UNIT IV

[Answer 1]: Numeric Control or NC is a method of controlling the movements of machine components by inserting coded instructions in the form of numbers and letters into the system. These codes are then interpreted by a computer, typically through two types of systems: Open-Loop and Closed-Loop systems.

In the open-loop system, signals are sent to a servo motor, but the final movements and positions are not checked for accuracy (Page 5). In contrast, closed-loop systems are equipped with sensors that accurately measure the position of the worktable and ensure the coordinates are correct. With feedback control, the position of the worktable is compared against signals, and the movements terminate when the proper coordinates are reached (Page 5).

NC has several advantages, including the flexibility to produce complex shapes with good dimensional accuracy and repeatability. Additionally, NC can have high production rates, productivity, and product quality. Furthermore, less skill is required of the operator than that for a qualified machinist, and machine adjustments are relatively easy to make (Page 6).

However, there are also limitations to NC, including its relatively high initial cost of the equipment. Additionally, programming and computer time can be expensive, and maintenance is specialized. As these machines are complex systems, breakdowns can be costly (Page 6).

[Answer 2]: The NC part program has four categories of instructions or commands (Page 7):

Geometric instructions: These instructions pertain to relative movements between the tool and the workpiece.

Processing instructions: These instructions concern spindle speeds, feeds, cutting tools, cutting fluids, and so on.

Travel instructions: These instructions pertain to the type of interpolation and to the speed of movement of the tool or the worktable.

Switching instructions: These instructions concern the on–off position for coolant supplies, direction or lack of spindle rotation, tool changes, workpiece feeding, clamping, and so on.

[Answer 3]: Adaptive Control (AC) is a dynamic-feedback process that enables operating parameters to automatically adapt themselves to conform to new circumstances. For modern manufacturing processes, Adaptive Control is a logical extension of computer numerical control (CNC) systems.

The purpose of adaptive control in manufacturing is to achieve optimal production rate, product quality, and minimize production costs. In AC, the part programmer sets the processing parameters based on existing knowledge of the workpiece material and relevant data on the particular manufacturing operation. In CNC machines, these parameters remain constant throughout a specific process cycle. In AC, the system is capable of automatic adjustments during the operation through closed-loop feedback control (Page 8).

Adaptive control systems have the ability to improve the quality of finished products, reduce manufacturing costs, and boost the productivity of manufacturing operations. Adaptive control is particularly useful when materials and operating conditions fluctuate widely from one part or batch to another, for example, when producing parts from composite materials that are difficult to handle.

[Answer 4]: An industrial robot refers to a machine designed by a mechanism with several degrees of freedom (DOF). It typically resembles one or several arms ending in a wrist capable of holding a tool, a workpiece, or an inspection device. Below is a simple sketch of an industrial robot:

Industrial robots can be used for various industrial operations requiring automated assembly, material handling, inspection, and many more (Page 11). Some typical components of robotic systems include:

Manipulator / Arm and Wrist for providing motions.

End Effector/End-of-arm tooling for holding the objects, and manipulation.

Power Supply/Actuators for controlling motions of the manipulator.

Controller/Processor for providing commands to the motions of the robot.

With these components, the intelligent motion capabilities of robotic systems have ultimately enhanced the efficiency, productivity, and flexibility, thus being a critical factor in the manufacturing industry.

[Answer 5]: Industrial robots are classified based on the following criteria:

Fixed-sequence and Variable-sequence Robots: The fixed-sequence robot is programmed for a specific sequence of operations. Its movements are from point to point, and the cycle is repeated continuously. The variable-sequence robot, on the other hand, is programmed for a specific sequence of operations but can be reprogrammed to perform a different sequence of operations (Page 13).

Playback Robot: An operator leads or walks the playback robot and its end effector through the desired path. In other words, the operator teaches the robot by showing it what to do. The robot records the path and sequence of the motions and can repeat them continually without any further action or guidance by the operator (Page 13).

Numerically Controlled Robot: The numerically controlled robot is programmed and operated much like a numerically controlled machine. The robot is servo controlled by digital data, and its sequence of movements can be modified with relative ease (Page 13).

Intelligent Robot: The intelligent robot, also called a sensory robot, is capable of performing some of the functions and tasks carried out by humans. It is equipped with a variety of sensors with visual (computer vision) and tactile capabilities. It can make appropriate decisions for the next movement and proceeds accordingly (Page 14).

In manufacturing, a range of different industrial robots can be used, including articulated robots, Cartesian robots, cylindrical robots, and parallel robots (Page 11). For example, articulated robots have multi-joint arms, while Cartesian robots use a system similar to that of a graph plotter. End-users select a suitable robot based on the specific task and operational environments such as weight and the range of motion required for the application in hand.

[Answer 6]: The selection of robots in manufacturing is influenced by various factors, which include:

Load-carrying capacity: It refers to the maximum load a robot can carry and handle without malfunction. The load range of the robot is an essential aspect when considering its selection.

Work envelope: It is the range available to the robot for executing a particular operation. The working range determines the required robot reach range and affects the degree of flexibility.

Speed of movement: Selecting the robot based on movement speed is essential in a manufacturing line, especially for a high-speed continuous production process. The faster the robot moves, the more product units can be produced in a given time.

Reliability: The robot's reliability refers to the dependability of the specified parameters like performance levels, accuracy, and efficiency during operation. The robot selection should be based on its ability to meet the production demands and system reliability.

Repeatability: Repeatability is the robot's ability to perform the same motion repetitively within the same point of the operation. The robot selected should have a high level of repeatability since it determines product quality and consistency.

Arm configuration and Degrees of freedom: Different robots have varying arm configurations and degrees of freedom (DOF). Depending on the number of DOF, the robot can adapt to different situations and workspaces, making it a significant factor to consider in robot selection.

The control system: The robot control system refers to the robots' communication and information-processing system that gives commands for the robot's movements. The control system's selection is essential since it influences the robot's performance during execution.

Program memory: The robot needs to have enough program memory to store and support multiple programs, especially for diverse manufacturing operations.

Robots are used extensively in flexible manufacturing systems to move parts, as well as orient them as required. Industrial robots offer advantages such as greater flexibility, high production rates, programming ease, and good dimensional accuracy (Page 6). Major applications of robots in manufacturing include:

Material handling operations: Industrial robots can perform material-handling operations reliably and repeatedly, moving, and packing materials into finished products.

Spot welding of automobile and truck bodies, producing welds of good Quality. Robots also perform other, similar operations, such as arc welding, arc cutting, and riveting.

Operations such as grinding and polishing can be done by using appropriate tools attached to the end effectors.

Applying adhesives and sealants, spray painting, and cleaning operations are also among the major applications of industrial robots in manufacturing.

Automated assembly and inspection at speeds much higher than those which can be achieved by humans. Robots are used for error-free assembly of components and inspection of critical features for precise geometry of the final product.

[Answer 7]: The sensors used in manufacturing automation are broadly classified into the following categories:

Mechanical sensors: These sensors measure physical quantities like position, shape, velocity, force, torque, pressure, vibration, strain, and mass. An example of a mechanical sensor is a limit switch which stops a machine tool's work table movement.

Electrical sensors: These sensors measure electrical quantities like voltage, current, charge, and electrical conductivity. An example of an electrical sensor is a proximity sensor that detects the presence of metal objects without contact.

Magnetic sensors: These sensors measure the magnetic field, flux, and permeability. An example of a magnetic sensor is a pick-up sensor that senses the movement of the robot arm.

Thermal sensors: These sensors measure temperature, heat transfer, and specific heat. An example of a thermal sensor is a thermocouple that detects the temperature or a heat sensor that detects heat transfer.

Acoustic sensors: These sensors measure sound waves or vibration, such as an accelerometer that senses vibration.

Optical sensors: These sensors detect light, such as a photoelectric sensor that detects a reflective surface or a transparent object.

Chemical sensors: These sensors detect chemicals, such as a gas sensor that detects the presence of gasses like carbon monoxide or hydrogen sulfide.

Fiber optic sensors: These sensors use fiber optics to detect light transmission, such as a fiber optic sensor used to detect temperature or pressure.

Manufacturing automation systems commonly use sensors for controlling and monitoring the manufacturing process. Sensor technology is critical for enhancing product quality and improving the manufacturing process's efficiency (Pages 17-19).

[Answer 8]: Tactile sensing in automation involves the continuous sensing of contact forces between two objects, such as between a robotic end-effector and a workpiece, using one or more sensors. Tactile sensors can be used to detect contact, measure force, and provide feedback about the nature of contact.

Tactile sensors can operate in different ways, such as strain gages, piezoelectric devices, magnetic induction, ultrasonic, and optical systems of fiber optics and light-emitting diodes (LEDs). These sensors are capable of operating within a three-dimensional space, which makes them ideal for handling objects with various shapes, sizes, and textures. Sensing technology allows robots to handle fragile parts, such as thin glass bottles, eggs, and electronic devices, without causing damage.

By using feedback control based on tactile sensing, robots can control the forces applied to workpieces accurately, minimize the risk of damage to sensitive parts, and avoid excessive forces that could compromise the precision and quality of the manufacturing process. Tactile sensing technology has been widely used in the robotic assembly of small parts, welding, and other manufacturing processes (Page 19).

[Answer 9]: Visual sensing in automation refers to the use of cameras/optical sensors to detect the presence, shape, size, and orientation of objects. This system is also called machine vision or computer vision, which utilizes a microprocessor that processes the image usually within less than one second. The image is then measured, the measurements are digitized, which is referred to as image recognition.

In machine vision, robots can use cameras to provide positional input relative to the workpiece. By detecting the precise location and orientation of the workpiece, this sensing technology allows the robots to perform a wide range of high-precision tasks, such as picking and placing parts, welding, painting, and inspection.

Machine vision technology is becoming more advanced, and the use of deep learning is becoming more common to improve image recognition further. Machine vision technology provides a means to standardize quality control and improve production efficiency, often with less need for human supervision. Therefore, it has become a popular tool in industrial automation (Pages 20-21).

[Answer 10]: Modular Fixturing:

Modular Fixturing is a type of fixturing used in manufacturing for small or moderate lot sizes, especially when the cost of dedicated fixtures and the time required to produce is difficult to justify. Modular fixtures usually are based on tooling plates or blocks configured with grid holes or T-slots upon which a fixture is constructed. Several other standard components, such as locating pins, adjustable stops, workpiece supports, V-blocks, clamps, and springs, can be mounted onto a base plate or block to quickly produce a fixture. This type is very common in job shop manufacturing because of the diverse product range.

Tombstone Fixtures:

Tombstone fixtures are multi-faceted fixtures that have several vertical faces (hence, they resemble tombstones) onto which workpieces can be mounted. Tombstone fixtures are typically designed to deal with the wide range of products produced in small-scale and mass production. They’re mostly used in automated or robot-assisted manufacturing systems.

[Answer 11]: Adjustable-force clamping is a method of clamping workpieces in flexible fixturing systems, which is used for quickly accommodating a range of part shapes and dimensions without requiring extensive changes, adjustments, or operator intervention. This kind of clamping system adjusts the force to keep the workpiece securely clamped to the workpiece for the particular application. This type of clamping helps to prevent excessive clamping forces that otherwise may damage the workpiece surface, particularly if it is soft or has a slender design.

A schematic illustration of this kind of system is shown in Figure (Page 24 of UNIT-4 PDF). The strain gauge mounted on the clamp senses the magnitude of the clamping force. The system then adjusts this force to keep the workpiece securely clamped to the workpiece for the particular application. It can also prevent excessive clamping forces that otherwise may damage the workpiece surface, particularly if it is soft or has a slender design. By allowing adjustable-force clamping, it means that a range of geometries and forces can be acclimated with ease in the same fixture, which results in a faster and more flexible process. This type of clamping can be used to complement other flexible fixturing methods, such as modular and tombstone fixturing (Pages 24-25).

[Answer 12]: Flexible Fixturing is a method for holding irregular-shaped or curved workpieces with the two main methods of hard tooling and using phase-change materials. Phase change materials (PCM) are thermally conductive materials that change their state, for example, from a solid to a liquid when heated and back to a solid when cooled. PCMs, therefore, offer significant potential to enhance the flexibility and versatility of manufacturing systems without the need to use hard tooling fixtures.

PCM can be used for Flexible Fixturing in two ways:

Low-melting-point metal: A low-melting-point metal such as lead is used as the medium for clamping the workpiece. An irregular-shaped workpiece is dipped into the molten lead, and after it sets, the solidified lead block is clamped in a simple fixture which provides a perfect fit of the workpiece while holding it firmly. This approach is suitable for small batch, high geometric variation workpieces.

Magnetorheological (MR) or electrorheological (ER) fluid: The supporting medium in this approach is a fluid that changes from a liquid to that of a solid when immersed into a workpiece, an external magnetic/electric field is applied that polarizes the particles and aligns with an external magnetic/electric field. This process provides a flexible fixturing system that can rapidly accommodate a range of part shapes and dimensions without requiring extensive changes, adjustments or operator intervention.

Overall, PCM can be used to increase the flexibility and versatility of a manufacturing system by providing a flexible alternative to hard tooling fixtures. However, they require a special setup and dye and so are best used for critical flexible fixturing applications (Pages 25-26).

[Answer 13]: Different types of assembly systems used in manufacturing are-

Manual Assembly: It uses simple tools and is economical for small lots. Workers can manually assemble even complex parts without much difficulty. In spite of the use of sophisticated mechanisms, robots, and computer controls, aligning and placing of a simple square peg into a square hole involving small clearances can be difficult in automated assembly.

High-Speed Automated Assembly: It utilizes special transfer mechanisms designed for assembly. Individual assembly is carried out on products that are indexed for proper positioning.

Robotic Assembly: One or two general-purpose robots operate at a single workstation, or the robots operate at a multi station assembly system.

Flexible Assembly Systems (FAS): These utilize computer controls, interchangeable and programmable workheads and feeding devices, coded pallets, and automated guiding devices. FAS is capable of assembling up to a dozen different transmission and engine combinations and power steering and air-conditioning units.

Overall, these different assembly systems offer different advantages and drawbacks, and their implementation in a particular manufacturing process depends on the product line, manufacturing process, and the production level required. (Pages 26-30)

[Answer 14]: Design for flexible fixturing involves the creation of work-holding devices that can handle complex geometries, changeover quickly from one part to another, and require little or no operator intervention. Some of the main design considerations that need to be addressed for flexible fixturing are stated below:

Automatic positioning and accurate workpiece clamping: Work-holding devices must position the workpiece automatically and accurately.

Sufficient stiffness: The fixtures must have sufficient stiffness to resist, without excessive distortion, normal and shear stresses developed at the workpiece–fixture interfaces. For heavy cutting, high accuracy positioning requirements, and/or high-production needs, more extensive fixturing can be employed.

Accommodation of different part models: A flexible fixture should be able to accommodate parts to be made by different processes and with different dimensions and surface features that vary from part to part.

Low profiles of clamps and fixtures: Clamps and fixtures should have low profiles to avoid collision with cutting tools.

Overall, the design of flexible fixturing requires a delicate balance between providing adequate strength and rigidity for accurate workpiece holding and leaving sufficient room for adaptability, rapid changeover, and economical manufacture. Modern design techniques, such as modular fixturing, can help in the rapid design of fixtures, but the quality of the final product ultimately depends on the engineer's knowledge and experience. (Pages 30-31)

[Answer 15]: The design for assembly involves various considerations to achieve the efficient assembly of components in a manufacturing process. Below are some key considerations:

Reduce part count: Reduction of the number and variety of parts in a product reduces assembly complexity and shortens assembly time and cost. By simplifying the product design and giving priority to the ease of assembly, there is a reduction in assembly errors and costs.

Parts symmetry: To avoid the need for locating, aligning, or making adjustments to parts, they should have a high degree of symmetry, making their installation foolproof. Symmetry can help shorten assembly time and eliminate human error.

Design for automation: Designing parts for easy handling by robots or other automated devices also makes the assembly process more straightforward and efficient. For example, designing parts that can be manipulated by the same gripper of the robot can make the assembly a much smoother process. Additionally, designing the parts to insert in one direction eases the assembly process.

Avoid extraneous fasteners: Avoiding the need for redundant hardware, such as bolts, nuts, and screws, can reduce the cost of assembly as well as the overall equipment costs while also contributing to faster product assembly. Considerations should also be taken to ensure the avoidance of fasteners between limited access components.

Color codes: Using color codes on parts that may appear similar, but are different, can help reduce the likelihood of errors and replace slow part identification methods during manufacturing.

Overall, the design considerations for assembly are aimed at standardizing quality control and increasing production efficiency. Careful consideration of these factors in the product design process can help reduce assembly times, minimize human error, and optimize the assembly process. (Page 31)