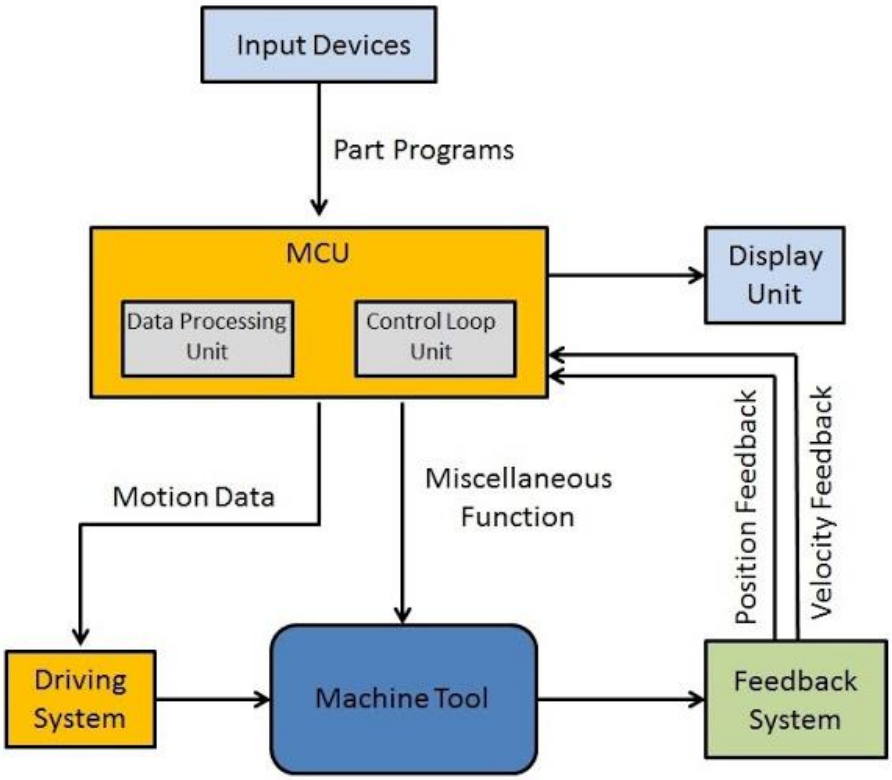
Computer Numerical Control (CNC): Introduction, Components of CNC, open loop and closed loop systems, advantages and disadvantages of CNC.

Introduction

Modern precision manufacturing demands extreme dimensional accuracy and surface finish. Such performance is very difficult to achieve manually, if not impossible, even with expert operators. In cases where it is possible, it takes much higher time due to the need for frequent dimensional measurement to prevent overcutting. It is thus obvious that automated motion control would replace manual "hand wheel" control in modern manufacturing. Development of computer numerically controlled (CNC) machines has also made possible the automation of the machining processes with flexibility to handle production of small to medium batch of parts.

Components of CNC



Any CNC machine tool essentially consists of the following parts:

1. **Part program:**

   A part program is a series of coded instructions required to produce a part. It controls the movement of the machine tool and on/off control of auxiliary functions such as spindle rotation and coolant. The coded instructions are composed of letters, numbers and symbols.

2. **Program input device:**

   The program input device is the means for part program to be entered into the CNC control. Three commonly used program input devices are punch tape reader, magnetic tape reader, and computer.

3. **Machine Control Unit:**

   The machine control unit (MCU) is the heart of a CNC system. It is used to perform the following functions:

   a. To read the coded instructions.
   b. To decode the coded instructions.
   c. To implement interpolations (linear, circular, and helical) to generate axis motion commands.
   d. To feed the axis motion commands to the amplifier circuits for driving the axis mechanisms.
   e. To receive the feedback signals of position and speed for each drive axis.
   f. To implement auxiliary control functions such as coolant or spindle on/off and tool change.

4. **Drive System:**

   A drive system consists of amplifier circuits, drive motors, and ball lead-screws. The MCU feeds the control signals (position and speed) of each axis to the amplifier circuits. The control signals are augmented to actuate drive motors which in turn rotate the ball lead-screws to position the machine table.

5. **Machine Tool:**

   CNC controls are used to control various types of machine tools. Regardless of which type of machine tool is controlled, it always has a slide table and a spindle to control of position and speed. The machine table is controlled in the X and Y axes, while the spindle runs along the Z axis.

6. **Feed Back System:**

   The feedback system is also referred to as the measuring system. It uses position and speed transducers to continuously monitor the position at which the cutting tool is located at any particular instant. The MCU uses the difference between reference signals and feedback signals to generate the control signals for correcting position and speed errors.

Open Loop Systems

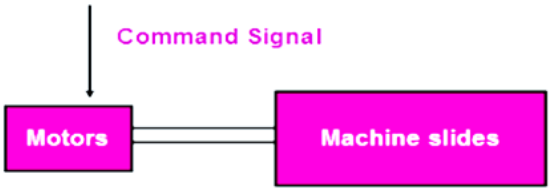


Figure: Open Loop System

In open loop systems, programmed instructions are fed into the controller through an input device. These instructions are then converted to electrical pulses (signals) by the controller and sent to the servo amplifier to energize the servo motors. The primary drawback of the open-loop system is that there is no feedback system to check whether the program position and velocity has been achieved. If the system performance is affected by load, temperature, humidity, or lubrication then the actual output could deviate from the desired output. For these reasons the open -loop system is generally used where the accuracy requirements are not critical.

Closed loop systems:

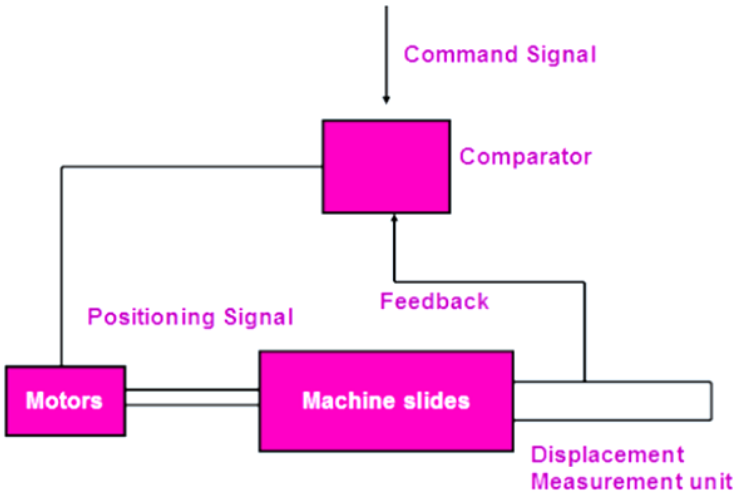


Figure: Closed Loop System

The closed-loop system has a feedback subsystem to monitor the actual output and correct any discrepancy from the programmed input. These systems use position and velocity feedback. The feedback system could be either analog or digital. The analog systems measure the variation of physical variables such as position and velocity in terms of voltage levels. Digital systems monitor output variations by means of electrical pulses. To control the dynamic behaviour and the final position of the machine slides, a variety of position transducers are employed. Majority of CNC systems operate on servo mechanism, a closed loop principle. If a discrepancy is revealed between where the machine element should be and where it actually is, the sensing device signals the driving unit to make an adjustment, bringing the movable component to the required location.

Closed-loop systems are very powerful and accurate because they are capable of monitoring operating conditions through feedback subsystems and automatically compensating for any variations in real-time.

Advantages of a CNC Machine

CNC machines offer the following advantages in manufacturing.

1. **Higher flexibility:** This is essentially because of programmability, programmed control and facilities for multiple operations in one machining centre,
2. **Increased productivity:** Due to low cycle time achieved through higher material removal rates and low set up times achieved by faster tool positioning, changing, automated material handling etc.
3. **Improved quality:** Due to accurate part dimensions and excellent surface finish that can be achieved due to precision motion control and improved thermal control by automatic control of coolant flow.
4. **Reduced scrap rate:** Use of Part programs that are developed using optimization procedures
5. **Reliable and Safe operation:** Advanced engineering practices for design and manufacturing, automated monitoring, improved maintenance and low human interaction
6. **Smaller footprint**: Due to the fact that several machines are fused into one.

Disadvantages of a CNC Machine

1. Relatively higher cost compared to manual versions
2. More complicated maintenance due to the complex nature of the technologies
3. Need for skilled part programmers.

The above disadvantages indicate that CNC machines can be gainfully deployed only when the required product quality and average volume of production demand it.
