nm. The combustion flame synthesis in which the burning of a gas mixture

Eg:- acetylene & oxygen or hydrogen & oxygen ∴ supplies the energy to initiate the pyrolysis of precursor compounds is widely used for the industrial production of powders in large quantities such as carbon black, fumed silica & titanium-di-oxide.

However, since the gas pressure during the reaction is high, highly agglomerated powders are produced which is disadvantageous for subsequent processing.

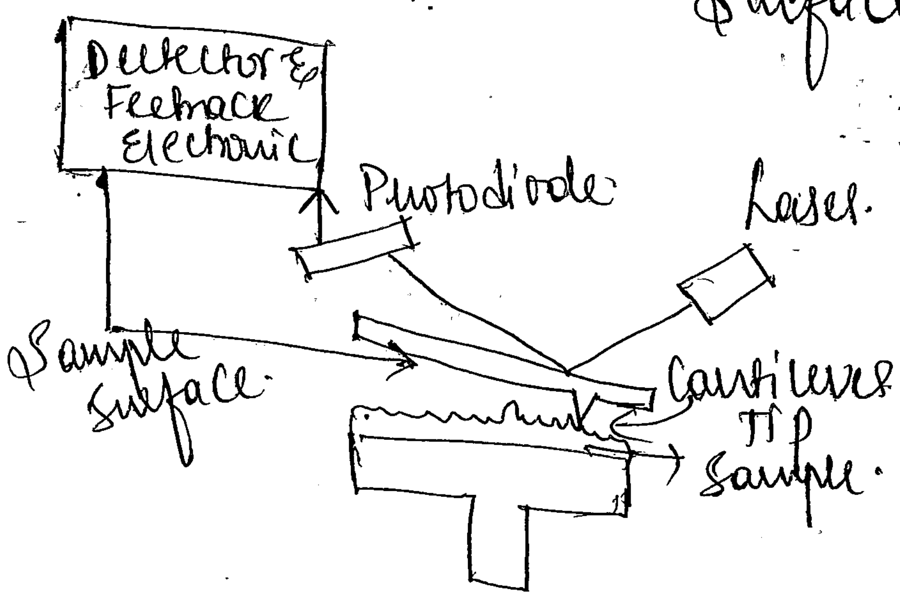


Flame assisted ultrasonic spray Pyrolysis.

8.b Explain with a neat sketch the salient features of Atomic force microscopy (AFM).

- It is a powerful microscopy technology for studying samples at nanoscale. AFM generate images at atomic resolution with angstrom scale resolution, height information with minimum sample preparation.

<u>Principle</u>:- An AFM uses a cantilever with a very sharp tip to scan over a sample surface. As the tip approaches the surface the close-range attractive force b/w the surface & tip causes the cantilever the deflect towards the surface. However as the cantilever is brought even closer to the surface such that the tip make contact with it, increasingly repulsive force takes over & causes the cantilever to deflect away from the surface.



- AFM provides a 3-dimensional surface Profile
- Does not need high vaccum
- Materials can be analyzed in different environment such in liquid under vaccum & at low temperature
- Provide a very high resolution

9.a Write a note on NC, CNC & DNC machine tools

NC - Numerical Control

* NC (Numerical Control) machine tools are the machine tool, of which the various functions are controlled by : letters, numbers & symbols
* The NC machine tool runs on a program fed to it, without human operator
* NC Programs consists of a set of instruction or statement for controlling the motion of the drives of the machine tools as well as the motion of the cutting tool

CNC - (Computer numerical Control)

* in CNC machines, a dedicated computer is used to perform the most of basic NC machine functions

* CNC machine is a NC machine which uses a dedicated Computer as the machine Control unit.
* The entire Program is entered & Stored in Computer memory.

DNC - (Direct numerical Control)

* DNC is a manufacturing system in which a number of machines are controlled by a Computer through direct-Connection & in real time.
* DNC is a set of NC machine to a Common memory for part Program or machine Program storage with Provision for on-demand distribution of data to machines.
* The Tape reader is omitted.

9.b. Explain briefly the various Strategies for automation & process improvement.

* Specialization of operations.
  This is analogous to the Concept of labour specialization, which is employed to improve labour productivity

* Combined operations
This is accomplished by Performing more than one operation at a given machine, there by reducing the number of separate machine needed.

* Simultaneous operations
A logical extension of the combined operations strategy is to simultaneous Perform the operations that are combined at one work station.

* Integration of operations
with more than one work station, several part can be processed simultaneously, there by increasing the overall output of the system.

* Increased flexibility.
Prime objective are to reduce setup time & Programming time for the Production machine.

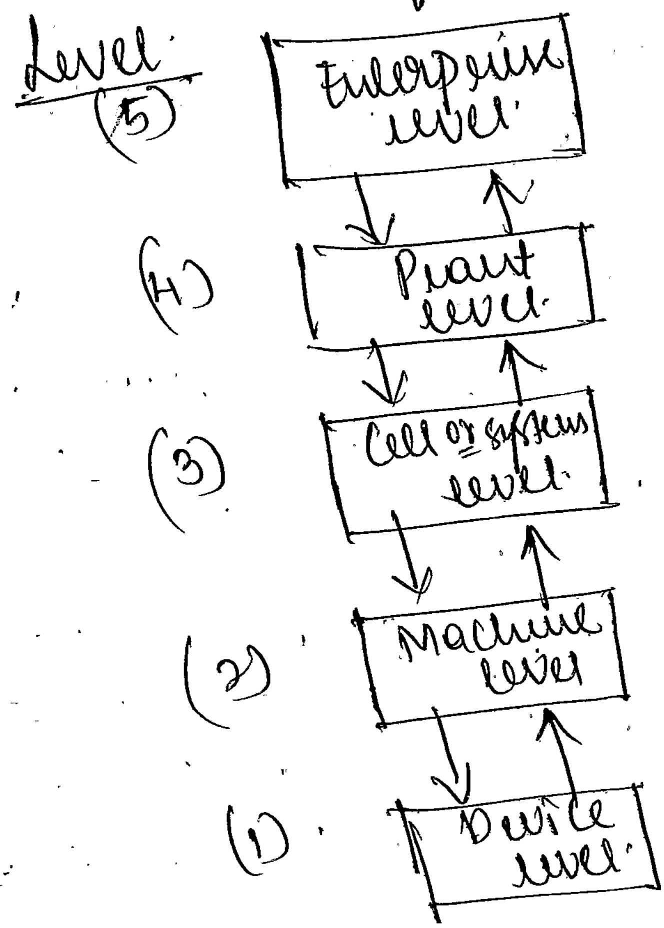
* On-line inspection
This reduces scrap & brings the over all quality of product closer to the nominal specifications intended by the designer.

* improved material handling & storage
Typical benefits include reduced work-in-process & shorter manufacturing lead times.

* Plant operations Control
* its implementation usually involves a high level of computer networking within the factory.

10.a Explain with a block diagram the level of automation

Levels of automation



Levels of automation

Enterprise level → Corporate or information system (marketing & sales, accounting, design, research, aggregate planning & MPS)

Plant level → Production system. Order Processing, process, inventory control, Purchasing, material requirement, SFC & quality control.

• Cell / system Level → Manufacturing system / Group of machines. (A manufacturing cell or system is a group of machines or work stations connected & supported by a material handling system, computer).

Machine level → individual machine (industrial robot, powered conveyors, & automated guided vehicles).

Device level → Sensors, Actuators, & other hardware elements.

10. b. Distinguish b/w continuous control in process industries & discrete control in manufacturing industries.

Comparison factor	Continuous Control in process industries	Discrete Control in Discrete manufac industries
Typical measure of product output	Weight measure, liquid volume measure, solid volume measure	Number of pat[illegible], number of produ[illegible]
Typical quality measure	Consistency, Concentration of solution, absence of Contaminants	Dimension, surface finish, appearance, Product reliabi[illegible]
Typical variable & Parameter	Temperature, volume flow rate, pressure	Position, velocity, forc[illegible]
Typical sensors	Flow meter, thermocouple, Pressure sensors	Limit switch,
Typical actuators	Valves, heater, Pumps	Switchs, motors.