Unit: 1

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✱ Numerical control machines:

(i) NC (Numerical control): Built in 1950's
- use papers/magnetic tape

(ii) CNC (Computer Numerical control): Built in 1970's
- Single directly computer directly connected with a machine.

(iii) DNC (Direct numerical control):
- Single computer can control no. of machine.

✱ Definitions:

(i) NC machine: It is define as the form of programable automation in which the process is controlled by numbers, letters and symbols. A machine tool is said to be numerically control, if it operates in semi-automatic or automatic cycles.

A system in which the action are controlled by direct insersion of numerical data at some point. The system must automatically interpret atleast some portion of this data

Operater → (NC code) → Numerical Control → (control drive) → machine control unit → (processing) → Final product

- where & why CNC machine required?
- when we need gross product.
- Whenever need high precision & accuracy.

(iii) CNC machine: In CNC machine, a dedicated computer is used to perform all basic Numeric control functions.

eg: CNC milling machine, CNC Lathe machine, CNC plasma cutter, water jet cutter etc.

→ Application:

(i) Complex part geometry.
(ii) closed tolerence.
(iii) Expensive products/parts.
(iv) several operation needed on the parts.
(v) Often changes in engineering design.
(vi) Parts process frequently in small lots (batches).

→ Advantages:

(i) Reduce lead time: (Time blw receiving of parts design & starting the actual production). It includes, setting time, planning, fictionness etc.

(ii) Elimination of operators error:

(iii) Lower labour cost:

(iv) Longer tool life.

(v) Elimination of special jigs & fixtures.
(vi) Fluxibility in part design.
(vii) less scrap generation.

• PCBN (Polycrystalline cubic Boron Nitride): 2nd hardest material after diamond
• EDM (Electric Discharge machine)

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→ Disadvantages:

(i) High investment cost.
(ii) High maintenance cost.
(iii) Skilled operater are required.

→ Classification:

(A) On the basis of motion control (tool/cutter movement)

i) Point-to-Point movement.
ii) Continuous movement.
— a) Straight cut
— b) Combination of linear & circular cut.

(B) On the basis of type of control.

i) Open loop control.
ii) Close loop control.

(C) On the basis of type of organisation of machine operation.

i) Machine tool.
ii) Machining centre.
iii) Turning centre.

(D) On the basis of no. of axis movement.

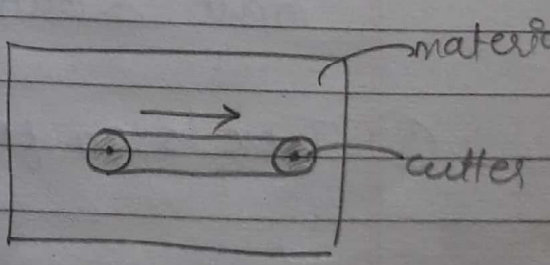
(1) Point-to-Point movement: The tool moves from one point to another point for performing machining operation. The path of tool/cutter b/w these points is not critical.

eg: Drilling, spot welding, die sinking EDM, soldering, brazing.

- The control system does not require an interpolater
- It generally covers the distance b/w the points at highest attenable velocity.
- Cutter/tool radius compensation is not required.
- There is no cutting action by tool is done by moving from one point to another.

(2) Continuous movement: Starting & ending points are same.

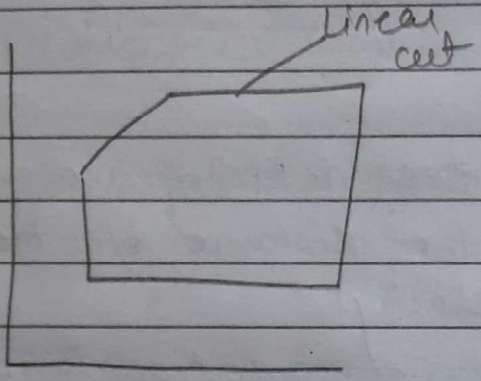
—Straight cut: The cutter moves along the straight line at controled rate b/w the points.



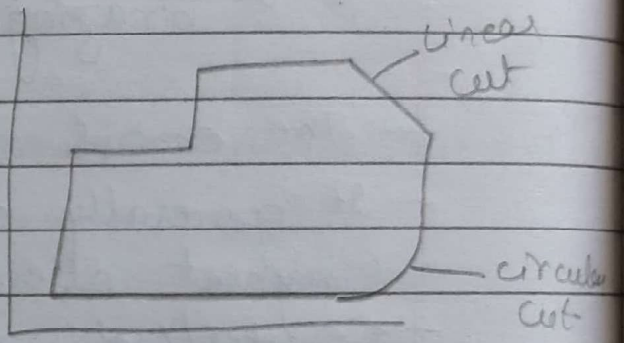
- Linear interpolation is very loud.
- No circular interpolation.
- Cutter remove material while moving.

Cutter moves at fixed feed rate.

— Combination of Lineas & circulas cut:
The path & the final destination of the tool/ cutter is need to be controlled.
— The tool/ cutter velocity is control.
— Lineas & circulas interpolation is very loud.



Streight cut

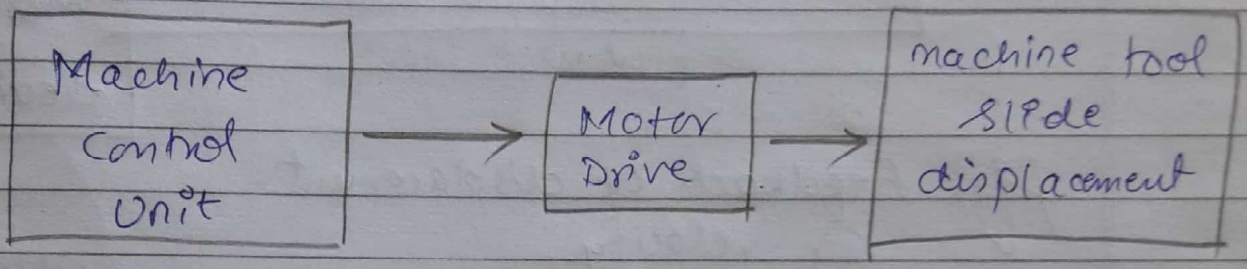


continuous cut

✱Type of control loop:

Open loop control System	Close loop control System
(i) There is no relation b/w input & output	(i) There is a relation b/w input & output.
(ii) There is no feed back	(ii) There is a feed back.
eg: light switch, washing machine	eg: FMS, AGV

(1) Open loop System: Machine tool control in which there is no provision to compare the actual position of a cutting tool or workpiece with the input command value is called an open loop system.



- Why open loop? Becoz machine control unit does not know how much machine tool slide displace (i.e. No feedback from actual slide displacement to MCU).

— In open loop control system, feedback is not required, It is less expansive & less accurate compared with close loop system.

(2) Close loop system: In close loop control system the actual output from the system is compared with the input signal. Actual displacement of machine slide is compared with the input displacement.

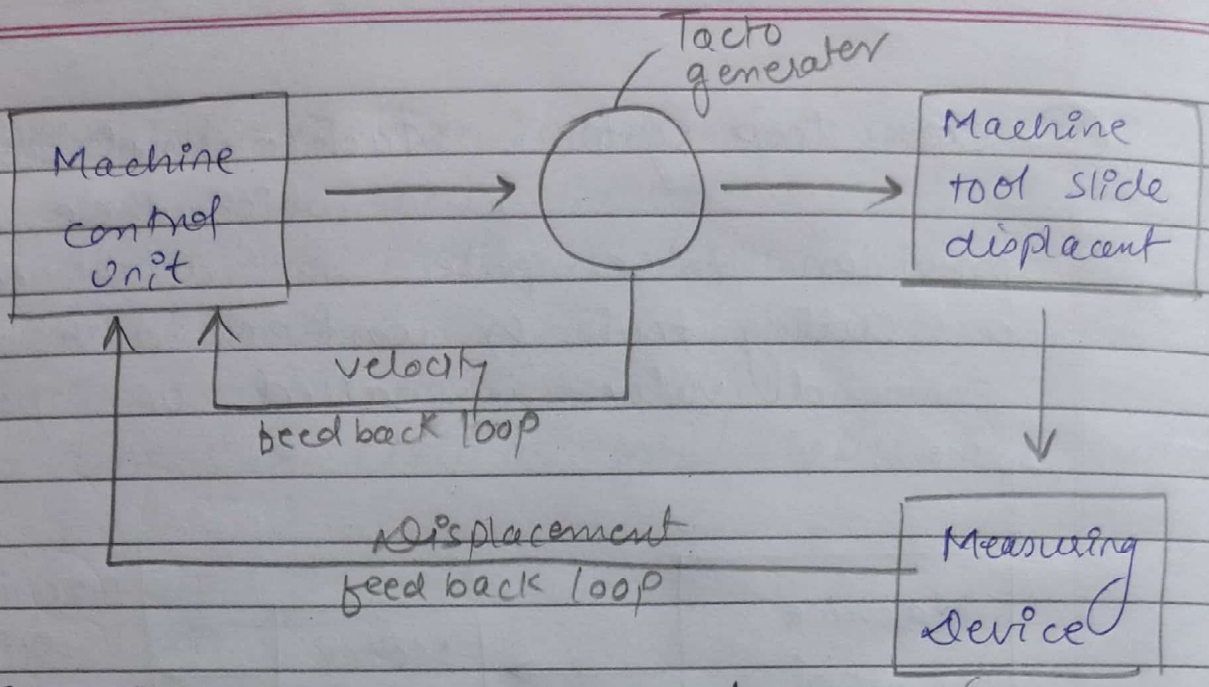


fig: Feedback of displacement & velocity.

✱ Coordinate (positioning) System in CNC machine:

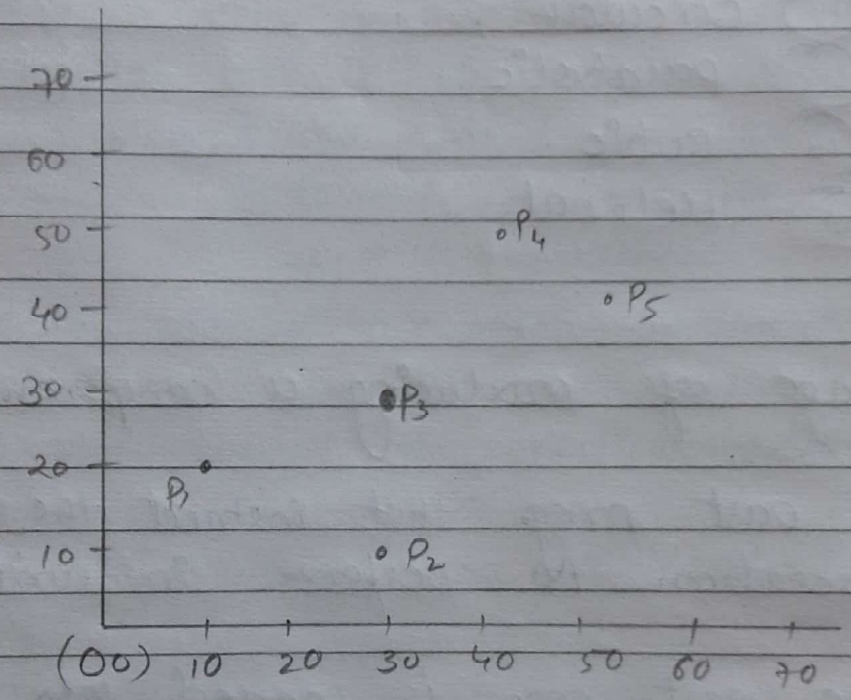
Two type of coordinate system are use in CNC machine to define & control the position of tool related to the work-piece.

(1) Absolute coord. system: In this system the coordinate of a point are always reffered with the same datum (base or origin) (i.e. (0,0))

- Major advantage of this system is that it is very easy to check & correct the program written with absolute coord. system.

(ii) Incremental Coordinate System: In this system, we coordinates ~~any~~ point are calculate with reference with previous point.

- It is difficult to check & modify a prog. written in incremental coord. system.



Points	Absolute Coor.	Incremental Coord.
P_1	(10,20)	(10,20)
P_2	(30,10)	(20,-10) P_2-P_1
P_3	(30,30)	(0,20) P_3-P_2
P_4	(40,50)	(10,20) P_4-P_3
P_5	(50,40)	(0,-10) P_5-P_4

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★ Intespolation: The method by which Contouring machine tool move from one point to the next is called intespolation.

- There are 5 method of intespolation:

(i) Linear.
(ii) circular.
(iii) parabolic.
(iv) cubic.
(v) Helical.

★ Stage of producing a component on CNC Sys:

(i) A part prog. that instruct the sequence of operation to perform is written.

(ii) The part prog. is loaded into the computer interface which is called controller.

(iii) The machine controller sends signals to the machine components directing the machine to perform the required sequence of operation encoded in the part prog. to produce the component.

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☆ Machine uses CNC

(iii) Lath :- Most lath machine are prog. on 2 axes (x & z)
— X-axis control the feet of cutting tool.
— Z-axis control the moment of tool along the length of workpiece.

(iv) Milling :- The milling machine prog. on 3 axes (x, y & z)
— X-axis control the table movement (Left or Right direction with respect to operater).
— Y-axis control the table movement toward or away from the column of machine.
— Z-axis control the vertical feet movement.

Horizontal milling machine	Vertical milling machine
Axis of spindle is Horizontal	Axis of spindle is vertical.

- Anthropomorphic : Human life.
- Automation is required for hazardious application.

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✱ Robotics : In general, "It is a special type of computes control machine that can perform wide variety of task."

- First definition of robot given by Computer aided manufacturing international (CAM-I) U.S.A. It states that, "

"A robot is a device that perform functions ordinarily ascribed to human beings, or operates with what appears to be almost human intelligence."

- Second definition of robot given by Robotics institude of America (RIA) U.S.A. It states that,

"A Robot as a programable multi-function manipulator design to move material, parts, tools or a special devices through variable programable motion for the performance of variety of task."

Industrial Robotics : An industrial robot is a general purpose programmable machine possessing certain anthropomorphic feature.

- The most obvious anthropomorphic feature is the robot's mechanical arm.

. A dedicated robot need 6 axes (Extra 3 on end effector)

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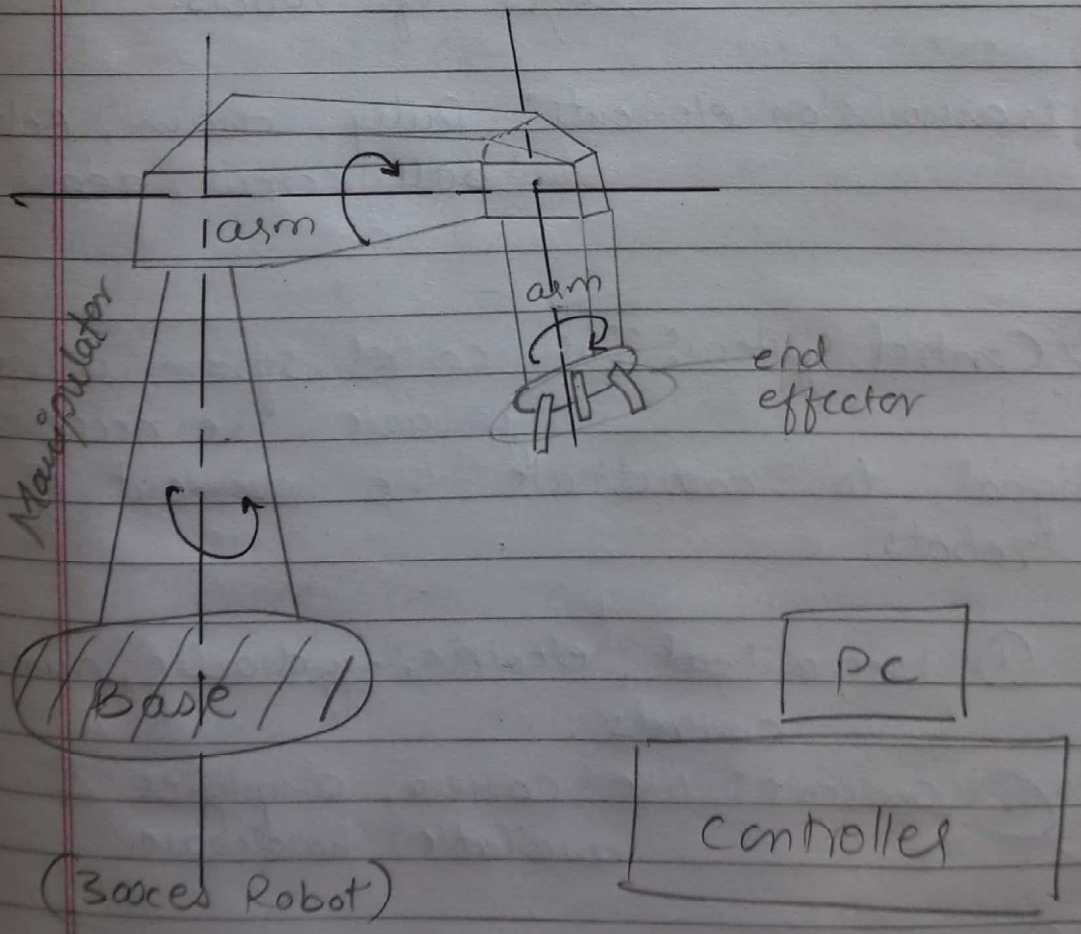
⇒ Tasks performed by Robots in factories are :
(I) Moment of material on shop floor.
(II) Automated Guided vehicle (AGV) or Rail Guided vehicle (RGV))
(III) Loading & unloading of components.
(IV) Inspection using vision sensor
(V) Manufacturing operation like painting, welding, marking, automatic assembly etc.

★ Elements of Robotics system.



- A robot is a system made up of several elements of hardware & software, includes;

(A) Robotic manipulater:

(i) A manipulator: - Base & arm assembly
- It consist of a series of link-joint-link combination (either linear or rotatory joint they are).

(ii) End of arm tooling: - Gripper & end effector

(iii) Actuator: - Moter or drives, that moves the links of robots.

(iv) Transmission elements: Pully, chain, Belts, ball screw, gears etc.

(B) Control system: The control system is use to generate the neccesory signal to coordinate the movement of robots.

(i) Mechanical, electric, hydraulic, numatic controls

(ii) Sensors: like camera, amplifies & available hardware.

(iii) Equipment interface

(c) Computer System: This provides the data processing capability to interpolate the intermediate position & control the movement of links or robotic arms.

(i) Microprocessor or Programable logic control (PLC)

(ii) Users interface: Keyboard, teach pendent, display.

★ Need for using robots: Robots are used increasingly in manufacturing industries for many reasons.

(i) Robots can be built with performance capabilities superior to those of human beings in terms of strength, size, speed, accuracy & repeatedly.

(ii) Robots are better than humans to perform simple & repeatative task with better quality & consistancy.

(iii) Robots can replace human in performing task that are difficult & hazardous due to size, weight, environment (heat, dust, chemical, Nuclear radiation & pollution).

(IV) Robots donot have the limitation & negative attributes of human being or human workers. like, fattique, need for rest, energy drink & refreshment.

(V) Robots can lowes the cost through reduction in uses of of material throegh theis efficiency

(VI) Robots become more economical as labour cost increase at highes pace.

→ Although may have many advantages they are not always the best choice for all manufacturing application Even though they may have wide variety of capabilities, they still can not match the unique combination of mental skill & atten physical dexterity of human operater.

Howeves, Robots can suppliment human operators to enhance their productivity.

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✱ Manipulater design :

3 axis : Base & arm assembly
3 axis : End effecter (Roll, Yaw, Pitch) (wrist assembly)

A Robot Manipulator can usually be divided into two section,

(I) Base & arm assembly (Body & arm assembly)
(II) Wrist & arm assembly

- There are different 3 joints associated with body and arm assembly and two or three joints associated with wrist.

- The function of arm & body is to position an object or tool.
- Positing is concern with moving the part/tool or object from one location to another.
- Orientation is concern with precisely allining the object relation to some stationary location.
- The arm & body consist of large link and joint the wrist consist of short link.
- The arm and body joint often consists of both Lineas and rotating types while the wrist joint are almost rotating types.

There are 3 joints of wrist motion:

(i) Roll: Rotation / survival motion or movement in a plane ⊥ to the end of arm.

(ii) Pitch: Rotational or Bending movement in a plane vertical to the arm.

(iii) Yaw: Rotational or twisting movement in a plane horizontal to the arm.

Application of industrial robot:

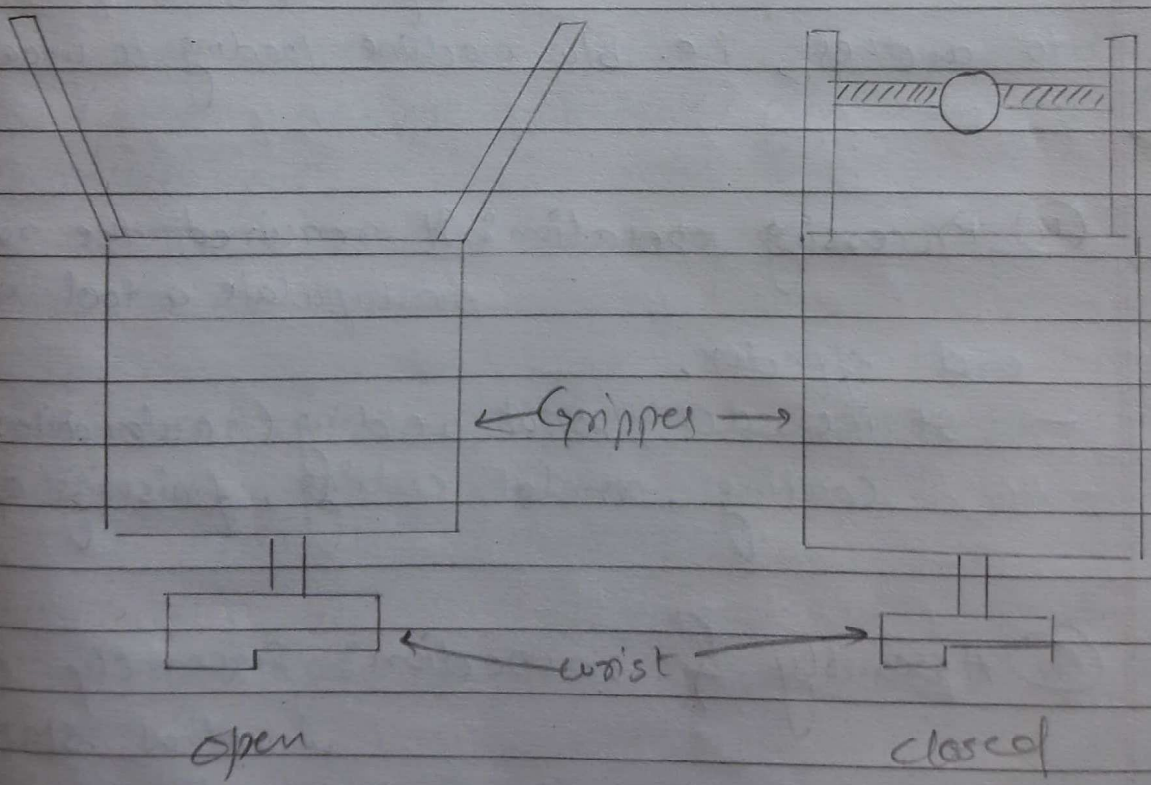
Robot are being used for a wide variety of task in industries. A study of application wise rise breakup with industrial robots in USA & japan

App.	USA	Japan
Welding	35%	28.5 %
Material handling	26 %	27.5 %
Casting	8%	9 %
Loading	5%	3.5 %
painting	16%	2.6 %
Other	10 %	5.5 %

End effecter: It is a special tool that connects to the robots wrist for performing special tasks.

Gripper: Grippers are design to grab and move object, during work cycle. The objects are usually work parts.

— They are used for part placement application, machine loading & unloading.



Application of industrial robots:

(i) Working environment is hazardous for human.
(ii) Workcycle is repeatative.
(iii) Part/tool handling would be difficult for human
(iv) Multishift operation.
(v) Long production run & infrequent change over.

— App. of industrial robots can be divided in three basic categories;

(i) Material handling: It involve the movement of material from 1 location to another, i.e. b/w machine loading to unloading etc.

(ii) Procesing operation: It required the robot to manupulate a tool as its end effecter.
— · It includes, spot welding (in automobiles), spray coating, metal cutting, finishing operation.

(iii) Assembly & enspection: Assembly operation involves staking of one part on to another part.
- Inspection oper. sometimes required the robot to position a work part relative to an inspection device or to load a part into an inspection machine.

✱ Robots manufacturing companies:

ABB
Kawasaki
KuKa
Universal

✱ Adaptive Control :- It is a type of AI.

- It controls the feed speed. i.e, it decrease / increase the tool speed to maintain vibrations in work piece.

- If it observe an obstacle along its path, then system analyse obstacle's dimension and changes robot's path.

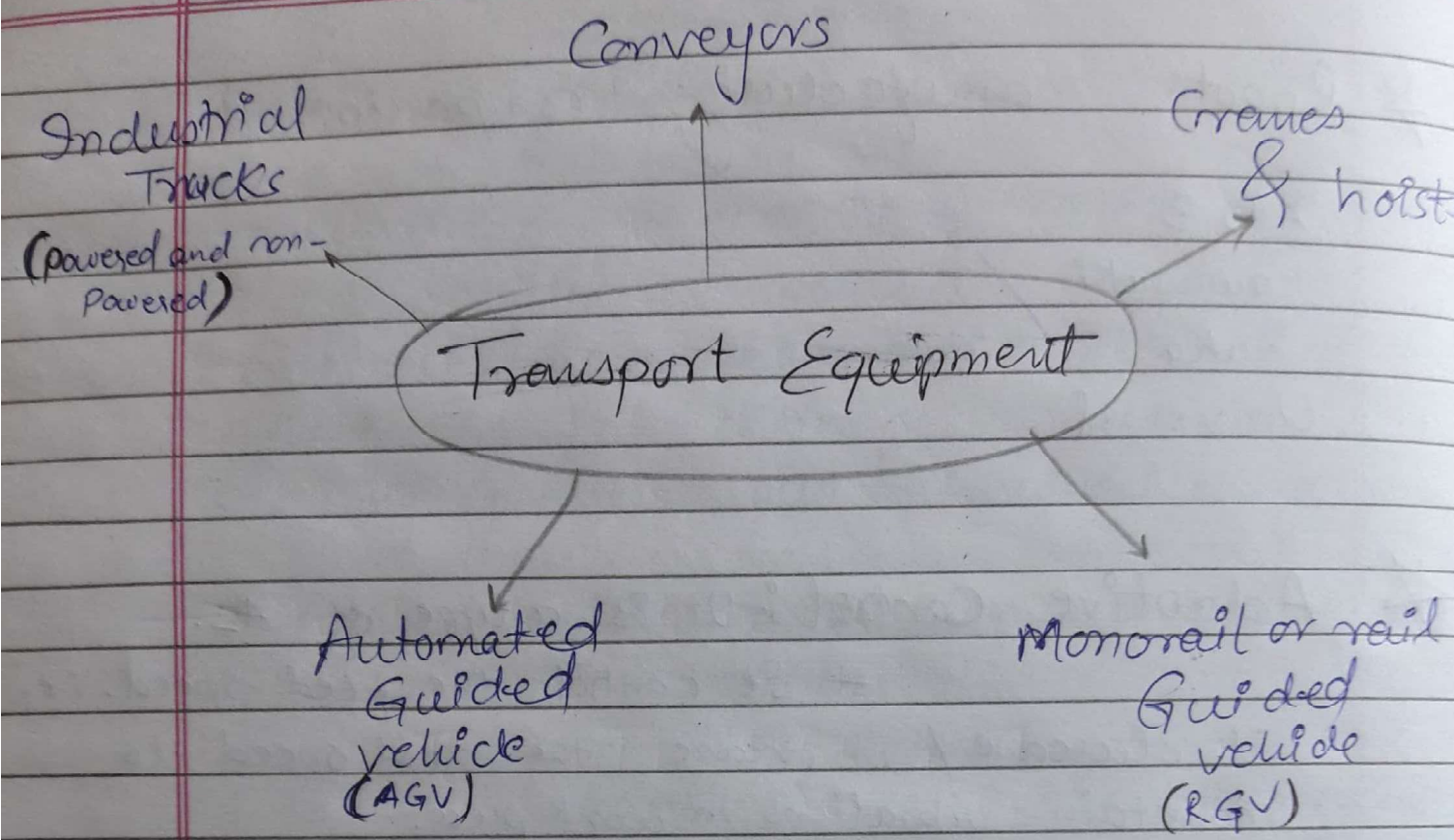
Material handling equipments:

(i) Transport equipment

(ii) Storage equipment

(iii) Unitizing / packaging equipment

(iv) Identification & tracking system.



⇒ Automated Guided Vehicle (AGV)

- 1954 (Barett firearms) by A.M. Barrett
- 1973 (Volvo), for transporting vehicle bodies from one workstation to another workstation

- AGV follow a pathway, and they are flexible along their path.
  - (i) Underground
  - (ii) Coloured paint.

- An Automated Guided Vehicle System (AGVS) is a material handling system that uses independently operated self-propelled vehicles guided along define pathways
- AGV are battery operated automatically steered vehicle, that followed define pathways on the road. Such vehicle have on road controller that can be programmed for complicated and variable roots as well as for load & unload operations.
- A distinguishable feature of AGV compase with conveyor or RGV is that the pathways are unobstrusive.
- An AGV is suitable for automated material handling system in batch production or mixed model production.

Advantages: (i) Flexibilities
(iv) Real time monitoring & control
(ii) Safety.

features: (i) High cost.
(ii) Battery powered vehicle. (ecofriendly)
(iii) Flexible rooting.
(iv) Non-obstrusive pathways

Analysis of AGVS:

- Delivery cycle consist of loading & pickuping stations
- Travel time to the drop stations
- Unloading at drop station
- Empty travel time of travel b/w deliveries

→ Total cycle time per delivery per vehicle

$$T_c = T_L + \frac{D_L}{V_c} + T_U + \frac{D_e}{V_c}$$

(min/delivery) — T_L (min); $\frac{D_L}{V_c}$ ($\frac{\text{meter}}{\text{meter/min}}$); T_U (min); $\frac{D_e}{V_c}$ ($\frac{\text{meter}}{\text{meter/min}}$)

Where; T_c = Delivery cycle time (Total time)
T_L = Time to load at load station.
T_U = Time to unload at drop station.
D_L = Distance travel by vehicle to preload & unload station
D_e = Distance travel by empty vehicle until the start of next delivery cycle
V_c = vehicle velocity.

Availability: It is a reliability factor define as, "The proportion of total shift time that a vehicle is operational and not broken down or being repair".

Available time per hour per vehicle:

$$AT = 60\ A\ T\ E$$

where: AT = Available time (min/hour/vehicle)
60 = 1 hour = 60 min (min)
A = Availability (unitless)
T = Traffic factor.
E = operator efficiency. (Generally E = 1)

The rate of delivery per vehicle.

$$R_{dv} = \frac{AT}{T_c}$$

R_{dv} — delivery/hour per vehicle
AT — min/hour
T_c — min/delivery
(delivery/hour)

Flow rate of total deliveries for system

$$R_f = N R_{dv}$$

N — Total no. of AGVs
R_f — delivery/hour

Work load: Total amount of work that have to be accomplished by material transport system in one hour.

$$WL = R_f T_c$$

min/hour

Total no. of AGVs: N AGV are required to accomplishe the specified workload.

$$N = \frac{WL}{AT}$$

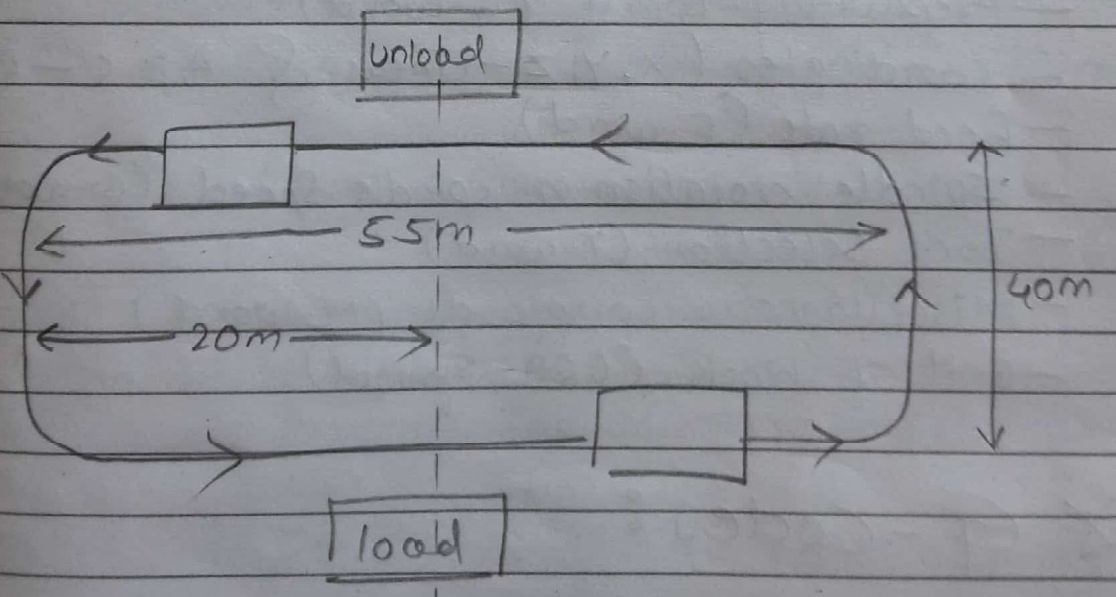
$$N = \frac{R_f \times T_c}{R_{dv} \times T_c}$$

$$N = \frac{R_f}{R_{dv}}$$

Ans: In the given AGVS layout vehicle travels counterclockise around the loop to deliver loads from load station to unload station. Loading time at load station 0.75 min & unloading time at unload station is 0.5 min. It is desired to determine, how many vehicle are required to satisfy the demand for this layout. If a total of 40 delivery/hours must be completed by AGVS. The following perfomace parameters are given as vehicle velocity is 50 m/min. Availability 0.95 Traffic factor 0.90 & E=1 (If it is not given, always consider E=1) determine. (i) Travel distance load & Empty.

(ii) Ideal delivery cycle time.

(iii) No. of vehicle required to satify delivery demand.



$A = 0.95$ $T_f = 0.90$ $T_L = 0.75 \text{ min}$ $T_0 = 0.50 \text{ min}$

$V_c = 50 \text{ m/min.}$

$D_L = 110 \text{ m}$; $D_E = 80 \text{ m}$

$$T_c = 0.75 + 0.50 + \frac{110}{50} + \frac{80}{50}$$

$T_c = 5.05$

$n = 4 \text{ vehicle}$

✡ Basics of CNC programming:

Word Address format: Words in an instruction block are intended to convey command needed for machine tool to execute specific operation.

Sequence of word in a block: We have to write program in sequence

- Sequence no. or sequence word (N-word)
- Preparatory word (G-word)
- coordinates (X, Y, Z - Linear & A, B, C - Rotation)
- Feed rate (F-word)
- Spindle rotation or spindle Speed (S-word)
- Tool selection (T-word)
- Miscellaneous commands (M-word)
- End of block (EOB - Symbol)

✡ G-Codes:

code	Description/ feature
G00	- Point to point movement (Rapid travel) b/w previous point & end point. - It must include x, y, z coord. of end point.

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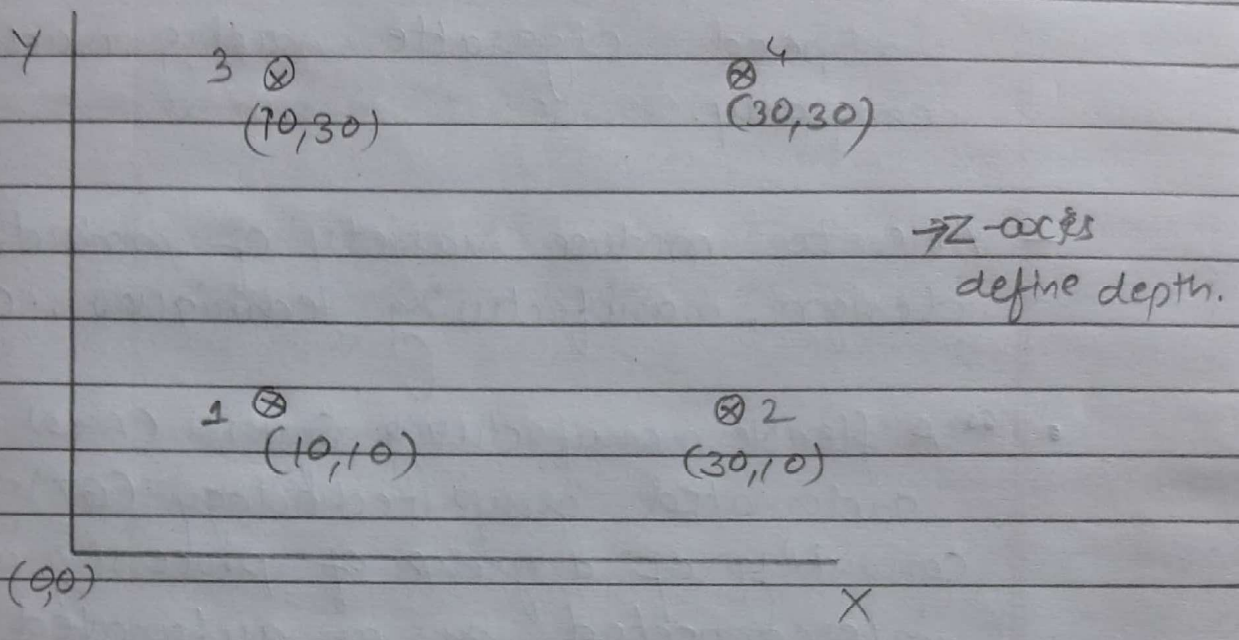
G01	- Linear interpolation movement. - It must include x, y, z coord. of end point & feed rate.
G02	- Circular interpolation (clockwise) - Block must include either arc radius or arc centre and coord. of endpoint - Feed rate required.
G03	- Circular interpolation (counter clockwise) - Block must include either arc rad. or arc centre and cood. of end point. - Feed rate.
G20	- Input values Specified in inches.
G21	- Input values specified in mm.
G90	- Programming in absolute coord.
G91	- Programming in incremental coord.
G92	- Specify location of coord. axes system, origin relative to starting location of cutting tool.
G94	- Specify feed per min (milling & drilling)
G95	- Specify feed per revolution (Milling & drilling)
G98	- Specify feed per min (Turning)
G99	- Specify feed per revolution (Turning)

☆ M-Codes:

Code	Description / fundion
M03	- Start spindle in clockwise direction.
M04	- Start spindle in anti-clockwise direction.
M05	- Spindle stops.
M06	- Execute tool change.
M13	- Start spindle in clockwise direction & turn on cutting fluid.
M14	- Start spindle in anti-clockwise direction & turn on cutting fluid.
M17	- Spindle & cutting fluid off.
M30	End of program (Machine stops)

Que: Write prog. to drill on a workpiece in specified cood.



- Generally all direction distances are in mm.
- Origin is always take away from starting point.
- Cutting tool is placed (rapidly), 2mm above from the working material to avoid breakdown of tool.

Prog:

```
N005 G21 G90 G00 X10 Y10 Z10;
10 S1000 M03;
15 G00 Z2;
20 G95 G01 Z-10 F0.05;
25 G95 G01 Z2 F0.10;
```

✱ Flexible Manufacturing System (FMS)

- In 1960's, David Williamson use FMS for high speed cigaratte making machine in Molin company.

- Able to produce variety of products, by changing design, manufacturing techniques, cell etc.

- "A flexible manufacturing system (FMS) is a highly automated group technology (GT) machine cell consisting of a group of processing workstation, interconnected by an automated material handling & storage system and controlled by a distributed computer system."

AS/RS: Automated storage & retrival System.

Why FMS is flexible? The reason behind the flexibility of FMS is that, it is capable of processing a variety of different parts type simultaneously at different workstation. The mix of parts style and quantities of production can be adjusted in responce to change in demand pattern

- FMS is most suitable for mid variety and mid volume production range.

Classification of FMS

- To qualify as being flexible a manufacturing system should satisfy several criterion (Test of flexibility)

(i) Part variety test:
Can the system process different parts style in a non batch mode

(ii) Schedule change test:
Can the system readily accept changes in production schedule and changes in either parts mix or production quantities.

(iii) Error recovery test:
Can the system recover greacefull from equipment breakdown so that production is not completely distructed or stoped.

(iv) New part test:
Can new part design be introduce into existing product mix with relative ease.

Note: If the automated system does not meet atleast 3 test, it should not be classified as FMS.

✱ Types of flexibilities:

(I) Machine flexibility: Capability to adapt a given machine in the system to a wide range of production operation.

(II) Production flexibility: The range of parts style that can be produced.

(III) Mixed flexibility: Ability to change the product mix while maintaining the same production quantities.

(IV) Product flexibility: Each with which design changes can be accomodated
Each with which new product can be produce.

(V) Routine flexibility: Capacity to produce parts through alternative workstations sequences in response to equipment breakdown (tool failure).

(VI) Volⁿ flexibility: Ability to produce parts economically in high & low quantities

(VII) Expansion flexibility: Easy with which the system can be expanded to increase total production.

* Comparision of 4 criterion of flexibility in manufacturing system with the 7 types of flexibility

Flexibility test	Type of flexibility
(i) Part variety test	- Production. - Machine.
(ii) Schedule change test	- Expansion. - Mix. - Vol".
(iii) Error recovery test	- Routine.
(iv) New part test	- Product.

* Types of flexible Manufacturing System:

(1) Based on No. of machine.

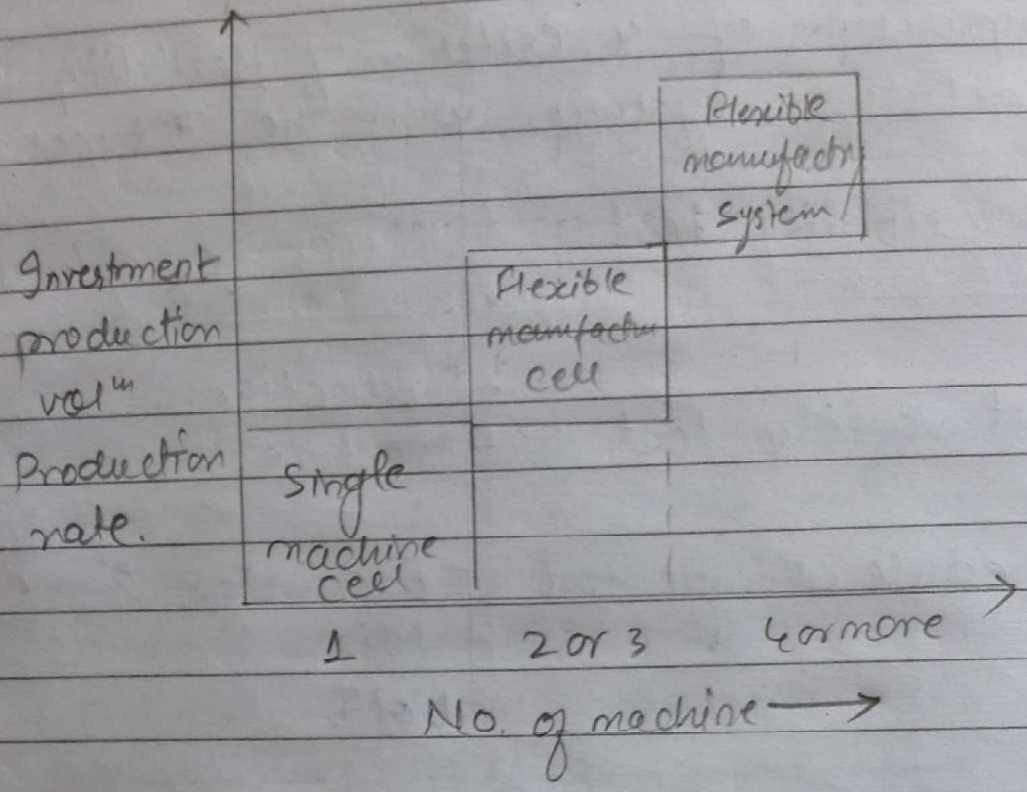
(a) Single machine cell: It does not satisfy error recovery test.

(b) Flexible manufacturing cell: It satisfy all 4 test.

It contains 2 to 3 machine or workstation, along with part entering system.

(c) Flexible manufacturing system: It satisfy all 4 test.

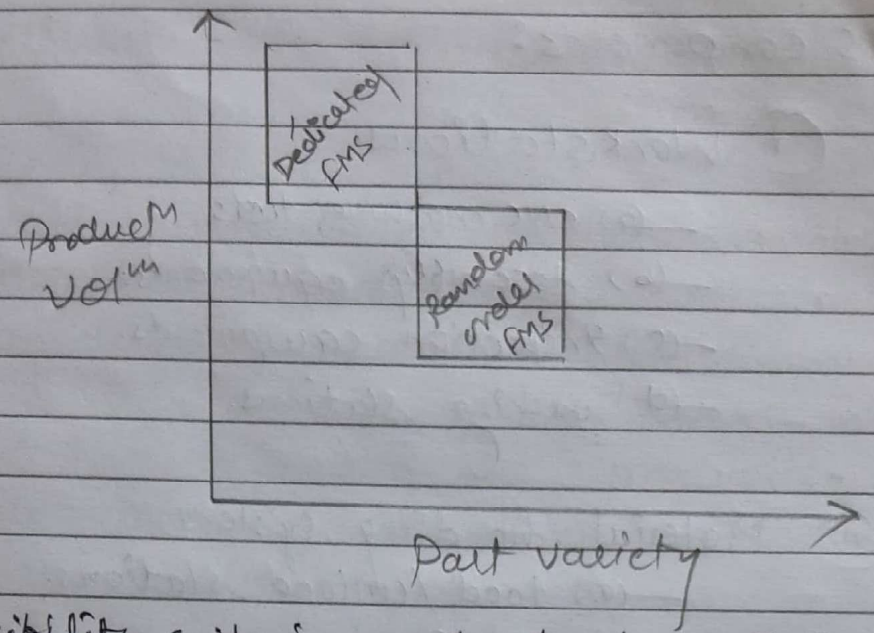
It has 4 or more workstation connected mechnically by a common part handling system and electronically by a distributed computer system.



(iv) Based on level of flexibility:

(a) Dedicated FMS: A dedicated FMS is design to produce a limited variety of parts and all parts to be made one system are known in advance.

(b) Random order FMS: A Random order FMS is more appropriate when the part family is large. and there is sustaintial change in part configuration, introducing new part design, day-to-day change in production schedule. It is equiped with general purpose machine to deal with variation in part design and demand fluctuation.



★ Flexibility criterion apply to types of FMS based on no. of machine & level of flexibility.

System types	Flexibility criterion: Part variety	Schedule change	Error recovery	New Part
Single manufactg cell	Yes	Yes	No (limited recovery)	Yes
Flexible manufactg cell	Yes	Yes	Yes (error recovery limited by fewer machine than FMS)	Yes
Flexible manufactg system	Yes	Yes	Yes (machine redundancy minimises effect of machine break-down)	yes.
Dedicated FMS	limited (all part known in advance)	limited changes can be tolerated	Limited by sequencial process	No (New part introduction is difficult)
Random order FMS	Yes	Frequent changes can be possible	Machine redundancy minimises effects of machine break down	Yes

☆ FMS components:

(i) Workstations
- (a) CNC machine tools
- (b) Assembly equipments.
- (c) Inspection equipments.
- (d) washing stations.

(ii) Material handling system.
- (a) load / unload stations.
- (b) AGVS
- (c) AS/RS

(iii) control System.
- (a) Monitoring equipments
- (b) Network
- (c) production control, traffic controls.

(iv) Tool system.
- (a) Tool setting station
- (b) Tool transport system.

☆ Benefits of FMS: (i) Increase machine Utilisation

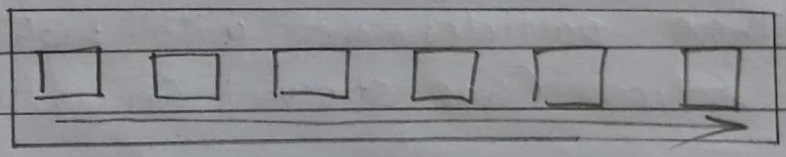
(ii) Fewer machine required.
(iii) Reduction in factory floor space required.
(iv) Reduce inventery requirement.
(v) Lower manufacturing lead time.
(vi) Reduce direct labour requirements.
(vii) Higher labour productivity

☆ Cellular manufacturing: Cellular manufacturing works on group technology, in which similar parts are identified and grouped together to take advantages of their similarities in design & production.

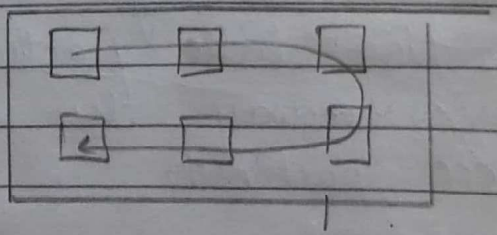
Grouping the production equipments into machine cell where each cell specilised in the production of part family, is called cellular manufacturing.

→ There are 3 types of machine cell design.

(i) Straight or inline cell



(iv) U-shape cell



(iii) L-shape cell