

CHAPTER 11

COMPUTER NUMERICAL CONTROL MACHINES

CHAPTER LEARNING OBJECTIVES

Upon completing this chapter, you should be familiar with the following:

- *Set up CNC lathes and milling machines.*
- *Develop CNC lathe and milling machine programs using CAD/CAM.*

As the hardware of an advanced technology becomes more complex, new approaches to the processing of materials into useful products come into common use. This has been the trend in machining processes in recent years. Parallel development in other technologies such as electronics and computers have made available to the machine tool designer methods and processes that can permit a machine tool to far exceed the capabilities of the most experienced machinist. To state it very simply, the MR rate has gone from the horse and buggy days to the space shuttle days almost overnight.

This chapter will give you some information on the impact numerical control (NC) has had in the field of machining. It is only an overview and cannot be expected to take the place of a programming manual for a specific machine, on-the-job training, or MR "C" school.

With the development of NC, a variety of input media has been used to convey the information from the print to the machine. The most common types of input media used in the past were magnetic tape, punched cards, and punched tape. However, most of the new machines are controlled by computers. All of the machines on board Navy intermediate maintenance activities (IMAs) are computer numerical control (CNC).

There are many advantages to using NC machines. The greatest advantage in NC machining comes from the unerring and rapid positioning movements possible. An NC machine does not stop at the end of a cut to plan its next move. It does not get fatigued and is capable of uninterrupted machining, error free, hour after hour. In the past, NC machines were used for mass production. With the introduction of CNC, a qualified machinist can program and produce even a single part economically.

NC MACHINE SAFETY

All safety rules that apply to conventional machine tools also apply to NC machines. Always wear appropriate eye protection. Remove all rings, bracelets, watches, necklaces, and loose clothing that may be caught by moving or rotating equipment. Always wear safety shoes.

Always keep the work area around the machine clean and clear of obstructions. Do not use compressed air to clean the machine or the area around it; chips can become dangerous missiles. Never use machine surfaces as worktables. Use proper lifting methods to handle heavy workpieces. Take measurements only after the spindle has come to a complete stop. Never handle chips with your bare hands.

Before you start the machine, make sure the work-holding device and the workpiece are securely fastened. When changing cutting tools, protect the workpiece from damage, and protect your hands from sharp cutting edges. Make sure cutting tools are installed correctly.

Do not operate any machine controls unless you understand their function. All NC machines have electrical compartments; keep the doors closed to keep out dirt and chips. Only authorized technicians should perform maintenance or repairs in these compartments.

To avoid damage to the machine or workpiece, check the tool path by making a dry run through the program; that is, let the machine make all the positioning and cutting moves without a cutting tool installed.

Above all, follow all safety precautions posted on the machine and any listed in *Navy Occupational Safety and Health (NAVOSH) Program Manual for Forces Afloat*, OPNAV Instruction 5100.19B.

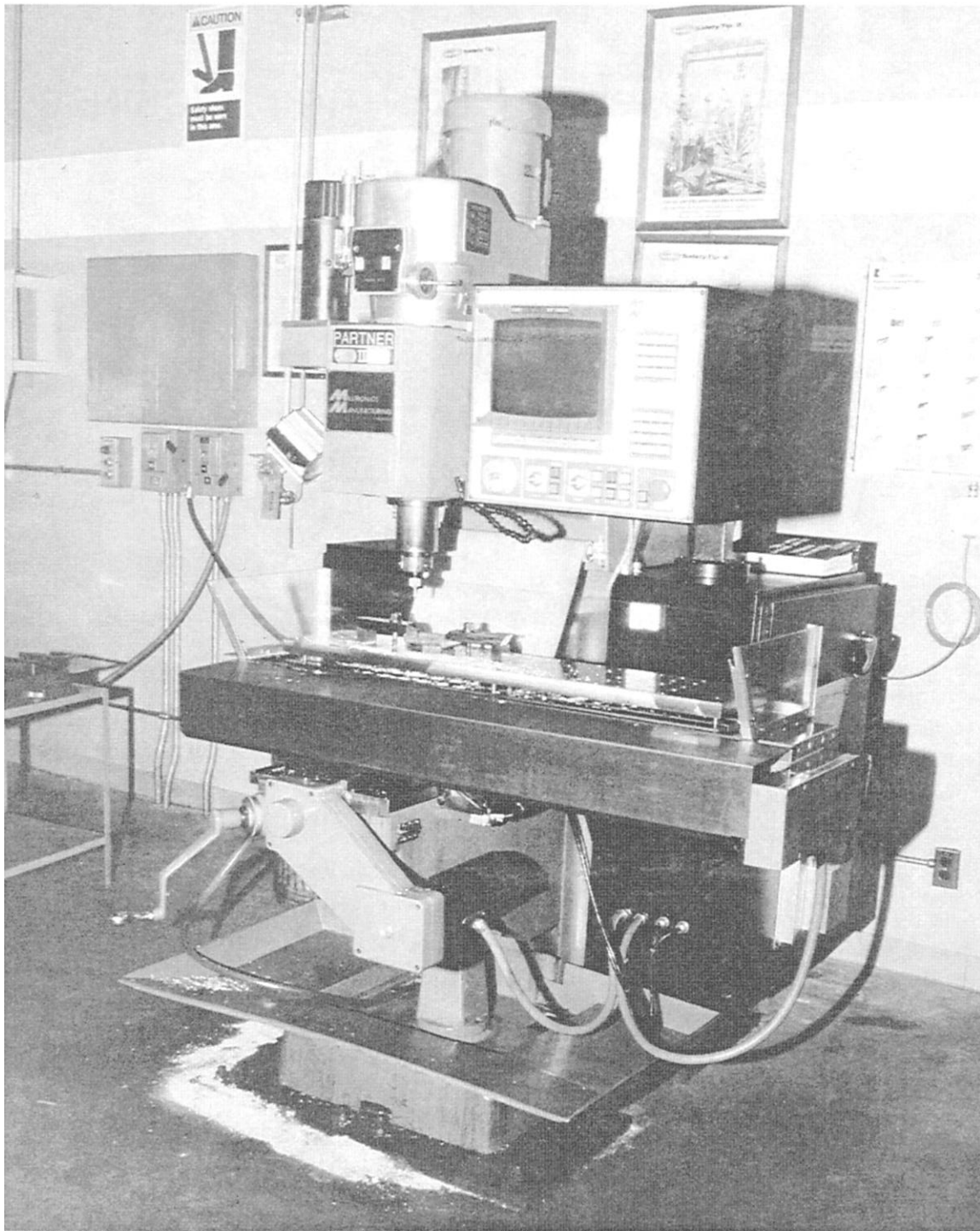


Figure 11-1.—CNC vertical spindle milling machine.

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MACHINES

With the rapid development of machining technology in the last few years, many new types of CNC machines have been introduced. Many of these

machines are not simply CNC machines, but are CNC turning centers. Turning centers may have one or more turret-type toolholders or have an automatic tool change system. For illustration purposes we will discuss a CNC vertical milling machine and a CNC lathe.



Figure 11-2.—CNC lathe.

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CNC VERTICAL SPINDLE MILLING MACHINE

Many of the CNC vertical spindle milling machines being introduced to the Navy today are similar to the one shown in figure 11-1. It is basically a vertical milling machine that has an onboard computer to control its motion. Most of these machines are manufactured with what is known as an R-8 spindle taper that employs a quick-change tool system.

The quick-change tool system consists of a quick release chuck (which is held in the spindle) and a set of toolholders that hold the individual tools needed for a particular part program. The chuck is a separate tool-holding mechanism that stays in the spindle. During a

tool change, the toolholder is removed from the chuck and a toolholder containing the next required tool is installed in its place. Many varieties of quick-change tool systems are available on the market.

Since this is only a brief overview, we will not discuss each part of the machine. Refer to your machine's technical manual for more information.

CNC LATHE

Many CNC lathes (fig. 11-2) look like traditional engine lathes. The lathe carriage rests on the ways. The ways are in the same plane and are parallel to the floor. On other CNC lathes, the turret tool post is mounted on

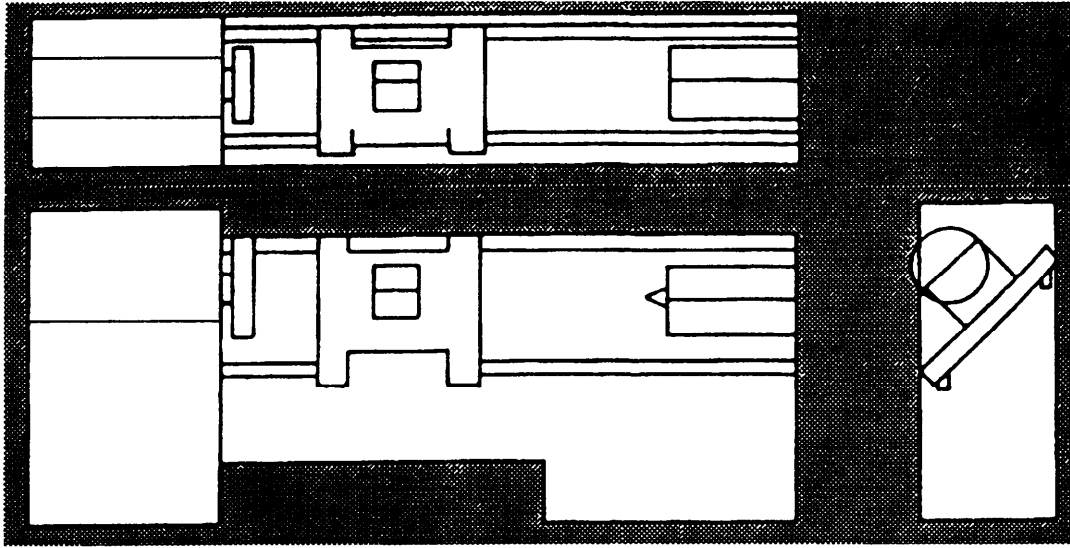


Figure 11-3.—Slant bed for CNC lathe.

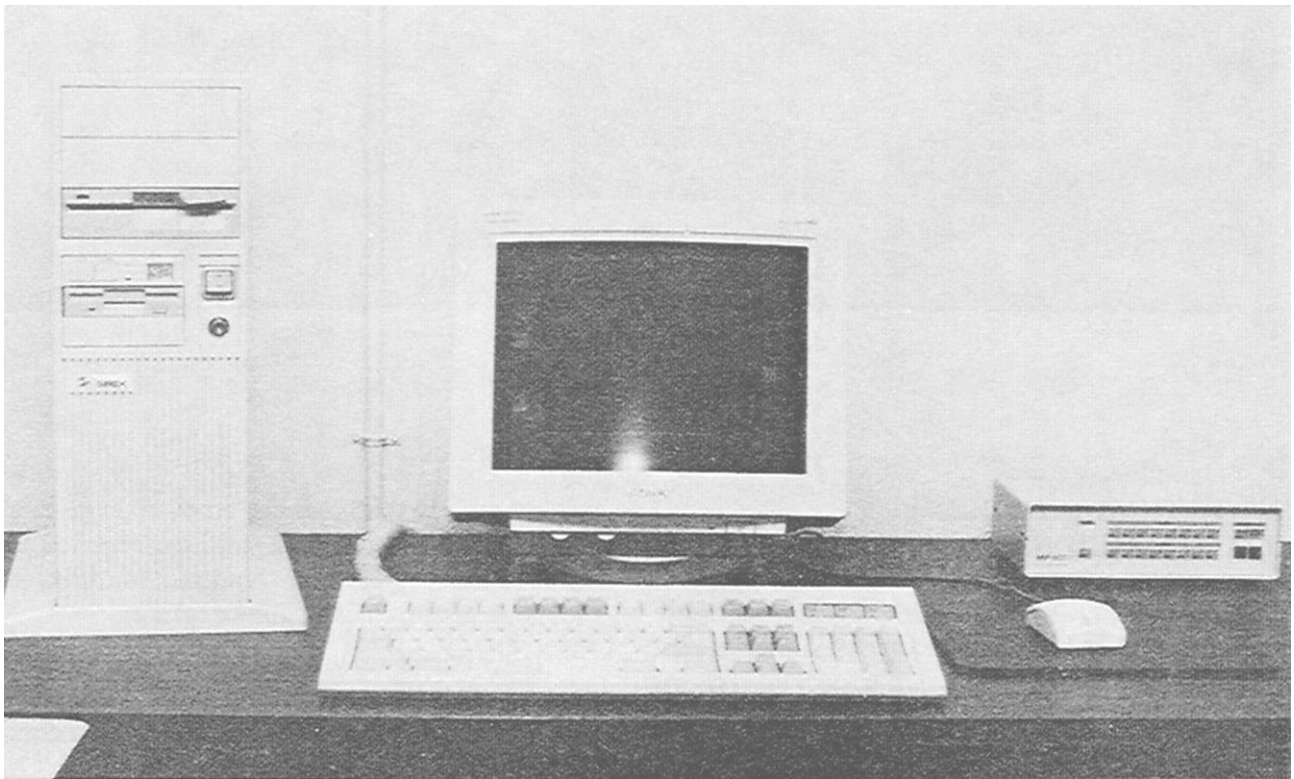


Figure 11-4.—CNC programming station.

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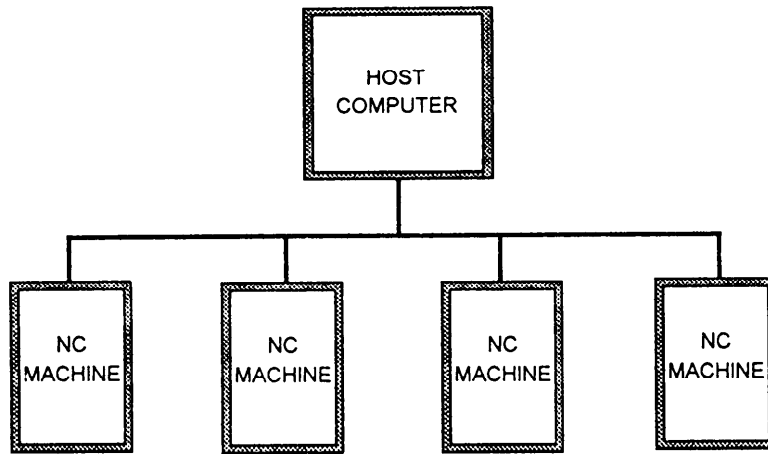


Figure 11-5.—Direct numerical control.

the opposite side of the saddle (fig. 11-3) and the machine has a slant bed. The slant bed allows the chips to fall into the chip pan, rather than on tools or bedways. Despite this odd appearance, the slant bed CNC lathe functions just like a conventional lathe.

As with CNC milling machines, you must have the controller manual for your machine's controller to program it and operate the machine.

CNC TOOLING

There are many different tool-holding devices used for CNC machines. They can be as simple as a quick-change tool post or as complicated as an automatic tool change system, but they all serve the same purpose. The tool-holding devices for each shop will vary since each machine comes with different tooling and because shop personnel will purchase the tooling they prefer.

Cutting tools are available in three basic material types: high-speed steel, tungsten carbide, and ceramic. Since we covered cutting tools in chapter 5, we will only briefly discuss them now. High-speed steel is generally used on aluminum and other nonferrous alloys, while tungsten carbide is used on high-silicon aluminums, steels, stainless steels, and exotic metals. Ceramic inserts are used on hard steels and exotic metals. Inserted carbide tooling is becoming the preferred tooling for many CNC applications.

COMPUTER-AIDED DESIGN/COMPUTER-AIDED MANUFACTURING

Computer technology has reached the stage where a machinist can use computer graphics (fig. 11-4) to

design a part. The computer is used to place the design elements (lines, curves, circles, and so on) and dimensions on the computer display screen.

The machinist defines the geometry of the part to the computer using one or more input devices. These devices may be the keyboard, a mouse, a digitizer, or a pen light. When the design has been edited and proofed, the computer can be instructed to analyze the geometry of the part and calculate the tool paths that will be required to machine the part. Each tool path is translated into a detailed sequence of machine axes movement commands that will enable a CNC machine tool to produce the part. No engineering drawing is required.

The computer-generated instructions can be stored in a central computer for direct transfer to a CNC machine tool for parts manufacture as shown in figure 11-5. This is known as direct numerical control (DNC). The data also can be stored on disk for future use.

The system that makes all this possible is computer-aided design/computer-aided manufacturing (CAD/CAM). There are several CAD/CAM software programs. They are constantly being upgraded and made more user friendly.

To state it simply, CAD is used to draw the part and to define the tool path. CAM is used to convert the tool path into codes that the computer on the machine can understand.

NUMERICAL CONTROL SYSTEMS

A CNC machine consists of two major components: the machine tool and the controller, which is an onboard computer. These components may or may not be



Figure 11-6.—A typical CNC controller.

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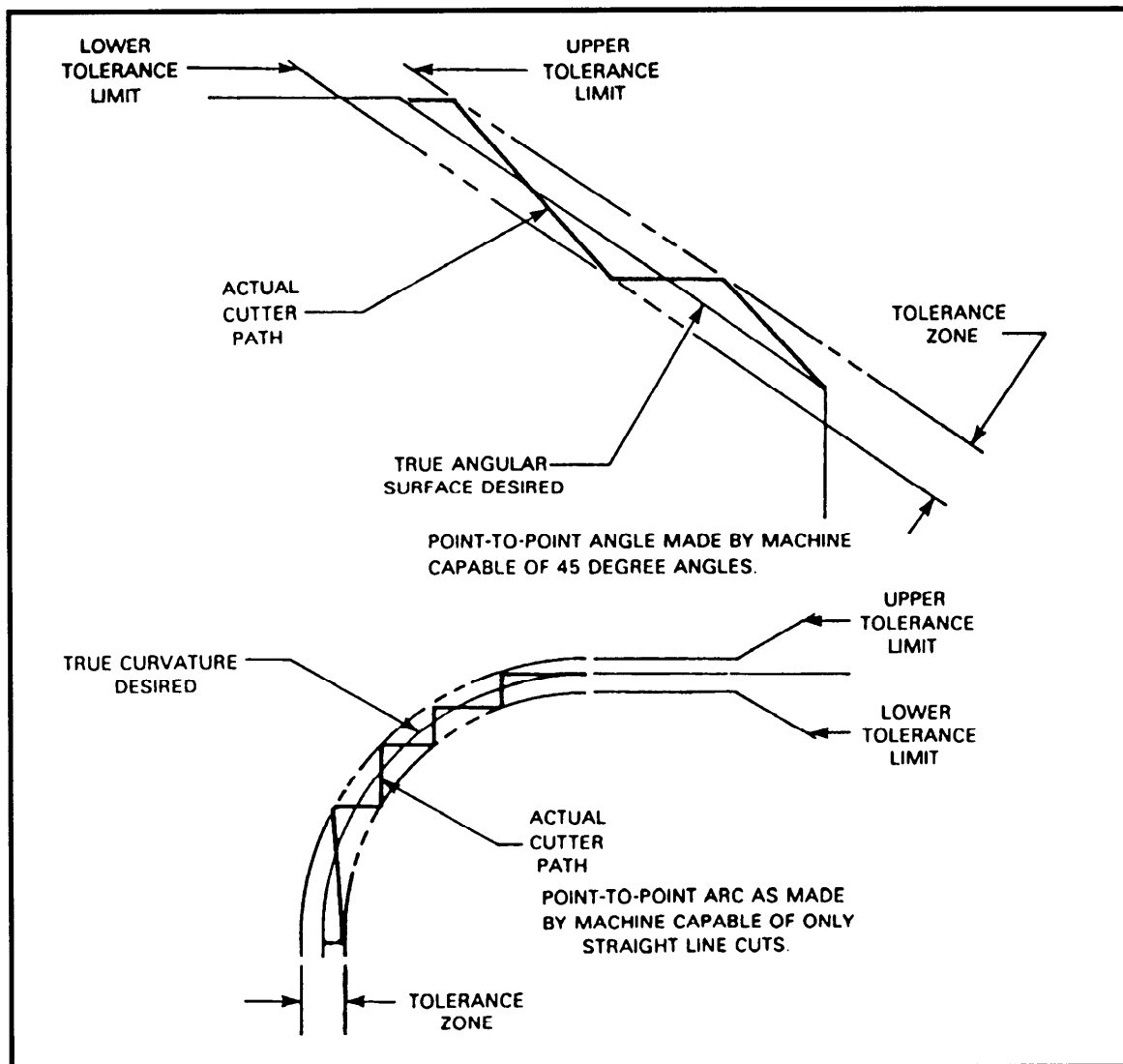


Figure 11-7.—Point-to-point angles and arcs.

manufactured by the same company. Figure 11-6 shows a typical controller. Each controller is manufactured with a standard set of built-in codes. Other codes are added by the machine tool builders. For this reason, program codes differ somewhat from machine to machine. Every CNC machine, regardless of manufacture, is a collection of systems coordinated by the controller.

TYPES OF CONTROL SYSTEMS

There are two types of control systems used on NC machines: point-to-point systems and continuous-path systems.

Point-to-point machines move only in straight lines. They are limited in a practical sense to hole operations (drilling, reaming, boring, and so on) and straight milling cuts parallel to a machine axis. When making an axis move, all affected drive motors run at the same speed. When one axis motor has moved the instructed amount, it stops while the other motor continues until its axis has reached its programmed location. This makes the cutting of 45-degree angles possible, but not arcs or angles other than 45 degrees. Arcs and angles must be programmed as a series of straight line cuts, as shown in figure 11-7.

A continuous-path machine can move its drive motors at varying rates of speed while positioning the machine. Therefore, it can more easily cut arcs and

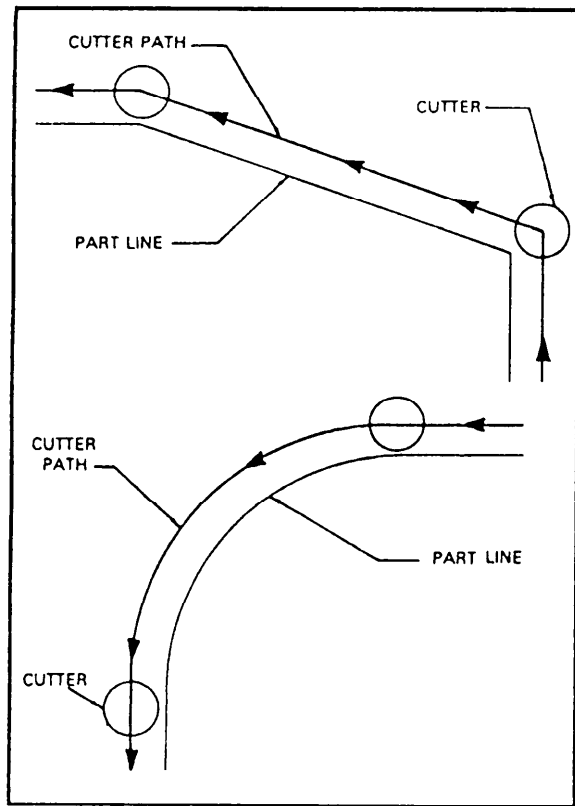


Figure 11-8.—Continuous-path angles and arcs.

angles, as shown in figure 11-8. Most newer NC machines are the continuous-path type.

SERVOMECHANISMS

It will be helpful to understand the drive systems used on NC machinery. The drive motors on a particular machine will be one of four types: stepper motors, dc servos, ac servos, or hydraulic servos. Stepper motors move a set amount of rotation (a step) every time the motor receives an electrical pulse. DC and ac servos are widely used variable-speed motors found on small and medium continuous-path machines. Unlike a stepper motor, a servo does not move a set distance. When current is applied, the motor starts to turn: when the current is removed, the motor stops turning. The ac servo is a fairly recent development. It can develop more power than a dc servo and is commonly found in newer CNC machines. Hydraulic servos, like ac or dc servos, are variable-speed motors. Because they are hydraulic motors, they can produce much more power than an electric motor. They are used on large NC machinery, usually with an electric or pneumatic control system.

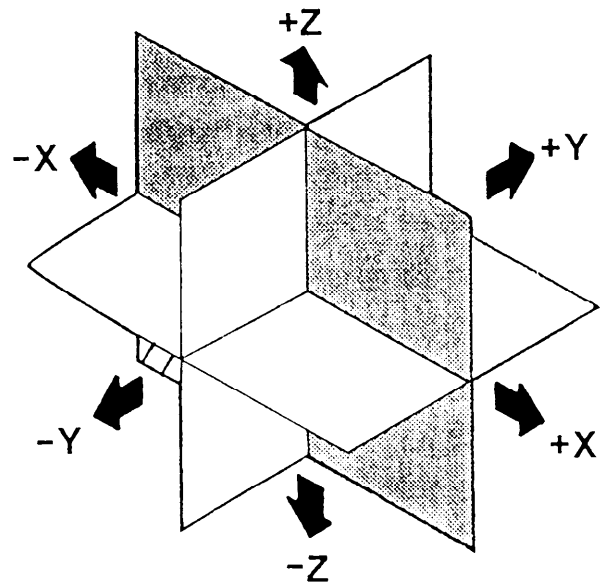


Figure 11-9.—Cartesian coordinate system.

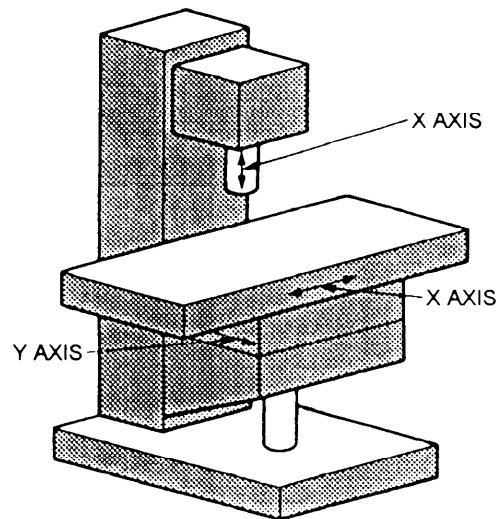


Figure 11-10.—Three-axis vertical mill.

CARTESIAN COORDINATE SYSTEM

The basis for all machine movement is the Cartesian coordinate system (fig. 11-9). Programs in either inch or metric units specify the destination of a particular movement. With it, the axis of movement (X, Y, or Z) and the direction of movement (+ or -) can be identified. Some machining centers may have as many as five or six axes, but for our purposes we will only discuss three axes. To determine whether the movement is positive (+) or negative (-), the program is written as though the tool, rather than the work, is doing the moving.

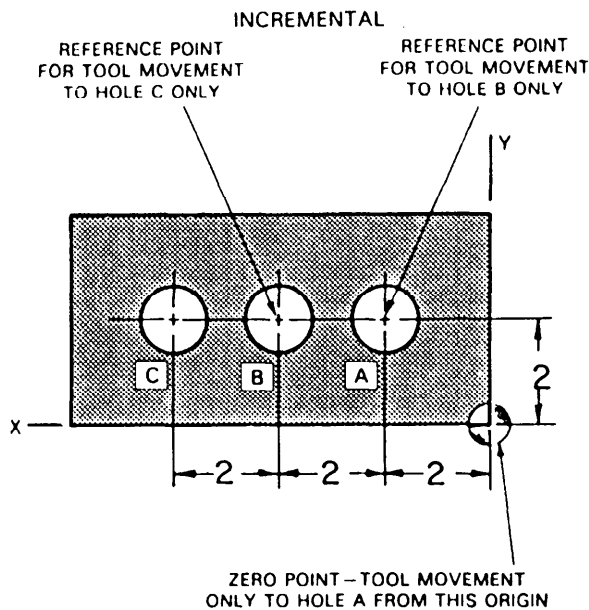


Figure 11-11.—Incremental positioning system.

Spindle motion is assigned the Z axis. This means that for a drill press or vertical milling machine the Z axis is vertical, as shown in figure 11-10. For machines such as lathes or horizontal milling machines, the Z axis is horizontal.

POSITIONING SYSTEMS

There are two ways that machines position themselves with respect to their coordinate systems. These systems are called incremental positioning and absolute positioning. With incremental positioning (fig. 11-11) each tool movement is made with reference to the prior or last tool position. Absolute positioning (fig. 11-12) measures all tool movement from a fixed point, origin, or zero point. Use absolute dimensioning where possible because a mistake on the dimensions at one point will not be carried over to the dimensions at other points. It is also easier to check for errors.

SETTING THE MACHINE ORIGIN

Most CNC machinery has a default coordinate system the machine assumes upon power-up, known as the machine coordinate system. The origin of this system is called the **machine origin** or **home zero**

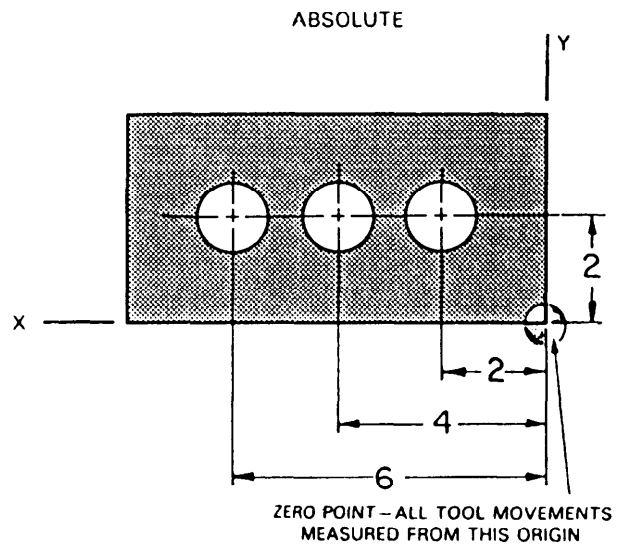


Figure 11-12.—Absolute positioning system.

location. Home zero is usually, but not always, located at the tool change position of a machining center. A part is programmed independent of the machine coordinate system. The programmer will pick a location on the part or fixture. This location becomes the origin of the coordinate system for that part. The programmer's coordinate system is called the local or part coordinate system. The machine coordinate system and the part coordinate system will almost never coincide. Before running the part program, the coordinate system must be transferred from the machine system to the part system. This is known as setting a zero point. In other words, the machine has a zero point that is already programmed into it, but you can place the part to be machined either in the chuck or on the table and establish your zero point, and then the machine will use that point as its zero point. This eliminates having to use fixtures and other complicated setups. You just put your work in the machine and by using the proper codes you tell the machine where the zero point is located.

As stated earlier in the chapter, this has only been a brief overview of CNC. It is a complicated subject that many books have been written about. To cover it completely you will need to have formal training and extensive on-the-job training. As the Navy expands into the world of CNC this training will become more readily available.

CHAPTER 12

METAL BUILDUP

CHAPTER LEARNING OBJECTIVES

Upon completing this chapter, you should be able to do the following:

- *Explain the thermal spray system.*
- *Explain contact electroplating.*

Metal buildup is a rapid and effective method that can be used to apply almost any metal to a base material. It is used to restore worn mechanical equipment, to salvage mismachined or otherwise defective parts, and to protect metals against corrosion. Compared to original component replacement costs, metal buildup is a low-cost, high-quality method of restoration.

As you advance in the MR rating you must know how to prepare a surface for metal buildup and to set up and operate the equipment used in the thermal spray systems and the contact electroplating process. In this chapter, we will briefly discuss the thermal spray systems and contact electroplating. We will not cover the actual spraying or plating processes; you will learn them in classes you need to attend before you can be a qualified sprayer or plater.

Additional information on metalizing is in MIL-STD-1687A(SH), *Thermal Spray Processes for Naval Ship Machinery Applications*.

Additional information on electroplating is in MIL-STD-2197(SH), *Brush Electroplating on Marine Machinery*.

As with any shop equipment, you must observe all posted safety precautions. Review your equipment operators manual for safety precautions and any chapters of *Navy Occupational Safety and Health (NAVOSH) Program Manual for Forces Afloat*, OPNAV Instruction 5100.19B, that apply to the equipment. Also, read the sections in MIL-STD-1687A(SH) and MIL-STD-2197(SH) that cover safety.

THERMAL SPRAY SYSTEMS

There are four different thermal spray processes: wire-oxygen-fuel spray, wire-consumable electrode spray, plasma-arc spray, and powder-oxygen-fuel

spray. All four generally perform the same basic function: they heat the wire or powder to its melting point, atomize the molten material with either high-velocity gas or air, and propel it onto a previously prepared surface. In this chapter we will discuss the wire-oxygen-fuel and powder-oxygen-fuel spray processes, with emphasis on the latter.

The rapid rate at which metal coatings can be sprayed and the portability of the equipment have increased the use of thermal spray processes. Metal coatings are especially useful to (1) rebuild worn shafts and other machine parts not subject to tensile stress, (2) apply hard surfacing that must resist wear and erosion, and (3) protect metal surfaces against heat and corrosion. Navy repair facilities use thermal spray processes to coat metallic and nonmetallic surfaces with practically any metal, metal alloy, ceramic, or cermet that can be made in wire or powder form. (Cermet is a strong alloy of a heat-resistant compound, a metal used especially on turbine blades.)

APPLICATIONS

Thermal spray coatings have been approved by NAVSEA for several applications. Case-by-case approval is not needed for the following applications, but the procedures used for these applications are limited to those approved by NAVSEA:

- Repair of static fit areas to restore original dimensions, finish, and alignment
- Repair of seal (including packing areas) to restore original dimensions and finish
- Repair of fit areas on shafts to restore original dimensions and finish (except for motor generator sets)