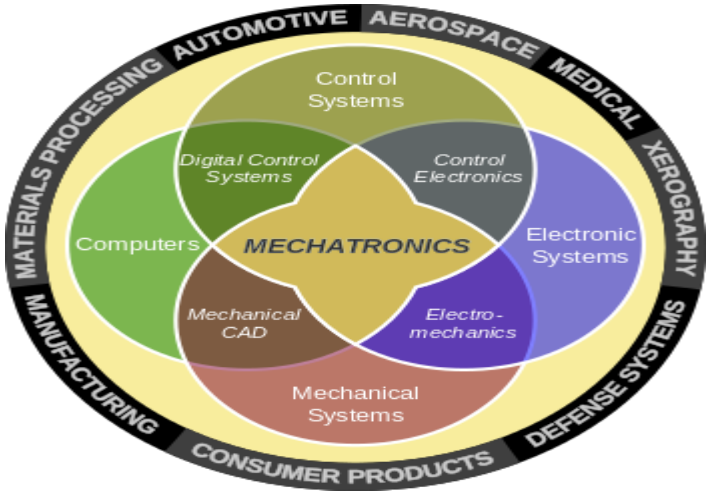
IIPM- SCHOOL OF ENGINEERING & TECHNOLOGY
(IIPM-SET), KANSBAHAL, ROURKELA

Mechatronics

(Th- 04)

(As per the 2020-21 syllabus of the SCTE&VT, Bhubaneswar, Odisha)



Fifth Semester

Mechanical Engg.

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MECHATRONICS

CONTENT

Chapter no.1

INTRODUCTION TO MECHATRONICS

Learning objective

1.1 Definition of Mechatronics

1.2 Advantages & disadvantages of Mechatronics

1.3 Application of Mechatronics

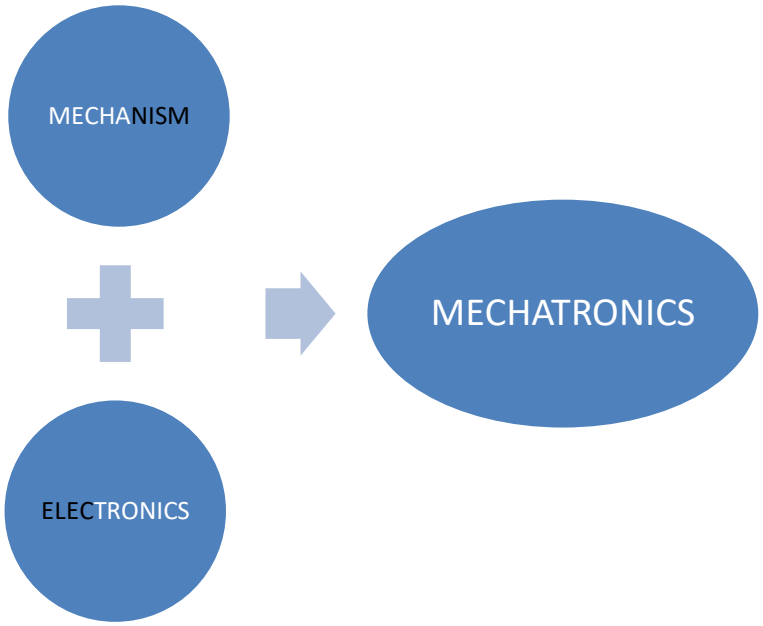
1.4 Scope of Mechatronics in Industrial Sector

1.5 Components of a Mechatronics System

1.6 Importance of mechatronics in automation

1.1 Defination of Mechatronics

- **Mechatronics** can be defined as the application of electronics and computer technology to control the motions of mechanical systems .
- **Mechatronics** is a co-ordinated ,and concurrently developed ,integration of mechanical engineering with electronics and intelligent computer control in the design and manufacture of products and processes .It involves the bringing together of a number of technologies : mechanical engineering ,electronic engineering ,electrical engineering ,computer technology and control engineering



Mechatronics brings together areas of technology involving sensors and measurement systems ,drive and actuation systems , and microprocessor systems , together with the analysis of the behaviour of systems and control systems .

1.2 Advantages and disadvantages of Mechatronics :

Advantages:

- There are many advantages of mechatronic systems . Mechatronics systems have made it very easy to design processes and products .
- The products produced are cost effective and very good quality .
- Application of mechatronics facilitates rapid setting up and cost effective operation of manufacturing facilities .
- High degree of flexibility .
- Greater extent of machine utilisation .
- Mechatronic systems help in optimizing performance and quality .These can be adopted to changing needs .

Disadvantages :

- Mechatronic systems are not without their disadvantages . One disadvantage is that the field of mechatronic requires a knowledge of different disciplines .
- High initial cost of the system .
- Also , the design cannot be finalized and safety issues are complicated in mechatronic systems . Such systems also require more parts than others , and involve a greater risk of component failure .

1.3 Application of Mechatronics :

Mechatronics has a wide range of applications , as discussed in the following subsections .

- **Design and Modelling :**
  Design and modelling are simplified to a large extent by the use of mechatronic systems . Basically ,design involves drawing ,analysis , and documentation .
- **Software Integration：**
  Different kind of software are used in manufacturing ,design , testing ,monitoring and control of the manufacturing process .
  Examples of such software include computer aided design (CAD) ,computer aided testing (CAT) ,computer aided engineering (CAE) ,and computer aided processing planning (CAPP) . The integration of the packets of software leads to computer integrated manufacturing (CIM) or just -in-time (JIT) manufacturing .
- **Actuators and Sensors :**
  Mechanical , electrical , hydraulic ,and pneumatic actuators are widely used in the industry .
  Toggle linkage and quick return mechanics are typical examples of mechanical actuators .

Switching devices ,solenoid-type devices ,and drives such as alternative current (ac) and direct current (dc) motors can be used as electrical actuators .
Hydraulic and pneumatic drives use linear cylinders and rotary motors as actuators .

- **Intelligent control :**
  Feedback control systems are widespread not only in nature and the home but also in industry .There are many industrial processes and machines which control many variables automatically .Temperature ,liquid level ,fluid flow ,pressure ,speed ,etc are maintained constant by process controllers .Adaptive control and intelligent manufacturing are the areas where mechatronic systems are used for decision making and controlling the manufacturing environment .
- **Robotics :**
  Robot technology uses mechanical , electronics , and computer systems . A robot is a multifunctional reprogrammable machine used to handle materials ,tools ,or any special items to perform a particular task .
- **Manufacturing :**

In the domain of factory automation , mechatronics has far-reaching effects in manufacturing .Major constituents of factory automation include computer numerically controlled (CNC) machines ,robots ,automation systems , and computer integration of all functions of manufacturing .Low volume , more variety ,higher levels of flexibility ,reduced lead time in manufacture ,and automation in manufacturing and assembly are likely to be the future needs of customers ,and mechatronic systems will play an important role in this cotext .

1.4 Scope of mechatronics in Industrial sector :

The scope of mechatronics in industrial sector are the following –

- To improve products and processes
- To develop novel mechanisms
- To design new products
- To create new technology using novel concepts

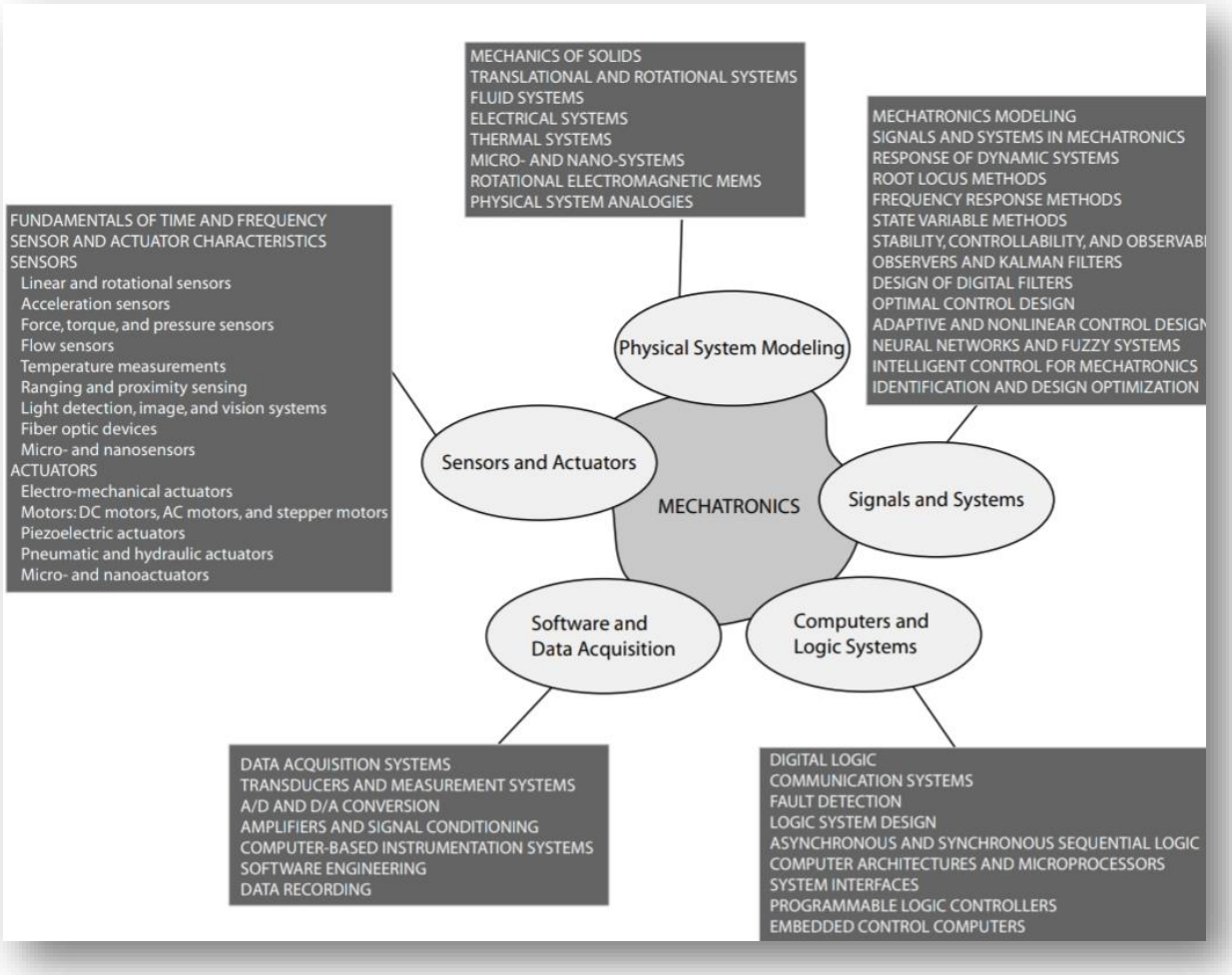
In the industry large scale improvements have been made using mechatronic systems in flexible manufacturing engineering systems (FMS) involving computer controlled machines , robots ,automatic material conveying and ,overall supervisory control .

Mechatronics play very important role in industrial sector in manufacturing industry .Major constituents of factory automation include computer numerically controlled (CNC) machines ,robots ,automation systems , and computer integration of all functions of manufacturing industry .Low volume , more variety ,higher levels of flexibility ,reduced lead time in manufacture ,and automation in manufacturing .

1.5 Components of a Mechatronics system:

Mechatronics system can be divided into the following :-

- **Physical systems Modeling**
- **Sensors and Actuators**
- **Signals and systems**
- **Computer and Logic systems**
- **Software and Data Acquisition**



Components of Mechatronics systems

1.6 Importance of mechatronics in automation:

In the domain of factory automation , mechatronics has far-reaching effects in manufacturing .Major constituents of factory automation include computer numerically controlled (CNC) machines **,**robots ,automation systems , and computer integration of all functions of

manufacturing .Low volume , more variety ,higher levels of flexibility ,reduced lead time in manufacture ,and automation in manufacturing and assembly are likely to be the future needs of customers ,and mechatronic systems will play an important role in this cotext .

SHORT QUESTIONS WITH ANSWER

Q.1 Define Mechatronics ? [2020 (w)New]

Ans :-The synergistic combination of precision mechanical engineering ,electronic control and systems thinking in the design of products and manufacturing process .

Q.2 What are the Components of a Mechatronics system ?

ANS: -Mechatronics system can be divided into the following :-

- **Physical systems Modeling**
- **Sensors and Actuators**
- **Signals and systems**
- **Computer and Logic systems**
- **Software and Data Acquisition**

Q.3 What are the Advantages and disadvantages of Mechatronics ?

Advantages:

There are many advantages of mechatronic systems . Mechatronic systems have made it very easy to design processes and products . Application of mechatronic facilitates rapid setting up and cost effective operation of manufacturing facilities . mechatronic systems help in optimizing performance and quality .These can be adopted to changing needs .

Disadvantages :

Mechatronic systems are not without their disadvantages . One disadvantage is that the field of mechatronic requires a knowledge of different disciplines .Also , the design cannot be finalized and safety issues are complicated in mechatronic systems . Such systems also require more parts than others ,and involve a greater risk of component failure .

4. " The system Mechatronics " is employed with how many systems ? [2020 (w) New]

Ans:- The system Mechatronics is employed with

(i)Mechanical Systems

(ii)Electrical System

(iii) Electronics Systems

(iv) Instrumentation and Control Systems

(v)Information Systems

(vi) Computer Systems

LONG QUESTIONS

Q.1 What kind of Scope of Mechatronics in Industrial sector have ?

Q.2 Importance of Mechatronics in automation ?

Q.3 Write down the Application of Mechatronics ?

Q.4 Explain Mechatronics System and Measurement system with appropriate block diagram with advantages and disadvantages ? [2020 (w) New]

Chapter No.5

ELEMENTS OF CNC MACHINES

Learning Objectives

5.1 Introduction to Numerical Control of machines and CAD/CAM

5.1.1 NC machines

5.1.2 CNC machines

5.1.3.CAD/CAM

5.1.3.1 CAD

5.1.3.2 CAM

5.1.3.3 Software and hardware for CAD/CAM

5.1.3.4 Functioning of CAD/CAM system

5.1.3.4 Features and characteristics of CAD/CAM system

5.1.3.5 Application areas for CAD/CAM

5.2 elements of CNC machines

5.2.1 Introduction

5.2.2 Machine Structure

5.2.3 Guideways/Slide ways

5.2.3.1 Introduction and Types of Guideways

5.2.3.2 Factors of design of guideways

5.2.4 Drives

5.2.4.1 Spindle drives

5.2.4.2 Feed drive

5.2.5 Spindle and Spindle Bearings

5.1 ELEMENTS OF CNC MACHINES

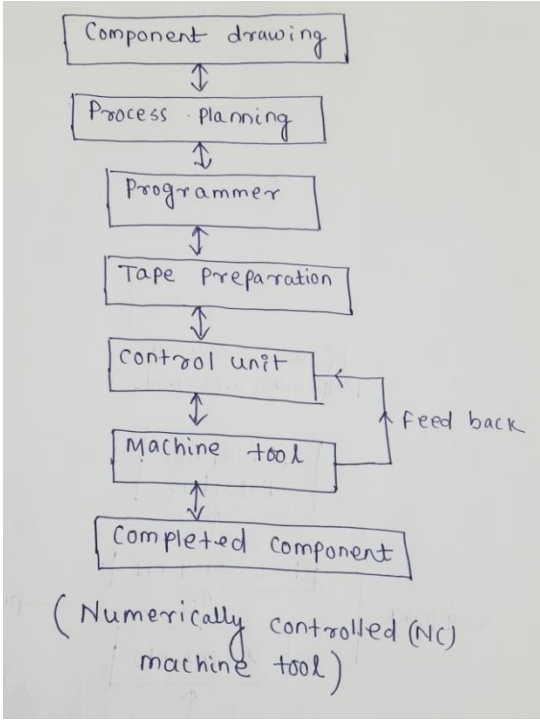
Numerical Control ,NC can be defined simply as control by numbers .A machine tool having a dedicated computer to help prepare the program and control some or all of the operations of the machine tool is called Computer Numerical Control (CNC) machine tool.

5.1.1 NC Machines

A system in which actions are controlled by the direct insertion of numerical data at some point . The system must automatically interpret at least some portion of this data .

In NC machines , the input information for controlling the machine tool motion is provided by means of punched tape or magnetic tapes in a coded language .

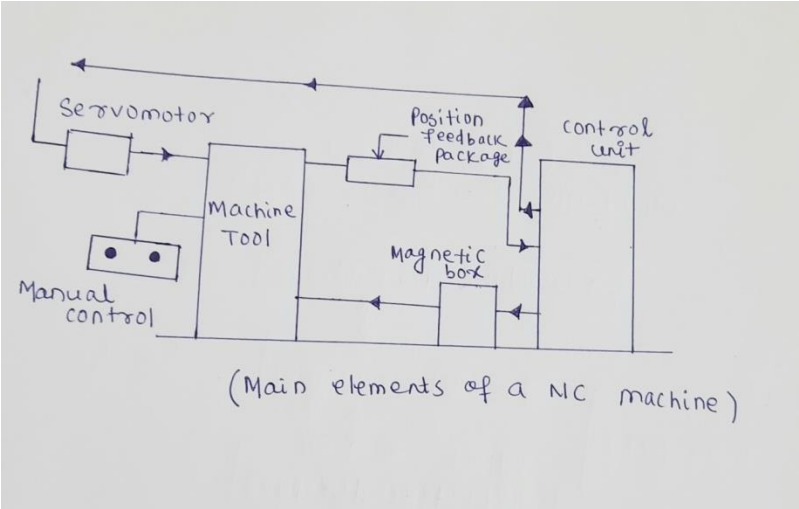
Working of NC machine tool:-



- Working sequence of a NC machine tool viz-a-viz operator controlled and NC machine tools are shown as above .
- In the operator controlled machine tools ,the operator controls the cutter position during manufacture and also makes necessary adjustments and corrections to produce the desired component .
- However , in NC machine tool the operator is replaced by the data processing part of the system and the control unit .

- In the data processing unit ,the co-ordinate information regarding the component is recorded on a tape by means of a teleprinter .
- Tape is fed to the control unit which sends the position command signals to slideway transmission elements of the machine .At the same time ,the command signal is constantly compared with the actual position achieved , with the help of position feedback signal derived from automatic monitoring of the machine tool slide position .The difference in two signals ,if any ,is corrected until the desired component is produced .

Main elements of a NC machine tool :



(Main elements of a NC machine)

The main elements of a NC machine tool are :-

- The control unit (also known as NC console or Director)
- The drive units .
- The position feedback package
- Magnetic box
- Manual control

- In the control unit , a tape recorder reads the instructions (written in a coded language) for manufacturing the component .
- The instructions under electronic processing and the control unit sends command signals to the drive units of the machine tool and also to the magnetic box .
- Command signals sent to the drive units of the machine tool ,control the length of travel and feed rates ,while the command signals sent to the magnetic box control other

functions such as spindle motor starting and stopping selecting spindle speeds, actuation of tool change ,coolant supply etc.

- A feedback transducer provided in the machine tool checks whether the required lengths of travel have been obtained .It sends the information of the actual position achieved to the control unit .In case there is any difference between the input command signal and the actual position achieved ,the drive unit is actuated by suitable amplifier from the error signal .
- Manual control provided in the machine tool assists the operator to perform some functions manually such as motor start-stop ,speed change ,feed change , axe movements ,coolant supply .

Classification of NC machines :-

NC machines may be classified as follows:

(i)According to control system:-

1. Point-to-system: The machining is done at specific positions .

Example: Drilling machine operation .

2.Straight line system: It is an extension of point to point system .

Example: Stepped turning on lathe , Pocket milling .

3.Contour system : There are continuous , simultaneous and co-ordinated motions of the tool and work piece along different coordinate axes .

Example: Machining of Profiles ,contours and curved surfaces .

(ii)According to feedback :-

1.Open loop system : There is no 'feedback' and no return signal to indicate whether the tool has reached the correct position at the end of operation or not .

Example: Co-ordinate drilling machine .

2.Closed loop system :A feedback is built into the system ,Which automatically monitors the position of the tool .

Application of NC machines :

I. Complex parts .
II. Parts which are frequently subjected to design changes .
III. Repetitive and precision quality parts which are to be produced in low to medium batch quantity .

IV. To cut down lead time in manufacture .
V. In situations where the investment on tooling and fixture inventory will be high if part are made on conventional machines tools .

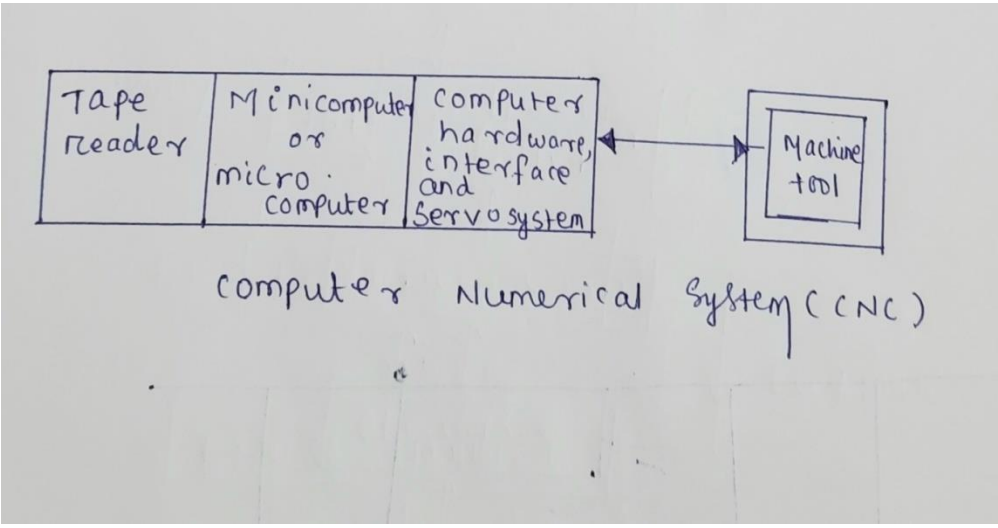
Advantages of NC machines :

I. Reduced production cost per piece .
II. Accuracy achieved is of high order .
III. Less scrap .
IV. High production rates .
V. Less operator skill required.
VI. Excellent reliability.
VII. Tooling cost low .
VIII. Less cycle time and increased tool life.
IX. Increased flexibility.
X. Production of complex parts .
XI. Reduced set- up time .
XII. Reduced inspection.
XIII. Lower labour cost
XIV. Easy and effective production planning.

5.1.2 CNC Machines:

Definition Of CNC:-

The numerical control system where a dedicated ,stored program computer is used to perform some or all of the basic numerical control functions in accordance with control programmes stored in read/write memory (RAM) of the computer .



Above figure shows the control unit panel of a CNC

Important points of CNC:-

1. The control unit and a panel of CNC differs from that of NC controls in that ,it works in on-line mode whereas NC works in batch processing mode .
2. A typical CNC may need only the drawing specifications of a part to be manufactured and the computer automatically generates the part program for the loaded part .
3. The part program once entered into the computer memory can be used again and again.
4. CNC control unit allows compensation for any changes in the dimensions of the cutting tool .
5. With CNC control systems ,it is possible to obtain information on machine utilisation which is useful to the managements .

Function of CNC :

1) Machine tool control
2) In-process compensation
3) Improved programming and operating features
4) Diagnostics

Advantages of CNC machines:

1) Greater flexibility
2) Reduced data reading error
3) Increased productivity
4) Consistent quality
5) Automatic material handling
6) Elimination of operator errors
7) Reduced operator activity
8) Lower labour cost
9) Smaller batches
10) Longer tool life
11) Just-in-time (JIT) manufacture
12) Reliable operation
13) Elimination of special jigs and fixtures
14) Reduced inspection
15) Accurate costing and scheduling

Disadvantages of CNC machines :

1. Higher investment cost
2. Higher maintenance cost

3. Costlier CNC personnel
4. Air conditioned places are required for the installation of the machines
5. Unsuitable for long run applications
6. Planned support facilities

Application of CNC :

1) Drilling machines
2) Turning machines
3) Boring machines
4) Milling machines
5) Grinding machines
6) Pipe bending machines
7) Coil winding machines
8) Flame cutting machines

5.1.3 CAD/CAM

5.1.3.1 CAD (Computer Aided Design):-

A design process using sophisticated computer graphics techniques, backed up with computer software packages to aid in the analytical ,development ,costing and ergonomic problems associated with design work .

Advantages:-

1. Drawings can be produced at a faster rate
2. Drawing produced by CAD systems are more accurate and neat
3. In this system there is no repetition of the drawings
4. CAD systems assimilate several special draughting techniques which are not available with conventional means
5. Design calculations and analysis can be carried out quickly
6. With CAD systems superior design forms can be produced
7. CAD simulation and analysis techniques can drastically cut the time and money spent on prototype testing and development
8. Using CAD systems design can be integrated with other disciplines

5.1.3.2 CAM (Computer Aided Manufacture):-

CAM (Computer Aided Manufacture) concerns any automatic manufacturing process which is controlled by computers .

The most important elements of CAM are:

I. CNC manufacturing and programming techniques
II. Computer controlled robotics manufacture and assembly
III. Flexible Manufacturing systems (FMS)
IV. Computer Aided Inspection (CAI) techniques
V. Computer Aided Testing (CAT) techniques

Advantages :

1. Product obtained is superior in quality
2. The manufactured form has a greater versatility
3. Higher production rates with lower work-forces
4. There is less likelihood of human error
5. As a result of increased manufacturing efficiency cost savings are materialised
6. The production processes can be repeated via storage of data

5.1.3.3 Software and hardware for CAD/CAM :-

The functions of CAD/CAM system are mainly determined by the software.

Software :-

Software usually consists of a number of separate application packages to perform the desired function .

The size of computer depends on the number and sizes of packages and number of work stations.

Hardware:-

Hardware is responsible for the reliability and speed of response of the system.

Though a system can be built up from standard software packages from different sources and standard hardware ,it is often costly because of the considerable programming effort required to interface the packages to a common data base to provide user friendly software to adapt the system to the user's requirements .

It is thus advisable to adopt turnkey system for turn key suppliers .

5.1.3.4 Functioning of CAD/CAM system:-

1. CAD/CAM is an interactive computer graphic tool that enhances design and manufacturing functions to create a highly profitable product. This technique is being applied by big industries for improving overall manufacturing performance.

2. It is not a standard tool which can be fitted into any company but has to be tailored to suit the need of the company .It is rather complex technology and has wide potential for immediate benefits.
3. Usually this tool consists of a dedicated computer ,which is connected to a number of work stations .The system is used to assist in the design and manufacturing ,through the use of an expandable set of linked software modules .

5.1.3.5 Features and characteristics of CAD/CAM systems

1) A major portion of the output of the engineering sector involves batch production and CAD/CAM offers immense cost and quality benefits for such requirements .
2) The work-in-progress , in batch production ,is reduced considerably .
3) It is possible to produce at random all the variants and series of a product planned to manufactured by a firm .
4) Such a system has inherent flexibility to cater to new models of the product in pipeline without major modification .
5) In such a system, several machining centres are arranged one after the other with robots and proper automatic materials handling equipment .
6) All the part programs for the different models are stored in memory .System has only to indentify the model of the product presented to machine in order to complete the machining operations .
7) The system can be conceived in multiplies of 15-20 minutes operations .If certain operations take longer ,then multiples of similar machines can be installed in the line .
8) The components are loaded on to a pallet .Means are provided to identify the exact model .

5.1.3.6 Application areas for CAD/CAM:-

1. **<u>Design and design analysis:</u>**
   - CAD system would be best suited for drawing offices where frequent modifications are required on drawing and several parts repeat.
   - It must be remembered that it is very easy with computer to make modifications and very fast to draw part profile once its details are fed into computer.
   - Once a drawing is entered in the CAD system ,later modifications can be done quickly ,and detail drawings can be prepared quickly from a general arrangement drawing.
   - NC tapes can be produced .
   - Storing of the drawing is very convenient ,easy ,occupies very less space and symbols for electrical ,hydraulic ,control and instrumentation circuits can be called up quickly and positioned on the schematic drawing .

- Standard components can be stored permanently in the data base and called up and positioned on the drawing ,resulting in saving of time and enforcement of standards .It is possible to associate non graphical information like past number ,supplier ,material etc .,for any component assembly .
- It is very convenient to calculate properties like weight ,centre of gravity ,moment of Inertia ,etc., because 3-D models can be easily produced .
- It is also possible to carry out finite analysis by producing meshing for analysis .

2.Manufacture:

- With CAD/CAM system the complete NC part programming process can be carried out interactively, including post processing and production of NC tape .
- Source programs in languages such as APT can be produced .Systems can verify tapes by producing tool centre path plots.

5.2 Elements of CNC Machines :-

A computer numerically controlled (CNC) machine is a mechatronic system since the machine tool which is a mechanical system is incorporated or integrated with the electronic controls for its different drives and computer system for interfacing the software with the mechanical and electronic system .

Hardware or electronic circuits control the motions of various drives .

Important parts of CNC:-

I. Machine structure
II. Guideways / Slideways
III. Drives
IV. Spindle and spindle bearings
V. Measuring systems
VI. Controls
VII. Gauging
VIII. Tool monitoring
IX. Swarf removal
X. Safety

5.2.2 Machine Structure:-

The ‘’machine structure “ is the load carrying and supporting member of the machine tool. The design and construction of CNC machine should be such that it meets the main “objectives”(i) High precision and repeatability,(ii) reliability;(iii) Efficiency. In order to meet these

requirements, the numerically controlled machine tools should have a structure with the following characteristics :

1. It does not deform or vibrate beyond the permissible limits under the action of static and dynamic forces, to which it is subjected.
   - Static load of a machine tool results from the weights of slides and the work piece and the forces due to cutting.
   - Dynamic load is a term used for the constantly changing forces acting on the structure while the movement is taking place. These forces cause the whole machine to vibrate and the origin of these vibration may be due to unbalanced rotating part, improper meshing of gears, bearings irregularities , and interrupted cuts while machining (as in milling).These vibrations can be reduced by :
     (i) Improving the damping properties
     (ii) Reducing the mass of structure and increasing the stiffness of the structure.
2. It's design should be such that the thermal distortion in minimum .

The machine tool should be protected from external and internal heat sources ;some of these heat sources are :Electric motor , friction in mechanical drives ,gear boxes ,gearing and guideways , machining process , temperature of surrounding object .

- Thermal deformation due to thermal load may be reduced by:-
  - Designing the structure thermo-symmetrically
  - External mounting of drives
  - Using a proper lubrication system for removing heat from bearings and guideways
  - Removing the coolant and swarf efficiently for the dissipation of heat generated from the machining process
3. The machine structure design should be such that the removal of swarf is easy and the chips etc., do not fall on the slideways .

5.2.3 Guideways/Slidways:-

5.2.3.1 :- introduction and types of guide ways

In machine tools the guideways are used to serve the following purposes :-

- To control the direction or line of action of the carriage or the table on which a tool or a work piece is held .
- To absorb all static and dynamic loads .

- The guideways may be an integral part of the machine structure or may be mounted separately on the structure.
- These guideways may be horizontal , vertical or inclined .

- However vertical and inclined guideways are preferred so that chips produced during the cutting operation do not get collected on the quick ways.
- The shape and size of the work produced depends on the accuracy of the movement and kinematic accuracy of the guideway. Kinematic accuracy depends on the straightness ,flatness and parallelism errors in the guideway.

In a CNC machine the design of guideway/slideway should:

- Reduce friction
- Reduce wear
- Improve smoothness of the drive
- Satisfy the requirement of movement of the slides

5.2.3.2 Factors affecting the design of guideways :-

- Geometric and kinematic accuracy
- Position in relation to work area
- Provision for adjustment of play
- Rigidity
- Damping capability
- Velocity slide
- Friction characteristics
- Wear resistance
- Protection against swarf and damage
- Protective guards to safeguard the guideways against accidental damages
- Efficient lubrication systems

Types of guideways :-

Guideways are broadly classified as follows:-

1.**Friction guideway**

I. Vee guideways
II. Flat guideways
III. Dovetail guideways
IV. Cylinder guideways

2.Antifriction linear motion (LM) guideways

3.Frictionless guideways

I. Hydrostatic guideways
II. Aerostatic guideways

Friction guideway :- used in conventional machine tools due to their low manufacturing cost and good damping properties and operate under condition of sliding friction and donot have a constant coefficient of friction. In Friction guideway **stick-slip phenomenon** occur .

(I)**Vee guideways :-**

- Vee guideways are widely used on machine tools ,especially on lathe beds.
- One of the advantages of Vee guideways is that part the parallel alignment of the guideway with the sindle axis is not affected by wear
- These guideways wear away rapidly due to lack of bearing surface .These are difficult to manufacture

(II)**Flat guideways** :-

- These guideways have better load bearing capabilities than other guideways
- These are easy to manufacture
- In such guidways the chip accumulation and lubrication problems are serious
- Theses do not wear uniformly
- Jibs are used to ensure accurate fitting of the slide on the flat surface
- Theses guideways are suitable for heavy load transmission

(III)Dovetail guideways:-

- Theses guideways have large load carrying capacity and tend to check the overturning tendency under eccentric loading
- There are preferred when both horizontal and vertical locations of moving parts are considered essential
- Jibs are used to ensure accurate fitting of the slide on the dovetail surface .The jibs are tapered and can be adjusted to reduce excessive clearance caused by wear
- Although the vee type guideways have certain advantages ,it is the flat or dovetail forms which are used on CNC machine tools .
- The majority of lathes have a combination of Vee and flat guideways to prevent twisting of slide.

(IV)Cylindrical guideways :-

In this case the bore in the carriage housing provides support all around the guideways .

Theses guideways are very efficient for relative short traverses and light loads .

2.Antifriction linear motion (LM) guideways :-

Theses guideways are used on CNC machine tool to reduce amount of wear ,friction ,heat generation and improve smoothness of the movement.

The antifriction guideways are employed to overcome the relative high coefficient of friction in metal to metal contacts and the resulting limitations addressed above.

They use elements in between the moving and stationary elements of the machine

Types of antifriction guideways :-

1. Liner bearing with balls

2. Liner bearing with rollers

1. Liner bearing with balls:-Theses are designed to run along precision ground shafts and offer frictionless movement over varying strokes of length with high linear precision

2. Liner bearing with rollers :-The recirculating linear roller bearings are used for movement along a flat plane.

Their main characteristic feature is that there is continuous roller circulation which allows unlimited linear movement

5.2.4 Drives:-

Drives are devices which impart motion to mechanical elements .

In a CNC machine tool there are three major group of elements
(i) Control and electronics.
(ii) Electric drives (electromechanical drives)
(iii) Mechanical elements (table, slide, tool holder etc.)
In addition, there can be hydraulic and pneumatic systems which are integrated with CNC machine tool .The primary function of the drive is to cause motion of the controlled machine tool member (spindle ,slide) to conform as closely as possible to the motion commands issued by the CNC system

Depending on their characteristics machine tool drives can be classified as follows :-

1. **Spindle drives(constant power)**

   (I)D.C spindle drives:

   - Separately excited D.C shunt motor
   - Controller:
     - Thyristor (SCR) amplifier
     - Microprocessor based self tuned thyristor amplifier
   - Armature and field control

(II)A.C. spindle drives :-

- ❖ Squirrel cage induction motor
- ❖ Controller:
  - Microprocessor based pulse with modulated (PWM)inverter
- ❖ Speed control:
  - Frequency ,vector control

2. Feed drives drives(constant Torque)

(I)D.C servo drive:

- ❖ Motor permanent magnet
- ❖ Controller:
  - Thyristor D.C. amplifier
  - Transistor PWM D.C. chopper
- ❖ Speed control:
  - Armature voltage

(II)A.C. servo drive :-

- ❖ Motor synchronous three phase A.C motor with permanent magnet rotor
- ❖ Controller:
  - Transistor for PWM frequency inverter ; analog drive amplifier
  - Transistor PWM frequency inverter ;digital drive amplifier
- ❖ Speed control:
  - Frequency control

5.2 .4.1 Spindle drives:-

The following motors are used in spindle drives :

(1) D.C. shunt motor (separately excited)'

(2) Three-phase A.C. induction motor

In CNC machines the D.C. spindle drives are commonly used (say for step less speed variation of spindles). However ,with the advent of microprocessor based A.C frequency inverter, of late, the A.C. drives are being referred to D.C. drives as they offer several advantages (e.g., more reliable, easily maintainable and less costly)

The main advantage of microprocessor-based frequency converter is the possibility of using the spindle motor for C-axis applications for speed control in the range of 1:1000000 with positioning.

5.2.4.2 Feed drives:-

The main components of a feed drive are :

(1) A feed servomotor;

(2) Mechanical transmission system.

A “Feed motor “ ,unlike a spindle motor, has special characteristics like constant torque and positioning. In continuing operations where a prescribed path has to be followed continuously, several feed drives have to operate simultaneously; this requires a sufficiently damped servo system with high band width, i.e., fast response and matched dynamic characteristics for different axes

5.2.5 Spindle:-

The spindle carrying the work piece or tool when subjected to high cutting speeds and high material removal rates, experience deflection and thrust forces. To ensure increased stability and minimise torsional strain, the machine spindle is designed to be short and stiff and the final drive to the spindle is located as near to the front bearing as possible .

The rotational accuracy of the spindle is dependent on the quality and design of bearings used. The ball or roller bearings are suitable for high speeds and high loads because of low friction, lower wear rate and lesser liability to incorrect adjustment and ease of replacement when necessary.

Spindle bearings:-

In modern machine tools, which employ high performance cutting tool materials, the designed characteristics of spindles used are :

1. Minimum deflection under varying loads.
2. Long service life.
3. Stiffness.
4. Thermal stability.
5. Good running accuracy both in radial and axial directions.
6. Axial load carrying capacity.
7. High speed of operation, without chatter vibration.

On these characteristics do the accuracy and quality of the jobs produced depend .This can be achieved by using proper spindle bearing. The various types of spindle bearings used in the design of a spindle for machine tools are:

1) Anti friction bearings.
2) Hydrostatic bearings.
3) Hydrodynamic bearings

(1) Anti friction bearings:-

The antifriction bearings are suitable for high speeds and high loads.

These are often preferred to hydrodynamic bearings because the following reasons :-

- High reliability
- Ease of replacement
- Low friction.
- Moderate dimensions.
- Lesser liability to suffer from wear or incorrect adjustment.

CNC machines, the following types of ball and roller bearings are used :

(1)**Ball bearings:-**

(a) Deep groove ball bearings

(b) Angular contact ball bearings

(2) **Roller bearings** :-

(a) Cylindrical roller bearings

(b) Cylindrical roller bearings (double row) with tapered bore .

(c) Tapered roller bearings

Ball and roller bearings are called antifriction bearings

(2) Hydrostatic bearings.:-

Here the spindle is supported by a relatively thick film of oil (called hydrostatic pockets) supplied under pressure; the oil in the pockets being stationary. The oil is supplied to the bearing through a throttling system to control pressure and volume. Lubricating seals are used to prevent the leakage of oil. There is no mechanical contact.
The load carrying capacity Hydrostatic bearings of this type of bearing is independent of the speed of rotation.
They have the following merits :-

(i) High wear resistance.
(ii) High damping properties.
(iii) High running accuracy.

Theses bearings are used in grinding and boring machine etc.

(3)Hydrodynamic bearings:-

The Pressure of oil within the bearing is created by the rotation of the spindle. As the spindle rotates, the oil in contact with the spindle is carried into wedge shape cavities between the

spindle and the bearing due to centrifugal action. As the oil is forced through the small clearances between the bearing and spindle, the oil Pressure is increased .

In this type of bearing there is a constant flow of oil round the spindle, maintaining a thick oil film.

The essential features of these bearings are :

(i) Good running accuracy.
(ii) Simplicity
(iii) Good damping Properties .

These bearings are used where the load carrying capacities are low-and frequent starting and stopping of the spindle is not required as in the case of grinding machines .

SHORT QUESTIONS WITH ANSWER

Q.1 What is NC and CNC ?

Ans**:-** Numerical Control ,NC can be defined simply as control by numbers .A machine tool having a dedicated computer to help prepare the program and control some or all of the operations of the machine tool is called Computer Numerical Control (CNC) machine tool.

Q.2 What is the use of Friction guideway ?

Ans :-Friction guideway used in conventional machine tools due to their low manufacturing cost and good damping properties and operate under condition of sliding friction and donot have a constant coefficient of friction. In Friction guideway **stick-slip phenomenon** occur

Q.3 What is the Function of guideways ?

Ans :-In machine tools the guideways are used to serve the following purposes :-

To control the direction or line of action of the carriage or the table on which a tool or a work piece is held . To absorb all static and dynamic loads

LONG QUSTIONS

Q.1 Write down the Application areas for CAD/CAM ?

Q.2 Write a short notes on spindle drive ? [2020 (w) New]

Q.3 Explain functioning of CAD/CAM System ? [2020 (w) New]

Q.4 Write a short notes on Guideways ? [2020 (w) New]

Chapter No. 6

ROBOTICS

Learning Objectives

6.1 Definition, Function and laws of robotics

6.2Types of industrial robots

6.3 Robotic systems

6.4 Advantages and Disadvantages of robots

6.1 Robotics

It is the science of designing and building robots suitable for real-life applications in automated manufacturing and other non-manufacturing environments .

Laws of Robotics:- (by Sir Issac Asimov)

Zeroth law:- A robot must not injure humanity or ,through inaction ,allow humanity to come to harm .

First law :- A robot must not harm a human being or ,through inaction , allow one to come to harm

Second law:-A robot must always obey human being unless it is in conflict with a higher order law

Third law:- A robot must protect itself from harm unless that is in conflict with a higher order law.

Definition of Robot by ISO :-

An "automatically controlled, reprogrammable, multipurpose manipulator, programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications."

The Robotic Industries Association (RIA) defines robot :-

"A **robot** is a reprogrammable, multifunctional manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks.

Function of a Robot :-

1. Sensing the environment by external sensors
   Example:-Vision ,Voice ,touch ,proximity etc.
2. Decision making based on the information received from the sensors
3. Performing the task decided

6.2 Types of Industrial Robots:-

1.General purpose robots:-

- These robots carry standard designs and parts and are readily available
- They can be easily adapted to the users requirements by attaching suitable end effectors or fingers to them according to the requirement of the work ,such as a part picking operation ,welding operation ,spray painting etc.
- Since such robots are produced ,they are cheaper .

2.Special purpose robots :-

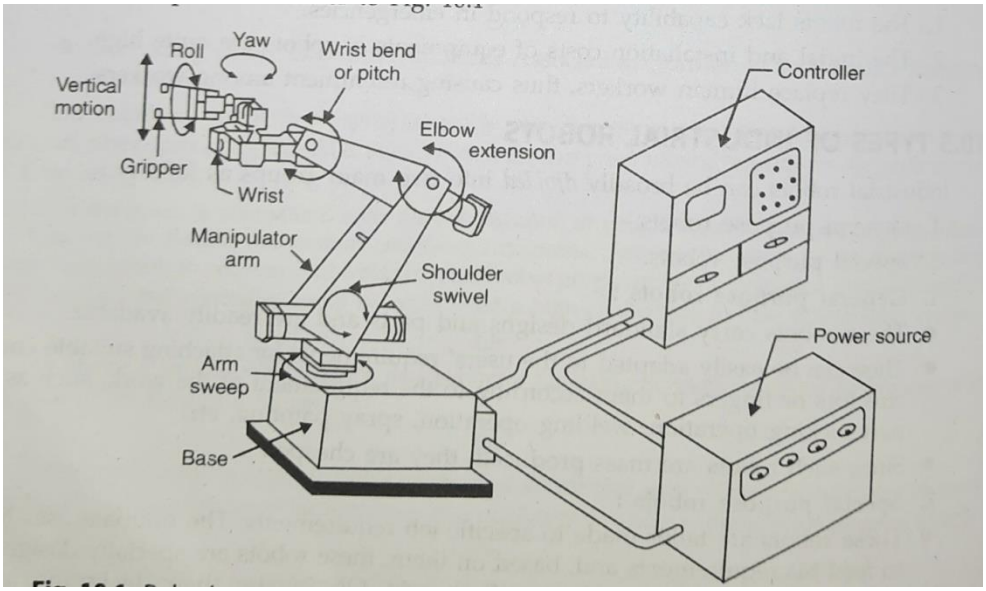
- These robots are tailor made to specific job requirements .The ultimate user has to feed his requirement and ,based on them ,these robots are specially designed and built to cater to such specific needs .Obviously ,their designing and manufacturing consumes a lot of time . As such ,they cannot be readily available in market
- Since they cannot be manufactured on mass scale ,their prices are bound to be higher .

6.3 Robotic Systems:-

A system is an integral whole of parts or subsystem .It has a specific goal or output for a given set of inputs ;a system may have many goals as well .

A robot should have following components for its assignments :

- A suitable manipulator arm with specified coordinate system to attain a designed reach in the working space
- A suitable gripper a match the geometry of the work piece to be handled
- A suitable control system with or without servo mechanisms for sending signals to the drives
- Some sensors to feed back information for modifying the motion or path
- A Controller is provided with interfacing units connected to external equipment in the outside world



The various components of a robot are enumerated and discussed below :-

- **Robotic arm**
- **End-effector**
- **Motors**
- **Controller**
- **Robot sensor**

Robotic Arm

A robotic arm is also known as a manipulator. It is the part of an industrial robot that is used to execute tasks. Its structure is akin to that of the human arm and consists of a shoulder, an

elbow, and a wrist. The shoulder is the part of the robotic arm linked to the mainframe of the industrial robot. The elbow is the jointed part of the arm that flexes as it moves and the wrist is the end of the arm that performs the actual task.

For flexibility, a robotic arm is fitted with various joints that allow it to move in different directions when working. A 6-axis robotic arm, for example, has more joints than a 4-axis arm which is less flexible. Additionally, the structures of robotic arms vary in terms of how far they can reach and the payloads they can handle.

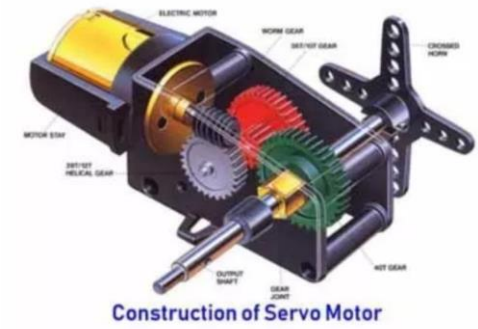
Nowadays, the robotic arm has been maturely developed, a lot of robotic arms are for sale on the market. Robotic arms need to be considered as a great option to improve the product's productivity and quality.

End-effector

An end-effector is a tool device attached to the wrist of a robotic arm. It gives the robotic arm more dexterity and makes it better suited for specific tasks. They are a more convenient solution than having to make a unique robot arm for each role. Examples of end effectors include:

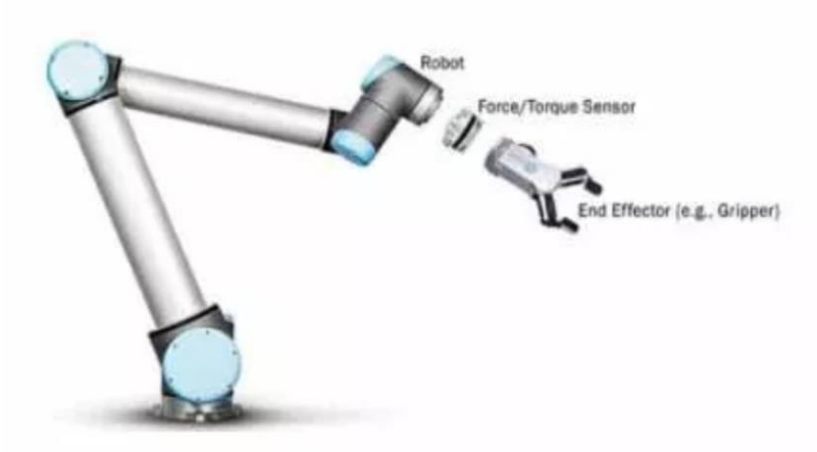
- Grippers
- Drills
- Welding guns
- Suction tool

Motors



The parts of an industrial robot need to be powered to move as they cannot move of their own volition. For this reason, parts like robotic arms are fitted with motors to facilitate motion. A motor can best be described as an electronic device that has linear and rotary actuators powered by electric, hydraulic or pneumatic energy. As the actuators move at high speed, they push and rotate robotic parts into motion.

Sensors



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Sensors in robots are devices that detect or measure specific parameters and trigger a corresponding reaction to them. They are implanted in robot structures for safety and control purposes. Safety sensors are used to detect obstacles to prevent human-robot and robot-robot collisions. They are a more recent addition to robot structures and more particularly, in collaborative robots. Control sensors, on the other hand, are used to receive prompts from an external controller which the robot then executes.

So, how do sensors work? A safety sensor, for instance, will detect an obstacle, send a signal to the controller which in turn slows or stops the robot to avoid a collision. In essence, a sensor always works in conjunction with the controller. Other parameters that robot sensors detect include position, velocity, temperature, and torque.

Controller

Think of the controller as the brain of a robot. It is the central operating system that controls how all other parts of the robot work. It is programmed with software that enables it to receive, interpret and execute commands. In more advanced robots, the controller can also have a 'memory' from which it executes repetitive tasks as it 'remembers' how they work. Artificial intelligence in smart robots is also inbuilt into the controller via software.

6.4 Advantages of robots & Disadvantages of robots :

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Advantages and Disadvantages of Robots :-

Advantages:-

I. Lifting and moving heavy objects
II. Working in hostile environment
III. Providing repeatability and consistency
IV. Working during unfavourable hours
V. Performing dull or monotonous jobs
VI. Increasing productivity ,safety ,efficiency and quality of products
VII. Achieving more accuracy than human beings

Disadvantages:-

I. The robots lack capability to respond in emergencies
II. The initial and installation costs of equipments of robots and quite high
III. They replace human workers ,thus causing resentment among workers

SHORT QUESTIONS WITH ANSWER

Q.1 Define Robotics ?

Ans :- Robotics is the science of designing and building robots suitable for real-life applications in automated manufacturing and other non-manufacturing environments .

Q.2 Write down all Laws of Robotics ?

Ans:-

Laws of Robotics:- (by Sir Issac Asimov)

Zeroth law:- A robot must not injure humanity or ,through inaction ,allow humanity to come to harm .

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Third law:- A robot must protect itself from harm unless that is in conflict with a higher order law.

Q.3 What is the Function of a Robot ?

Ans:- Function of a Robot :-

1. **Sensing** the environment by external sensors
   Example:-Vision ,Voice ,touch ,proximity etc.
2. **Decision making** based on the information received from the sensors
3. **Performing** the task decided

LONG QUESTIONS

Q.1 Write all the Advantages of robots & Disadvantages of robots ?

Q.2 Explain about Robotic Systems ?

Q.3 Write down the all Types of Industrial Robots

Q.4 Explain different types of Industrial Robot ? [2020 (w) New]