9 NUMERICAL CONTROL OF MACHINE TOOLS

CHAPTER CONTENTS

9.1 FUNDAMENTALS OF NUMERICAL CONTROL

Definitions

Numerical Control (NC) refers to the method of controlling the manufacturing operation by means of directly inserted coded numerical instructions into the machine tool. It is important to realize that NC is not a machining method, rather, it is a concept of machine control. Although the most popular applications of NC are in machining, NC can be applied to many other operations, including welding, sheet metalworking, riveting, etc.

Because of the introductory character of this chapter, we will restrict our discussion only to two-dimensional machining operations (e.g. turning), which are among the most simple applications of NC. Nevertheless, most of the principles and conclusions here are also valid for more advanced NC applications.

The major advantages of NC over conventional methods of machine control are as follows:

- *higher precision*:NC machine tool are capable of machining at very close tolerances, in some operations as small as 0.005 mm;
- *machining of complex three-dimensional shapes*: this is discussed in *Section 6.2* in connection with the problem of milling of complex shapes;
- *better quality*: NC systems are capable of maintaining constant working conditions for all parts in a batch thus ensuring less spread of quality characteristics;
- *higher productivity*: NC machine tools reduce drastically the non machining time. Adjusting the machine tool for a different product is as easy as changing the computer program and tool turret with the new set of cutting tools required for the particular part.
- *multi-operational machining*: some NC machine tools, for example machine centers, are capable of accomplishing a very high number of machining operations thus reducing significantly the number of machine tools in the workshops.
- *low operator qualification*: the role of the operation of a NC machine is simply to upload the workpiece and to download the finished part. In some cases, industrial robots are employed for material handling, thus eliminating the human operator.

Types of NC systems

Machine controls are divided into three groups,

❶ *traditional numerical control* (NC);
❷ *computer numerical control* (CNC);
❸ *distributed numerical control* (DNC).

The original numerical control machines were referred to as NC machine tool. They have “hardwired” control, whereby control is accomplished through the use of punched paper (or plastic) tapes or cards. Tapes tend to wear, and become dirty, thus causing misreadings. Many other problems arise from the use of NC tapes, for example the need to manual reload the NC tapes for each new part and the lack of program editing abilities, which increases the lead time. The end of NC tapes was the result of two competing developments, CNC and DNC.

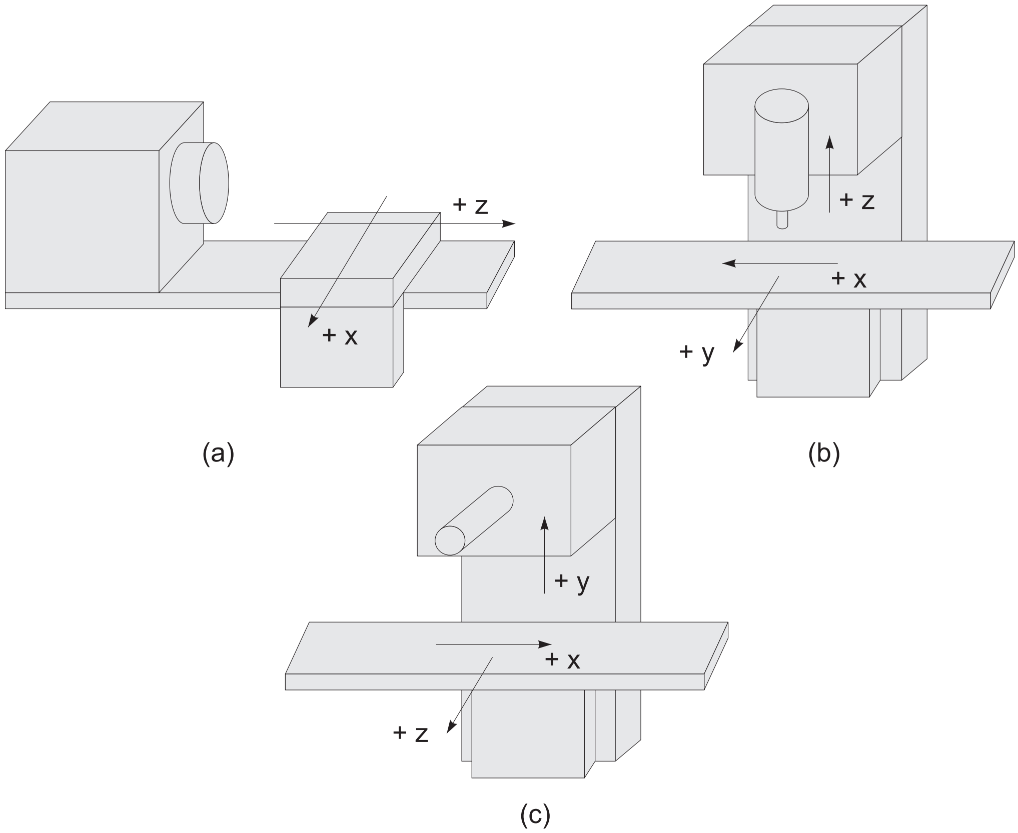
CNC refers to a system that has a local computer to store all required numerical data. While CNC was used to enhance tapes for a while, they eventually allowed the use of other storage media, magnetic tapes and hard disks. The advantages of CNC systems include but are not limited to the possibility to store and execute a number of large programs (especially if a three or more dimensional machining of complex shapes is considered), to allow editing of programs, to execute cycles of machining commands, etc.

The development of CNC over many years, along with the development of local area networking, has evolved in the modern concept of DNC. Distributed numerical control is similar to CNC, except a remote computer is used to control a number of machines. An off-site mainframe host computer holds programs for all parts to be produced in the DNC facility. Programs are downloaded from the mainframe computer, and then the local controller feeds instructions to the hardwired NC machine. The recent developments use a central computer which communicates with local CNC computers (also called *Direct Numerical Control*)

Controlled axes

NC system can be classified on the number of directions of motion they are capable to control simultaneously on a machine tool. Each free body has six degree of freedom, three positive or negative translations along x, y, and z-axis, and three rotations clockwise or counter clockwise about these axes. Commercial NC system are capable of controlling simultaneously two, two and half, three, four and five degrees of freedom, or axes. The NC systems which control three linear translations (3-axis systems), or three linear translations and one rotation of the worktable (4-axis systems) are the most common.

Five-axis machining center.



Identification of controlled axes for a lathe (a), vertical spindle milling machine (b), and horizontal spindle milling machine (c).

Although the directions of axes for a particular machine tool are generally agreed as shown in the figure, the coordinate system origin is individual for each part to be machined and has to be decided in the very beginning of the process of CNC part programming (*Section 9.2*).

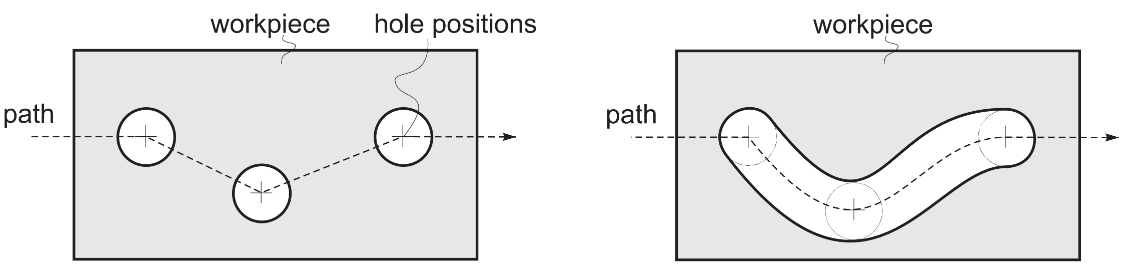
Point-to-point vs. continuous systems

The two major types of NC systems are (see the figure):

❶ *point-to-point* (PTP) system, and
❷ *contouring* system.

PTP is a NC system, which controls only the position of the components. In this system, the path of the component motion relative to the workpiece is not controlled. The travelling between different positions is performed at the traverse speed allowable for the machine tool and following the shortest way.

Contouring NC systems are capable of controlling not only the positions but also the component motion, i.e., the travelling velocity and the programmed path between the desired positions:



Schematics of point-to-point (*Left*) and contouring (*Right*) NC systems.