PNS SCHOOL OF ENGINEERING AND TECHNOLOGY

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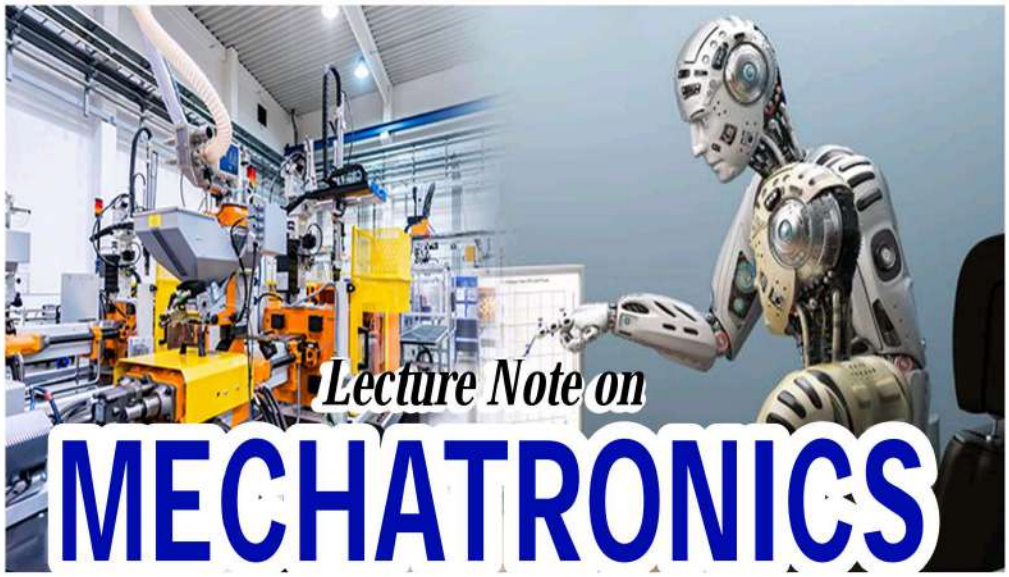

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5th Semester

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Unit 4: PROGRAMMABLE LOGIC CONTROLLERS (PLC)

4.1 Introduction

A PLC is an industrial computer that has been adapted for the control of manufacturing processes, such as assembly lines, machines, robotic devices, or any activity that requires high reliability, ease of programming, and process fault diagnosis.

4.2 Advantages

PLC increases the reliability, flexibility, and accuracy of the automation system.

PLC has a lower cost associated with it as compared to the other automation technology.

PLC has good capabilities and flexibility for programming. Even, you can easily make the modification in the existing program at any time.

Programming used for PLC is easy to write and understand.

PLC does not take much space. It occurs smaller in size,

especially compact PLC. Fast operation

PLC has low maintenance associated with it.

In the PLC system, we require less and simple wiring as compare to

the other systems. One can easily make the changes in an already

implemented design.

In the case of PLC design, if anything goes wrong, one can easily

troubleshoot the problem. It can sustain in a robust environment with

less maintenance.

4.3 Selection and uses of PLC

Uses

1. Industrial Applications of PLC-

Transportation System likes Conveyor Belt

System. Packing and Labeling System in

Food & Beverage. Automatic Bottle or

Liquid Filling System.

Packaging and Labelling System in Pharma Industries.

Industrial Crane Control System for Operation of Overhead

Traveling Crane. Glass Industries for glass production and

recording data.

Paper Industries for the production of Pages, Books or Newspapers, etc.

Cement Industries for manufacturing or mixing the right quality and quantities of raw materials, and accuracy of data regarding.
Fault Detection and Protection of Industrial Machines

2. Power Station Applications of PLC-

PLC is used to Monitor and Detect fault conditions.

It is used in the Power Generation, Transmission, and

Distribution System. PLC used in Underground Coal Mine

or Water Level Sensing and Data Survey.

3. Commercial

Applications of PLC- Smart

Traffic Control Signal

System. Fire Detection and

Alarm System. Luggage

Handling System.

Sequence or Numerical Counting and

Packing System. Mining Equipment Line

Detection

Selection of a PLC

For selection of a PLC, the following criteria need to be considered:

1. Types of inputs/outputs required
2. Input/Output capacity required.
3. Size of memory required.
4. Speed and power required for CPU

4.4 Basic Internal Structures

The main components of a PLC consist of a central processing unit (CPU), power supply, programming device, and input and output (I/O) modules.

CPU
The CPU is the brain of the PLC and carries out programmed operations. These operations or outputs are executed based on signals and data provided from connected inputs.

I/O Modules
PLC input modules connect various external devices, such as sensors, switches, and push buttons to the PLC to read various digital and analog parameters, such as temperature, pressure, flow, speed, etc.

Output modules convert signals from the CPU into digital or analog values to control output devices.

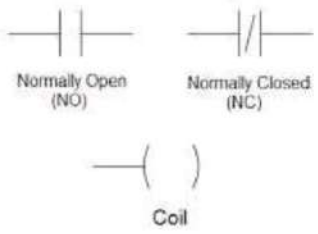
PLC Programming Language

The most common methods of PLC programming include Ladder Logic, Function Block, and structured text.

Ladder Logic
Ladder Logic is a graphical PLC programming language and is the most common method of programming. Ladder Logic can be used to execute tasks such as sequencing, counting, timing, data manipulation, and more.

For the Ladder Diagram (LD) programming language, normally open and normally closed contact is used in the form of input. And the coil or lamp is used in the form of output.

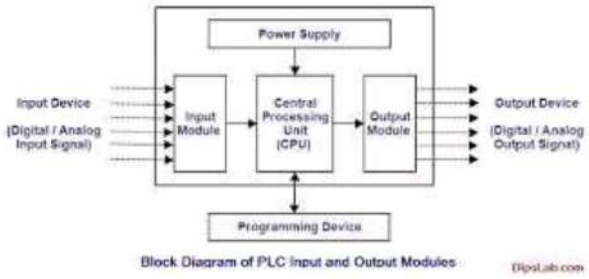
The symbolic representation of I and O modules in the LD program.



Structured Text
Structured text is a text-based PLC programming. Programming with structured text has multiple advantages, such as the program requiring less space due to being text based instead of graphic based.

Function Block
Function block PLC programs are represented in the form of graphical blocks. Function blocks can have standard functions such as timers, counters, calculating min and max values, obtaining averages, and more.

4.5 Input/Output Processing & Programming



Block Diagram of PLC Input and Output Modules

The input device provides a signal to an input module. This input module is connected with the CPU for the initial automated processes. CPU processes all the input data.

After processing by CPU, it gives output data to the output module. The output module provides a signal to the output device.

And the main function of the programming device is to change or monitor the PLC programming.

Classification of PLC Input and Output Modules

The classification of input and output (I/O) modules of PLC is based on the types of signals.

1. Digital I/O Module

The digital module is also called Discrete Module.
In this module, the I/O signal work on the binary system i.e.

only 0 or 1 value. It is useful in the ON or OFF condition.

2. Analog I/O Module

The analog module is called a Continuous Module.
This analog signal provides any intermittent value between the two extreme limits (initial to final range) for the analog input module.

4.6Mnemonics

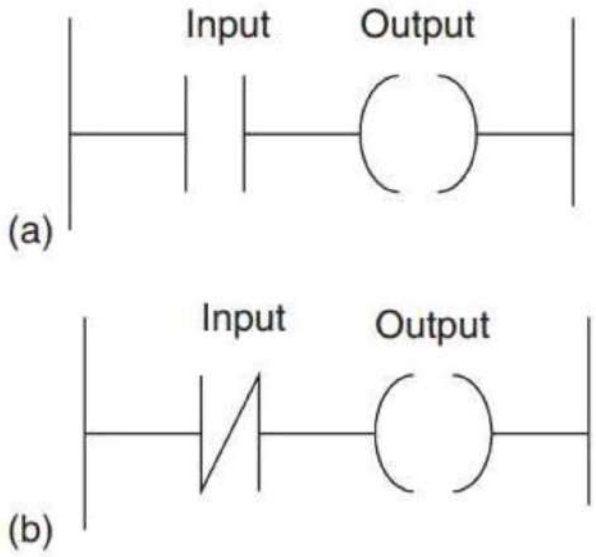
Mnemonics are memory devices that help learners recall larger pieces of information, especially in the form of lists like characteristics, steps, stages, parts, etc.

Mnemonic code provides the same information as ladder diagram and can be typed directly on Programming Console.

There are a lot of instructions used to develop the PLC program.
Each instruction has a respective function.

LD - LOAD Instruction
These instructions are used to start a line of the program.
It is used in the first contacts in the normally open condition (NO).

LD NOT - LOAD NOT Instruction
These instructions are used to start a line of the program.
It is used in the first contacts in the normally closed condition (NC).

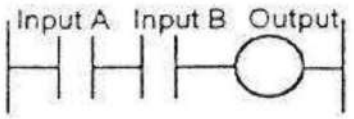


AND - AND Instruction
These instructions are used in the second contact in a normally open (NO) and a series with previous contacts

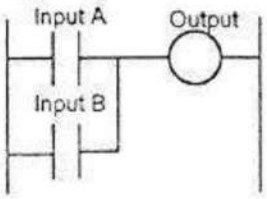
AND NOT - AND NOT Instruction
These instructions are used in the second contact in a normally closed (NC) and in series with previous contacts

OR - OR Instruction
These instructions are used in the second contact in a normally open (NO) and in line (parallel) with previous contacts.

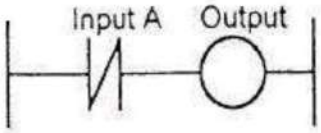
OR NOT - OR NOT Instruction
These instructions are used in the second contact in a normally closed (NC) and in line (parallel) with previous contacts



AND



OR



NOT

OUT - OUTPUT Instruction

These instructions are used for the coil output.

END

- END instruction has no physical contact device.
- It is the last instruction required for completion of a program. If no END instruction, the program cannot be implemented

4.7Master and Jump Controllers

Master controls can be thought of as "emergency stop switches".

PLC manufacturers offer a form of a master control relay as part of their instruction set. These instructions function in a similar manner to the hardwired master control relay; that is, when the instruction is true, the circuit functions normally, and when the instruction is false, non-retentive outputs are switched off.

Jump instruction in ladder logic is used to skip some process or rungs according to the requirement

When the jump instruction is used, the PLC will not execute the instructions of a rung that is jumped

The MCR instruction sets all non-retentive outputs to the false state and keeps the retentive outputs in their last state. The JMP instruction leaves all outputs in their last state.

Previous Year Questions

Q1. Define PLC ?

A PROGRAMMABLE LOGIC CONTROLLER (**PLC**) is an industrial computer control system that continuously monitors the state of input devices and makes decisions based upon a customprogram to control the state of output devices.

Q2. White the advantages of PLC ?

1. Very fast
2. easy to change logic i.e. flexibility
3. Reliable due to absence of moving parts
4. Low power consumption
5. Easy maintenance due to modular assembly
6. Facilities in fault finding and diagnostic
7. Capable of handling of very complicated logic operations
8. Good documentation facilities
9. Easy to couple with the process computers
10. Analog signal handling and close loop control programming
11. Counter, timer and comparator can be programmed

Q3. Explain Selection and uses of PLC ?

Choosing a PLC or Controller for your Process is very important as it helps in Cost optimization.To determine the most suitable PLC to be used in the automation task, there are several basic considerations to be made:

- Necessary input/output capacity
- Types of I/O required
- Size of memory required
- Speed and power required of the CPU and instruction set
- Manufacturer's support and backup
- They are user friendly and easy to operate
- They eliminate the need for hard-wired relay logic
- Its input and output modules can be extended depending upon the requirements

Q4. What is the Architecture basic internal structures of PLC System ?

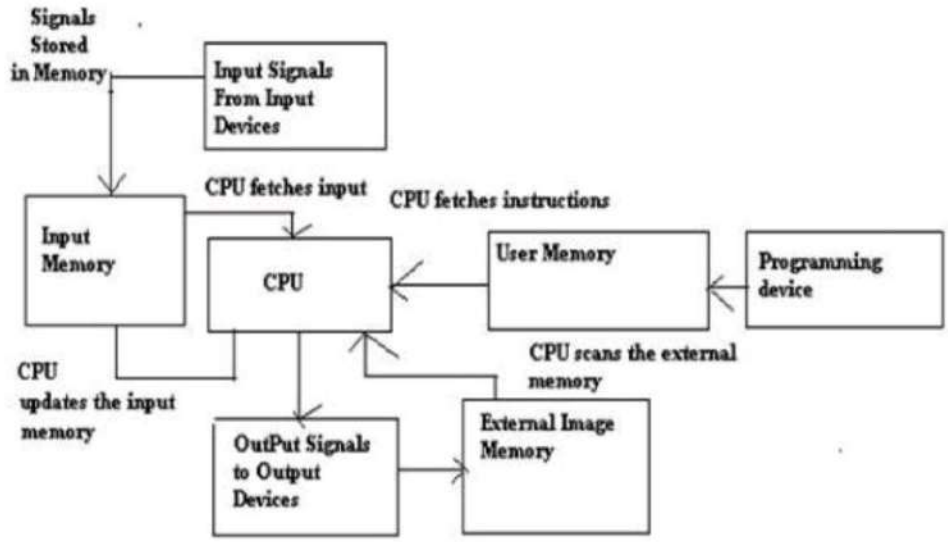
A basic PLC system consists of the following sections:

- **Input/ Output Section**: The input section or input module consists of devices like sensors, switches, and many other real-world input sources. The input from the sources is connected to the PLC through the input connector rails. The output section or output module can be a motor or a solenoid or a lamp or a heater, whose functioning is controlled by varying the input signals.

- **CPU or Central Processing Unit**: It is the brain of the PLC. It can be a hexagonal or an octal microprocessor. It carries out all the processing related to the input signals in order to control the output signals based on the control program.
- **Programming Device**: It is the platform where the program or the control logic is written. It can be a handheld device or a laptop or a computer itself.
- **Power Supply**: It generally works on a power supply of about 24 V, used to power input and output devices.
- **Memory**: The memory is divided into two parts- The data memory and the program memory. The program information or the control logic is stored in the user memory or the program memory from where the CPU fetches the program instructions. The input and output signals and the timer and counter signals are stored in the input and output external image memory respectively.

Working of a PLC

- The input sources convert the real-time analog electric signals to suitable digital electricsignals and these signals are applied to the PLC through the connector rails.
- These input signals are stored in the PLC external image memory in locations known as bits.This is done by the CPU
- The control logic or the program instructions are written onto the programming devicethrough symbols or through mnemonics and stored in the user memory.
- The CPU fetches these instructions from the user memory and executes the input signals bymanipulating, computing, processing them to control the output devices.
- The execution results are then stored in the external image memory which controls theoutput drives.
- The CPU also keeps a check on the output signals and keeps updating the contents of theinput image memory according to the changes in the output memory.
- The CPU also performs internal programming functions like setting and resetting of thetimer, checking the user memory.



Q5. Define Mnemonics?

A ladder diagram written in alphanumeric characters for easier understanding than the machine language program to be executed by CPU Unit. The **mnemonic** code can be convertedto a ladder diagram in the **PLC**.

Q6. Short Note on Master and Jump Controllers ?

Master controller - A **controller**, which is used in a cascade **control** system. It provides an output which acts as a variable desired value for a slave **controller**.

Master controls can be thought of as "emergency stop switches".

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Jump Controllers

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Unit 5: ELEMENTS OF CNC MACHINES

5.1.1 NC machines

Numerical control, popularly known as the NC is very commonly used in the machine tools.

The numerical control machine is defined as the machine that is controlled by the set of instructions called as the program.

In numerical control method the numbers form the basic program instructions for different types of jobs; hence the name numerical control is given to this type of programming.

When the type of job changes, the program instructions of the job also change.

It is easier to write the new instructions for each job, hence NC provides lots of flexibility in its use.

The NC technology can be applied to wide variety of operations like drafting, assembly, inspection, sheet metal working, etc. But it is more prominently used for various metal machining processes like turning, drilling, milling, shaping etc.

Due to NC all the machining operations can be performed at the fast rate resulting in bulk manufacturing becoming quite cheaper.

There are 3 types of NC machines and are as follows.

- **Traditional Numerical Control (NC Machine)**

They can run with the help of a tape reader system i.e. whatever the operation you want to perform, youcan punch it on the tape, and thereby the NC machine can perform that operation.

- **Computer Numerical Control (CNC Machine)**

The Evolution of the CNC machine takes place after the evolution of NC machines. To overcome thelimitation of the NC machine, the CNC machine has come into the picture.

In the case of NC machines, the Tape Reader system is used, which after several usages, the wear and tear of the tape take place and the operator has to punch again on the new tape to carry out the operation.

In order to avoid this limitation of NC Machine, the CNC machine uses a computer-generated file to store the program which was written by the usage of G-Codes and M-Codes.

Whatever operation you need to change like speed, feed, depth of cut, etc. can be changed in the program instantly and there is no damage to the file as of tape reader. This is the reason, CNC machines are used which are highly accurate compared to NC Machines.

- **Distributed Numerical Control (DNC Machine)**

The DNC Machine is similar to CNC Machine, except a remote computer is used to control no. of machinesthat can perform no. of operations at a time

A NC Machine is consist by following parts:

1. MCU or CPU
2. Drive Unit
3. Feedback Devices
4. Tape Reader system
5. Very Few Manual Controls

MCU (Memory Controlled Unit):

MCU is the Memory Control Unit that is taking the information from the input devices via the keyboard or mouseand analyze the data, and send the data to the output devices available in the NC machine.

Drive Unit:
Drive unit is a device that is used for converting Electrical energy into Mechanical energy which is required fortraveling the axis.

Feedback Devices:
Feedback device is a Displacement Measuring Equipment. MCU will compare the distance traveled by the axis withthe distance to be traveled and determines the difference in distance.
The MCU will calculate the no.of pulses and send it to the drive unit. This process continues in the form of a cycle. Feedback Device→MCU→Drive Unit.

Tape Reader System:
The instructions for doing operation was punched on the paper tape. For reading the instruction given in the punchedpaper tape, a **tape reader system** will be used.
Light is provided on one side of the tape and light receiving sensors are placed on the other side. When the tape is moving and stopping at some location where the holes are present, the light is passing and is incident on light receiving sensors. The sensors which are receiving the light generate the electrical pulse and that is to be sent to the Memory Control Unit (MCU) to drive the motor of a machine to do the operation precisely.

Very Few Manual Controls:
Even though the above parts are present in the NC machine, still the manual interventions are required for loadingand unloading of the work piece, switching ON and OFF, etc. called manual controls.

5.1.2 CNC machines

Computer Numerical Control (CNC) machining is a manufacturing process in which pre-programmed computer software dictates the movement of factory tools and machinery. The process can be used to control a range of complex machinery, from grinders and lathes to mills

With a numerical control machine, programs are inputted via punch cards. By contrast, the programs for CNC machines are fed to computers through small keyboards. CNC programming is retained in a computer's memory. The code itself is written and edited by programmers.

The language behind CNC machining is alternately referred to as G-code, and it's written to control the various behaviors of a corresponding machine, such as the speed, feed rate and coordination.

Functions of CNC:
The principal functions of CNC are:
1.Machine tool control.
2.In-process compensation.
3.Improved programming and operating features.
4.Diagnostics.

Advantages of CNC machines:
CNC machines offer the following advantages in manufacturing:

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 manufacture.
12. Reliable operation.
13. Elimination of special jigs and fixtures.
14. Reduced inspection.
15. Less scrap.

16.Accurate costing and scheduling.
17.CNC machine can diagnose program and can detect the
18. Machining malfunctioning even before the part is produced.
19.Conversion of units - possible within computer memory.

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.

Applications of CNC:
CNC is being used in the following machines/areas:
Drilling machines.
Turning
machines. Boring
machines. Milling
machines.
Grinding
machines. Pipe
bending
machines. Coil
winding
machines.
Flame cutting machines.
Welding, wire cut EDM and several other areas.

5.1.3 CAD/CAM

CAD/CAM (Computer-Aided Design/Computer-Aided Manufacture) technology was initiated in the aerospace industry but presently it is spreading at a rapid pace in all industries.
It can be defined most simply as the use of computers to translate a product's specific requirements into the final physical product.

With this system, a product is designed, produced and inspected in one automatic process. It plays a key role in areas such as design analysis, production planning, detailing, documentation,N/C part programming, tooling fabrication, assembly, jig and fixture design, quality control, and testing.

Whenever any deviation is noted, a programmable controller takes automatic corrective action to compensate for the deviation. Thus a closed loop system is formed which produces consistent quality products, reduces wastes and increases productivity.

CAD/CAM system is ideally suited for designing and manufacturing mechanical components of free form complex with three dimensional shapes

5.1.3.1 CAD

CAD (Computer Aided Design) is defined as:
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:
The following are advantages of CAD:
1. Drawings can be produced at a faster rate.
2. Drawings 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 - often the costliest stage in the design process.
8. Using CAD systems design can be integrated with other disciplines.

5.1.3.2 CAM

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

The most important elements of CAM are:
1. CNC manufacturing and programming techniques.
2. Computer controlled robotics manufacture and assembly.
3. Flexible Manufacturing Systems
4. Computer Aided Inspection (CAI)
5. Computer Aided Testing (CAT)

Advantages:
CAM entails the following, 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. Increased manufacturing efficiency
6. The production processes can be repeated via storage of data.

5.1.3.3 Software and hardware for CAD/CAM

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

CADD Hardware

- System Unit
- Central Processing Unit (CPU)
- Memory
- Hard Disk, Floppy Disk, CD-ROM
- External Storage Devices
- The Monitor
- Printers and Plotters
- Digitizer, Puck and Mouse

CADD Software

- Draw
- Edit
- Data output
- System control
- Data storage and management

5.1.3.4 Functioning of cad cam systems

In order to generate the actual model, **CAM works alongside CAD**—using CAD designs, CAM uses numerical coding to run the machine that creates the product. A CAD/CAM package allows companies to develop and save their own product designs, and program machines to create the actual component.

Computer-aided design & computer-aided manufacturing (CAD/CAM) software is **used to design and manufacture prototypes, finished products, and production runs of products**.

5.1.3.5 Features and characteristics of CAD/CAM system

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 be 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. Software is developed to integrate the machine CNC control and the handling system. Each machining centre is equipped with several tool magazines. All the tools required to complete each operation on each model of the product can be stored in the magazine.

6. All the part Programs for the different models are stored in the memory. System has only to identify the model of the product presented to a machine in order to complete the machining operations. Thus it is possible to have totally random mixes of models of a product proceeding down the line at any one time.

7. 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. Sometimes identical machines are introduced for each operation so that production can continue even if one machine goes down.

5.1.3.5 Application areas for CAD/CAM

1. Design and design analysis:

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.

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 nongraphical 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 element analysis by producing meshing for analysis.

2.Manufacture:
With CAD/CAM system the complete NC part programming process can be carried out interactively,

5.2 Elements of CNC machines

1. Machine structure.
2. Guideways/Slideways.
3. Drives.
4. Spindle and spindle bearings.
5. Measuring systems.
6. Controls.
7. Gauging
8. Tool monitoring.
9. Swarf removal.
10. Safety.

Measuring Systems-
Measuring systems are used on all the CNC machines to perform the following functions:
1. To monitor the position of a slide on a slideway.
2. To orient the spindle/table.
3. To measure the spindle speed.

Controls
For CNC machines, CNC controls are of significant importance. Earlier, CNC controls were developed for simple applications in turning, machining centres and grinding, but these days CNC systems have been developed to meet with the increased machine tools requirements of higher spindle speeds, higher rapid traverses and more number of axes. The new generation computer numerical controls allow simultaneous control of more axes, interpolate positions faster, and use more data points for precise control.

The new controllers offer the following:
- Advanced graphic interfaces;
- Program simulation;
- Some cutter selecting capabilities.

Gauging

The quality can be maintained by eliminating the effect of parameter like tool wear and thermal growth, with the use of automatic gauging system.

The gauging on a machine tool may be used for the following purposes- To inspect work piece. To detect tool breakage. To define tool offsets. To automatically align the work piece. To detect the stock variation

Tool Monitoring System

The tools wear out or even break during machining. If tool n ear and breakage is not properly monitored, the productivity of the machine and the quality of the component produced are affected. Now-a-days established monitoring sensors and systems are available commercially which can be integrated with CNC machines.

Following are the two ways of monitoring tool wear and breakage:

1. Direct monitoring: In this type of monitoring a touch probe is directly used to monitor the tool condition by checking the tool edge position and checking for the existence of a tool edge.

2. Indirect monitoring: Here, the tool condition is checked indirectly by monitoring the change in certain parameter whose value when affected reflects the tool condition.

Following parameters are used to monitor tool condition:

(I) Cutting forces.
(ii) Tool life.
(iii) Work piece dimensions.
(iv) Emission of noise during cutting
(v) Power of the spindle or a feed drive or a driven tool.

Swarf Removal

In CNC machines the cutting time is much more and as such the volume of swarf generated is also more.
- Unless the swarf is quickly and efficiently removed from the cutting zone, it can affect the cutting process and quality of the finished product.

- Also the swarf cannot be allowed to accumulate at the machine tool because it may hamper the access to the machine tool.
- In addition some auxiliary functions like automatic component loading or automatic tool change may also be affected by accumulation of swarf.

To overcome all above problems it is necessary to provide an efficient swarf control system with the CNC machine tools with some mechanism to remove the swarf from the cutter and cutting zone and for the disposal of swarf from the machine tool area itself.

Safety

As the CNC machines are under continuous automatic operation, there is a need to protect the machine guideways and to ensure operators safety since the machines run at high speeds with automatic auxiliary operations.

- In order to have efficient working and long life of the machine it is essential to protect machine guideways, drive screws and transducers etc. These elements are protected by the use of various types of collapsible guards and covers.

All the sliding elements are fitted with wipers and drive screws are normally protected by using telescopic covers. Jets of cutting fluids are used to wash away swarf and clear the tool work area.

- Operator's safety is very important aspect which cannot be overlooked. To ensure safe working conditions the CNC machine tools are provided with metallic or plastic guards.

5.2.1 Introduction

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 workpiece, and the forces due to cutting. Dynamic loads 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 vibrations may be due to unbalanced rotating parts, improper meshing of gears, bearings irregularities

2. Its design should be such that the thermal distortion is 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, bearings and guideways; machinery Process; temperature of surrounding objects.

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/Slide ways

5.2.3.1 Introduction and Types of Guideways

Introduction

In machine tools the guideways are used to serve the following purposes;
(i) To control the direction or line of action of the carriage or the table on which a tool or a workpiece is held.
(ii) 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 quickways.
The shape and size of the work produced depends on the accuracy of the movement

Guideways are broadly classified as follows:
1. Friction guideways.
(i) Vee guideways.
(ii) Flat guideways
(iii) Dovetail guideways.
(iv) Cylindrical guideways

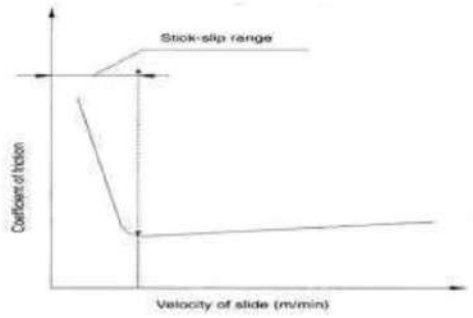
2. Antifriction linear motion (LM) guideways.

3. Frictionless guideways:
(I) Hydrostatic guideways.
(ii) Aerostatic guideways.

Friction guideways

These guideways find wide application in conventional machine tools due to their low manufacturing cost and good damping properties.

It operate under conditions of sliding friction and do not have a constant coefficient of friction. The frictional coefficient varies with the sliding velocity



At the commencement of the movement, the coefficient of friction is very high, but as the velocity increases it falls rapidly and beyond a certain critical velocity it remains almost constant. Thus, to start motion/movement, the force to overcome friction has to be correspondingly high. This phenomenon is known as, stick-slip phenomenon.

Vee guideways:
The Vee guideways are widely used on machine tools, especially ' on lathe beds.

These guideways wear away rapidly due to lack of bearing surface. These are difficult to manufacture.

Flat guideways
These guideways have better load bearing capabilities than other guideways.
- These are easier to manufacture.
- In such guideways the chip accumulation and lubrication problems are serious.
- These do not wear uniformly.
- Jibs are used to ensure accurate fitting of the slide on the flat surface.

Dovetail guideways
These guideways have large load carrying capacity and tend to check the overturning tendency under eccentric loading.
- They 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.

Cylindrical guideways

These guideways are aery efficient for relatively short traverses and light loads.

- Their use for long traverses and heavy loads is not suitable because the guideways may sag or bend in the centre of the span under a load.

Antifriction linear motion (LM) guideways

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

The antifriction guideways are employed to overcome the relatively high coefficient of friction in metal-to-metal contacts. .

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

Advantages: The antifriction guideways claim the following advantages over the friction guides:

1. High load carrying capacity.
2. Heavier preloading possibility.
3. High traverse speeds.
4. Low frictional resistance.
5. No stick-slip.
6. Ease of assembly.
7. Commercially available in ready-to-fit condition.

Their main disadvantage is 'lower

damping capacity'. Types of antifriction

guideways

1.Linear bearing with balls uses recirculating balls within a bush type of bearing. These are designed to run along precision ground shafts and offer frictionless movement making strokes of length with high linear precision.

2.Linear 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.

Frictionless

guideways

Hydrostatic

guideways:

- In these guideways the surface of the slide is separated from the guideway by a very thin film of fluid supplied at pressures as high as 300 bar.
- In hydrostatic guideways frictional wear and stick slip are entirely eliminated.
- In such guideways a high degree of dynamic stiffness and damping is

obtained, both the characteristics contributing to good machining capabilities.
- Owing to high cost and difficulty in assembly, their application is limited.

Aerostatic guideways:
In these guideways, the slide is raised in a cushion of compressed air which entirely separates the slide and guideway surfaces.

Advantages of frictionless guideways:
1.Longer life.
2.Large damping capability.
3.Frictionless.
4.High stiffness.
5.No stick-slip.
6.Less thermal distortion due to better heat dissipation.

Disadvantages:
1.Difficulty in assembling the guideways.
2.High cost.
3.Leakage problems.

5.2.3.2 Factors of design of guideways

(i) Reduce friction;
(ii) Reduce wear;
(iii) Satisfy the requirements of movement of the slides;
(iv) Improve smoothness of the drive

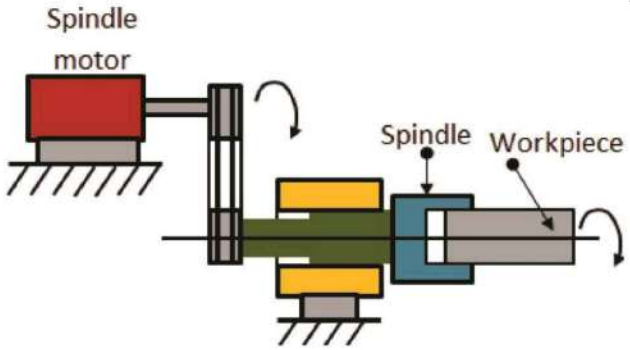
The following factors should be considered while designing guideways:
1. Geometric and kinematic accuracy.
2. Position in relation to work area.
3. Provision for adjustment of play.
4. Rigidity.
5. Damping capability.
6. Velocity slide.
7. Friction characteristics.
8. Wear resistance.
9. Protection against swarf and damage.
10. Protective guards to safeguard the guideways against accidental damages.
11. Freedom from unnecessary restraints.
12. Effective lubrication and efficient lubrication svstems.

5.2.4 Drives

Devices which impart motion to mechanical components

The primary function of the drive is to cause motion of the controlled machine tool member to conform as closelyas possible to the motion commands issued by the CNC system.

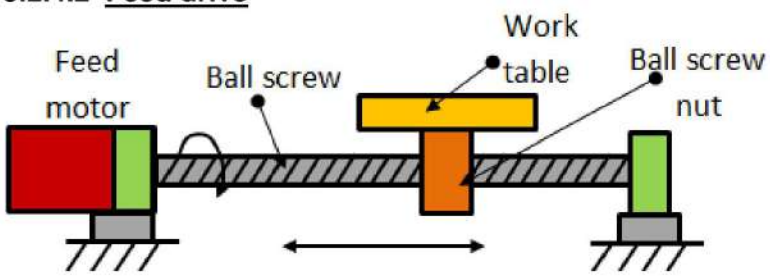
5.2.4.1 Spindle drives



The spindle drives are used to provide angular motion to the workpiece or a cutting tool. These drives are essentially required to maintain the speed accurately within a power band which will enable machining of a variety of materials with variations in material hardness. The speed ranges can be from 10 to20,000 rpm.

The machine tools mostly employ DC spindle drives. High overload capacity is also needed for unintended overloads on the spindle due to an inappropriate feed. It is desirous to have a compact drive with highly smooth operation.

5.2.4.2 Feed drive



These are used to drive the slide or a table
The requirements of an ideal feed drive are as follows.
- The feed motor needs to operate with constant torque characteristics to overcome friction and working forces.
- The drive speed should be extremely variable with a speed range of about 1: 20000, which means it should have a maximum speed of around 2000 rpm and at a minimum speed of 0.1 rpm.
- The feed motor must run smoothly.
- The drive should have extremely small positioning resolution.

5.2.5 Spindle and Spindle Bearings

Spindle
The spindle carrying the workpiece or tool when subjected to high cutting speeds and high material removal rates, experiences deflection and thrust forces. To ensure increased stability and minimize torsional strain, the machine spindle is designed to be short and stiff & the final drive to the spindles is located 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 are suitable for high speeds and high loads because of low friction, low wear rate &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:
(I) Minimum deflection under
varying loads. (il) Long service
life.
(Ili) Stiffness.
(Iv) Thermal stability'.
(v) Good running accuracy both in radial and axial directions.
(vi) Axial load carrying capacity'.
(vii) High speed of operation,

The various types of spindle bearings used in the design of a spindle for machine tools are:
1. Antifriction bearings.
2. Hydrostatic bearings.
3. Hydrodynamic bearings

1.Antifriction 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.

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 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. (ili) High
running accuracy.

These bearings are used in grinding and boring machines 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 shaped 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.
IV. Good damping Properties.

The main limitation of this type of bearing is that a definite clearance must be provided for the oil film to be maintained between bearing and the spindle; the clearances normally provided vary from 50 pm to 200 pm depending upon the journal diameter'

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