1.0 COMPUTER AIDED MANUFACTURING (CAM)

Since the age of the Industrial Revolution, the manufacturing process has undergone many dramatic changes. One of the most dramatic of these changes is the introduction of Computer Aided Manufacturing (CAM), a system of using computer technology to assist the manufacturing process.

Through the use of CAM, a factory can become highly automated, through systems such as real-time control and robotics. A CAM system usually seeks to control the production process through varying degrees of automation. Because each of the many manufacturing processes in a CAM system is computer controlled, a high degree of precision can be achieved that is not possible with a human interface.

The CAM system, for example, sets the tool path and executes precision machine operations based on the imported design. Some CAM systems bring in additional automation by also keeping track of materials and automating the ordering process, as well as tasks such as tool replacement.

Computer Aided Manufacturing is commonly linked to Computer Aided Design (CAD) systems. The resulting integrated CAD/CAM system then takes the computer-generated design, and feeds it directly into the manufacturing system; the design is then converted into multiple computer-controlled processes, such as drilling or turning.

Another advantage of Computer Aided Manufacturing is that it can be used to facilitate mass customization: the process of creating small batches of products that are custom designed to suit each particular client. Without CAM, and the CAD process that precedes it, customization would be a time-consuming, manual and costly process. However, CAD software allows for easy customization and rapid design changes: the automatic controls of the CAM system make it possible to adjust the machinery automatically for each different order.

The specter of robots replacing workers, however, is currently a fallacy. Robotic arms and machines are commonly used in factories, but these do still require human workers. The nature of those workers' jobs change however. The repetitive tasks are delegated to machines; the human workers' job descriptions then move more towards set-up, quality control, using CAD systems to create the initial designs, and machine maintenance.

1.1 Overcoming the historical shortcomings of CAM

Over time, the historical shortcomings of CAM are being attenuated, both by providers of niche solutions and by providers of high-end solutions. This is occurring primarily in three arenas:

1. Ease of use
2. Manufacturing complexity
3. Integration with PLM and the extended enterprise

1.1.1 Ease in use:

For the user who is just getting started as a CAM user, out-of-the-box capabilities providing Process Wizards, templates, libraries, machine tool kits, automated feature based machining and job function specific tailorable user interfaces build user confidence and speed the learning curve.

User confidence is further built on 3D visualization through a closer integration with the 3D CAD environment, including error-avoiding simulations and optimizations.

1.1.2 Manufacturing complexity:

The manufacturing environment is increasingly complex. The need for CAM and PLM tools by the manufacturing engineer, NC programmer or machinist is similar to the need for computer assistance by the pilot of modern aircraft systems. The modern machinery cannot be properly used without this assistance.

Today's CAM systems support the full range of machine tools including: turning, 5 axis machining and wire EDM. Today’s CAM user can easily generate streamlined tool paths, optimized tool axis tilt for higher feed rates and optimized Z axis depth cuts as well as driving non-cutting operations such as the specification of probing motions.

Integration with PLM and the extended enterprise LM to integrate manufacturing with enterprise operations from concept through field support of the finished product:

To ensure ease of use appropriate to user objectives, modern CAM solutions are scalable from a stand-alone CAM system to a fully integrated multi-CAD 3D solution-set. These solutions are created to meet the full needs of manufacturing personnel including part planning, shop documentation, resource management and data management and exchange.

1.2 Components of Computer Aided Manufacturing

A part created in CAD can be downloaded and manufactured, without a human hand touching the part. The process is called CAM, and involves CAD, Networking, and NC programming, as shown below.

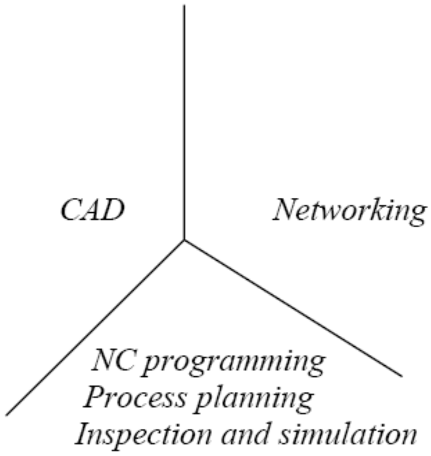


Figure 1.1: Components of Computer Aided Manufacturing

The implementation of the CAM process on CAD/CAM systems is shown in Fig. The geometric model developed during the CAD process forms the basis of the CAM activities. CAM activities may require various CAD information. Interface algorithms are usually utilized to extract such information from CAD databases. In case of process planning, features that are utilized in manufacturing (e.g., holes, slots, etc.) must be recognized to enable efficient planning of manufacturing. NC programmes, along with ordering tools and fixtures, result from process planning. Once parts are produced, CAD software can be used to inspect them. This is achieved by superposing an image of the real part with a master image stored in its model database. After passing inspection, CAM software can be utilised to instruct robot systems to assemble the parts to produce the final product.

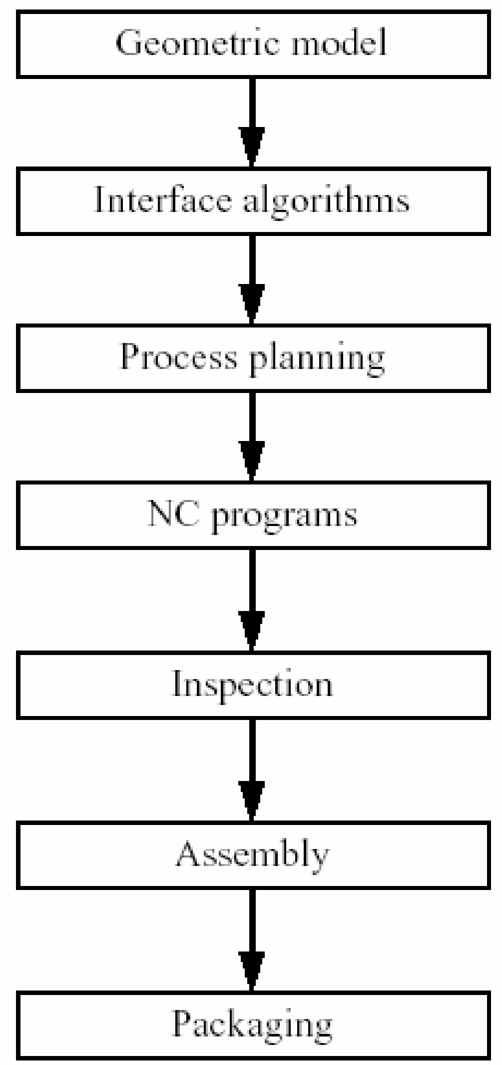


Figure 1.2: Implementation of a typical CAM process on a CAD/CAM system

1.3 Computer and Numeric Control (CNC)

Conventionally, an operator decides and adjusts various machines parameters like feed, depth of cut etc depending on type of job, and controls the slide movements by hand. In a CNC Machine functions and slide movements are controlled by motors using computer programs.

1.3.1 Numeric Control NC:

- A numerical control, or “NC”, system controls many machine functions and movements which were traditionally performed by skilled machinists.
- Numerical control developed out of the need to meet the requirements of high production rates, uniformity and consistent part quality.

- Programmed instructions are converted into output signals which in turn control machine operations such as spindle speeds, tool selection, tool movement, and cutting fluid flow.

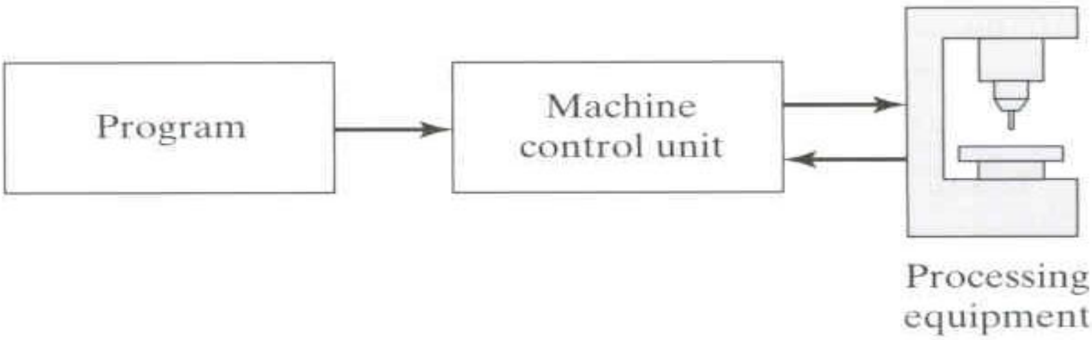
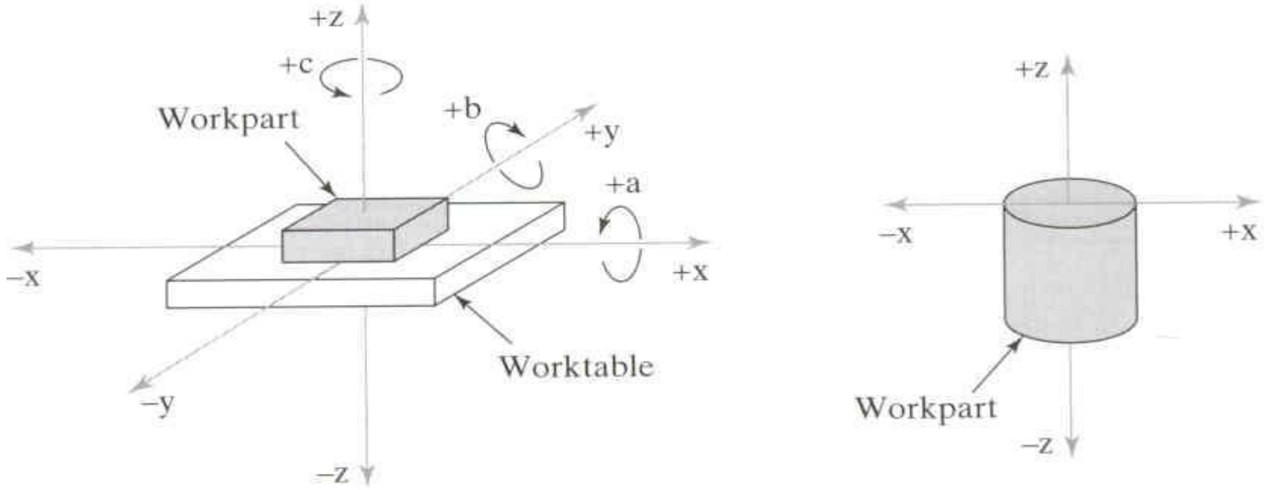


Figure 1.3: Basic Components of NC system

- By integrating a computer processor, computer numerical control, or "CNC" as it is now known, allows part machining programs to be edited and stored in the computer memory as well as permitting diagnostics and quality control functions during the actual machining.
- All CNC machining begins with a part program, which is a sequential instructions or coded commands that direct the specific machine functions.
- The part program may be manually generated or, more commonly, generated by computer aided part programming systems.

1.3.2 Basic CNC Principles

All computer controlled machines are able to accurately and repeatedly control motion in various directions. Each of these directions of motion is called an axis. Depending on the machine type there are commonly two to five axes. Additionally, a CNC axis may be either a linear axis in which movement is in a straight line or a rotary axis with motion following a circular path.



(a) Flat and prismatic work (b) rotational work

Figure 1.4: Coordinate systems used in NC

1.3.3 Motion control - the heart of CNC

- The most basic function of any CNC machine is automatic, precise, and consistent motion control.
- Rather than applying completely mechanical devices to cause motion as is required on most conventional machine tools, CNC machines allow motion control in a revolutionary manner.
- All forms of CNC equipment have two or more directions of motion, called axes. These axes can be precisely and automatically positioned along their lengths of travel.

Three Basic Categories of Motion Systems

- Point to Point - No contouring capability
- Straight cut control - one axis motion at a time is controlled for machining
- Contouring - multiple axis's controlled simultaneously

1.3.4 Types of Motion Control in NC

The motion control in NC systems have been divided in to two categories such as open loop system and closed loop systems as illustrated in Figures 1.5 and 1.6

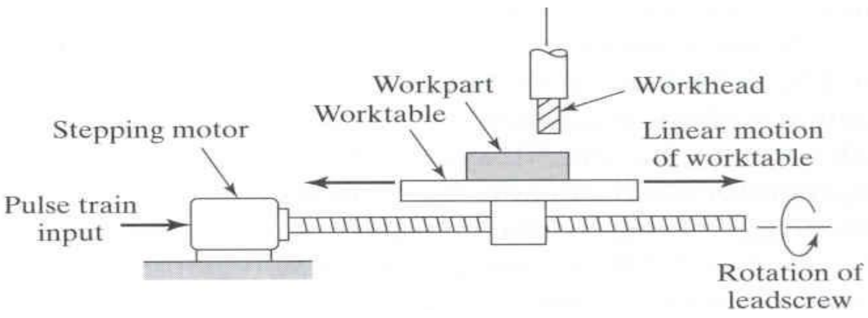


Figure 1.5: Open loop control system

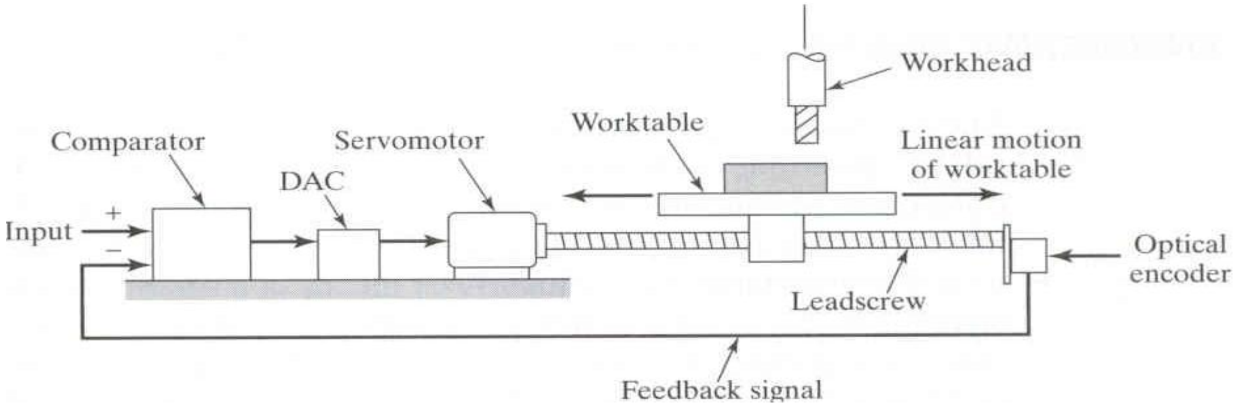


Figure 1.6: Closed loop control system

1.3.5 Basic CNC Principles Coordinates System

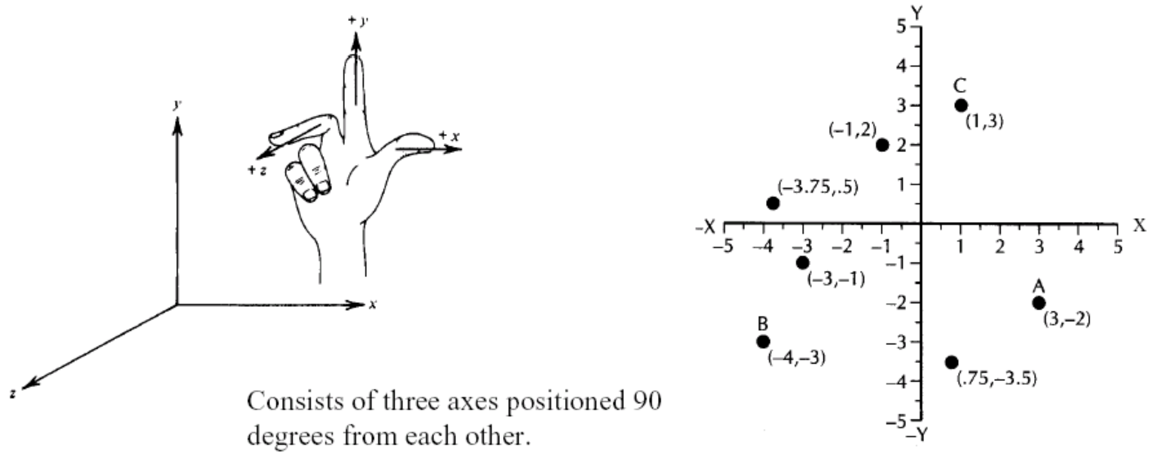
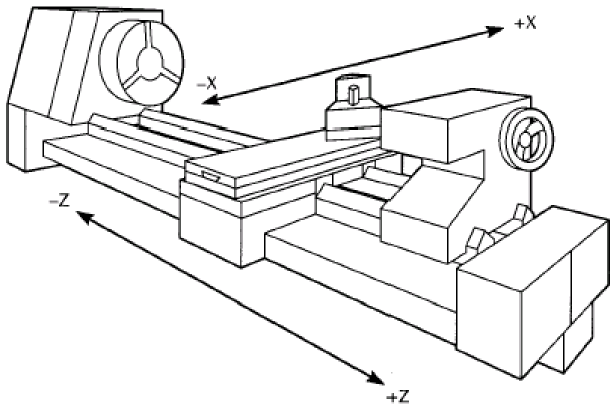


Figure 1.7: Absolute Coordinate System



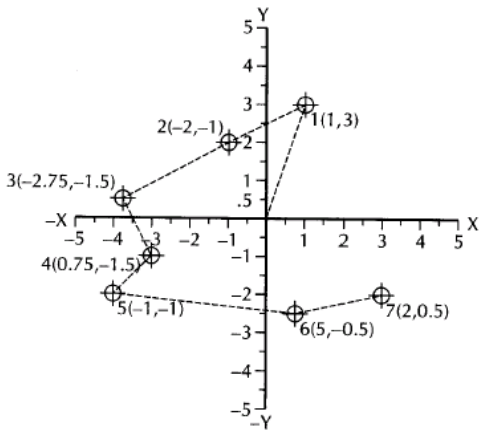


Figure 1.8: Incremental Coordinate System

1.3.6 CNC Working

- Each axis consists of a mechanical component, such as a slide that moves a servo drive motor that powers the mechanical movement, and a ball screw to transfer the power from the servo drive motor to the mechanical component.
- These components, along with the computer controls that govern them, are referred to as an axis drive system.

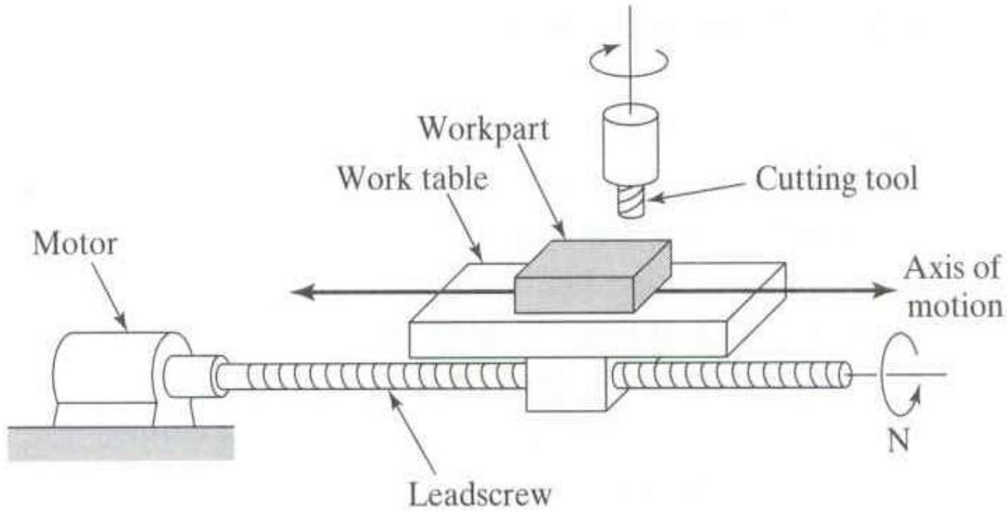


Figure 1.9: Motor and lead screw arrangement in an NC positioning system

- Using a vertical mill machining center as an example, there are typically three linear axes of motion. Each is given an alphabetic designation or address. The machine table motion side to side is called the “X” axis. Table movement in and out is the “Y” axis, while head movement up and down the column is the “Z” axis.

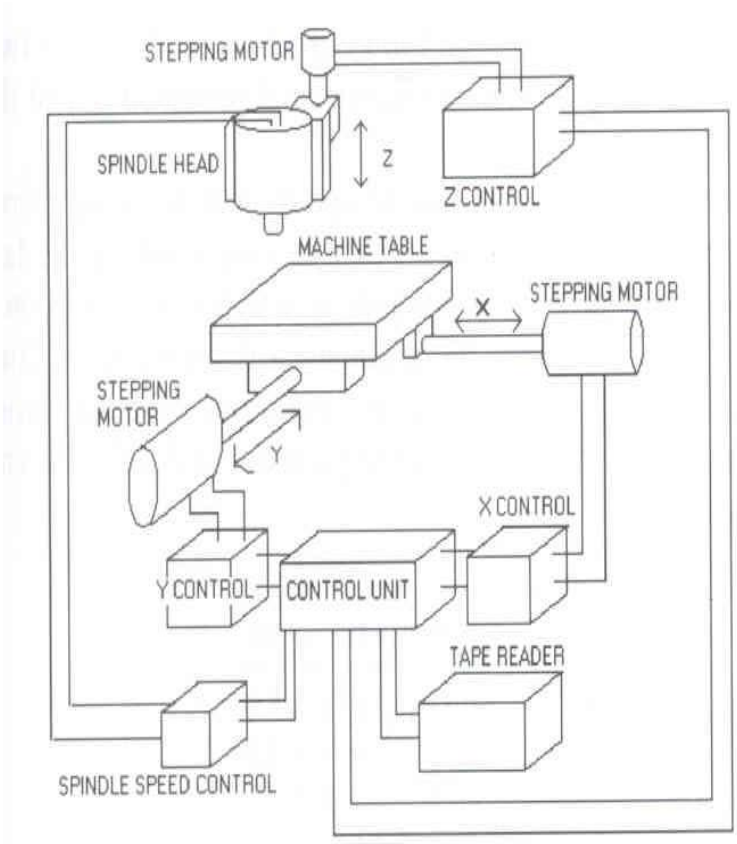
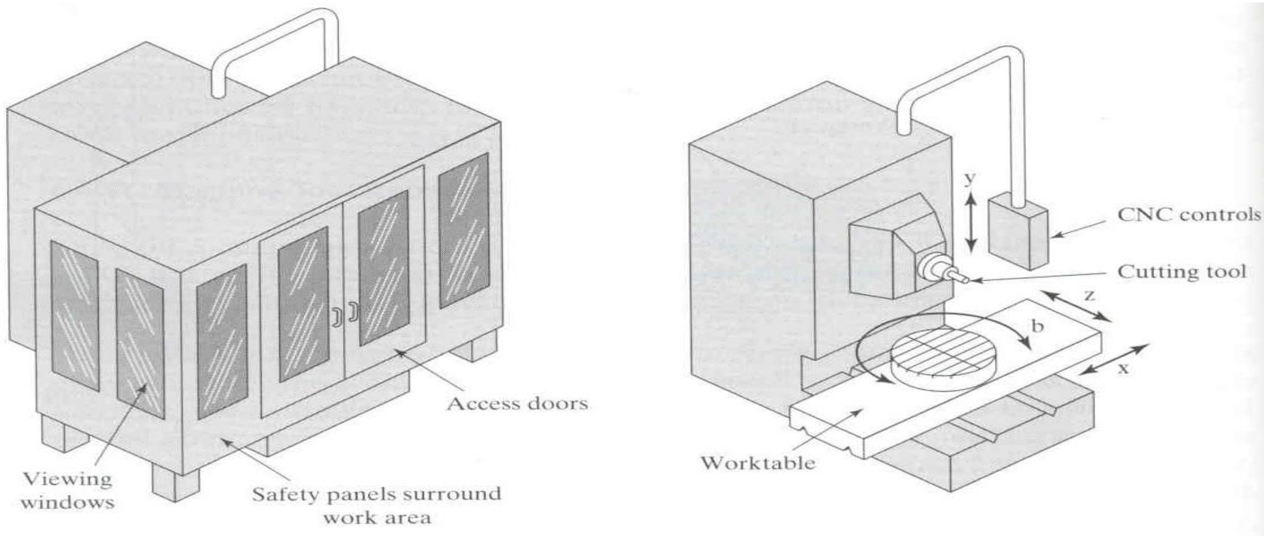


Figure: Servo Mechanism

Servo drives are

- Tolerant to tool cutting forces
- Insensitive to load mass inertias (stiffness)
- Insensitive to running friction forces
- Linear to high degree

- If a rotary table is added to the machine table, then the fourth axis is designated the "b" axis.



(a) (b)

Figure 1.10: (a) Four-axis CNC horizontal milling machine with safety panels installed and (b) with safety panels removed to show typical axis configuration for the horizontal spindle.

1.3.7 Work Positioning

- The method of accurate work positioning in relation to the cutting tool is called the "rectangular coordinate system." On the vertical mill, the horizontal base line is designated the "X" axis, while the vertical base line is designated the "Y" axis. The "Z" axis is at a right angle, perpendicular to both the "X" and "Y" axes.
- Increments for all base lines are specified in linear measurements, for most machines the smallest increment is one ten-thousandth of an inch (.0001). If the machine is graduated in metric the smallest increment is usually one thousandth of a millimeter (.001mm).

- The rectangular coordinate system allows the mathematical plotting of points in space. These points or locations are called “coordinates.” The coordinates in turn relate to the tool center and dictate the “tool path” through the work.

1.3.8 CNC Machines- Advantages / Disadvantages

Advantages:

- High Repeatability and Precision e.g. Aircraft parts
- Volume of production is very high
- Complex contours/surfaces need to be machined. E.g. Turbines
- Flexibility in job change, automatic tool settings, less scrap
- More safe, higher productivity, better quality
- Less paper work, faster prototype production, reduction in lead times

Disadvantages:

- Costly setup, skilled operators
- Computers, programming knowledge required
- Maintenance is difficult