

# ABSTRACT

**Numerical control** technology as it is known today emerged in the mid 20th century. It can be traced the year of 1952, the U.S Air Force, and the names of John Parsons and the Massachusetts Institute of Technology in Cambridge, MA, USA. It was not applied in production manufacturing until the early 1960's. The real boom came in the form of CNC, around the year of 1972, and a decade later with the introduction of affordable micro computers. The history and development of this fascinating technology has been well documented in many publications.

In the manufacturing field, and particularly in the area of metal working, Numerical Control technology has caused something of a revolution. Even in the every day before computers became standard fixtures in every company and in many homes, the machine tools equipped with Numerical Control systems found their special place in the machine shops. The recent evolution of micro electronics and the never ceasing computer development, including its impact on Numerical Control, has brought significant changes to the manufacturing sector in general and the metalworking industry in particular.

## 1. DEFINITION OF NUMERICAL CONTROL

In various publications and articles, many descriptions have been used during the years, to define what Numerical Control is. Many of these definitions share the same idea, same basic concept, just use different wording.

The majority of all the known definitions can be summed up into a relatively simple statement:

Numerical control can be defined as an operation of machine tools by the means of specifically coded instructions to the machine control system.

The instructions are combinations of the letters of the alphabet, digits and selected symbols, for example, a decimal point, the percent sign or the parenthesis symbols. All instructions are written in a logical order and a predetermined form. The collection of all instructions necessary to machine a part is called an NC program, CNC program, or a part program. Such a program can be stored for a future use and used repeatedly to achieve identical machining results at any time.

### ▪ **NC and CNC Technology**

In strict adherence to the terminology, there is a difference in the meaning of the abbreviations NC and CNC. The NC stands for the order and original Numerical Control technology, whereby the abbreviation CNC stands for the newer Computerized Numerical Control technology, a

modern spin-off of its older relative. However, in practice, CNC is the preferred abbreviation. To clarify the proper usage of each term, look at the major differences between the NC and the CNC systems.

Both systems perform the same tasks, namely manipulation of data for the purpose of machining a part. In both cases, the internal design of the control system contains the logical instructions that process the data. At this point the similarity ends.

The NC system (as opposed to the CNC system) uses fixed logical functions, those that are built-in and permanently wired within the control unit. These functions can't be changed by the programmer or the machine operator. Because of the fixed writing of the control logic, the NC control system can interpret a part program, but it does not allow any changes that must be made away from the control, typically in an office environment. Also, the NC system requires the compulsory use of punched tapes for input of the program information.

The modern CNC system, but not the old NC system, uses an internal micro processor (i.e., a computer). This computer contains memory registers storing a variety of routines that are capable of manipulating logical functions. That means the part programmer or the machine operator can change the program of the control itself (at the machine), with instantaneous results. This flexibility is the greatest advantage of the CNC systems and probably the key element that contributed to such a wide use of the technology in modern manufacturing. The CNC programs and the logical functions are stored on special computer chips, as software instructions. Rather than used by the hardware connections, such as wires, that control the logical functions. In contrast to the NC system, the CNC system is synonymous with the term "softwired".

When describing a particular subject that relates to the numerical control technology, it is customary to use either the term NC or CNC. Keep in mind that NC can also mean CNC in everyday talk, but CNC can never refer to the older technology, described here under the abbreviation of NC. The letter "C" stands for computerized, and it is not applicable to the hardwired system. All control systems manufactured today are of the CNC design. Abbreviations such as C&C or C'n'C are not correct and reflect poorly on anybody that uses them.

## **2. NUMERICAL CONTROL ADVANTAGES**

What are the main advantages of numerical control?

It is important to know which areas of machining will benefit from it and which are better done the conventional way. It is absurd to think that a two-horse-power CNC mill will win over jobs that are currently done on a twenty-times-more-powerful manual mill. Equally unreasonable are expectations of great improvements to cutting speeds and feedrates over a conventional machine. If the machining and tooling conditions are the same, the cutting time will be very close in both cases.

Some of the major areas where the CNC user can and should expect improvement:

- Setup time reduction

- Lead time reduction
- Accuracy and repeatability
- Contouring of complex shapes
- Simplified tooling and work holding
- Consistent cutting time
- General productivity increase

Each area offers only a potential improvement. Individual users will experience different levels of actual improvement, depending on the product manufactured on-site, the CNC machine used, the setup methods, complexity of fixturing, quality of cutting tools, management philosophy and engineering design, experience level of the workforce, individuals attitudes, etc.

### ▪ **Setup Time Reduction**

In many cases, the setup time for a CNC machine can be reduced, sometimes quite dramatically. It is important to realize that setup is manual operation, greatly dependent on the performance of CNC operator, the type of fixturing and general practices of the machine shop. Setup time is unproductive, but necessary – it is a part of the overhead costs of doing business. To keep the setup time to a minimum should be one of the primary considerations of any machine shop supervisor, programmer and operator.

Because of the design of CNC machines, the setup time should not be major problem. Modular fixturing, standard tooling, fixed locators, automatic tool changing, pallets and other advanced features, make the setup time more efficient than comparable setup of a conventional machine. With a good knowledge of modern manufacturing, productivity can be increased significantly.

The number of parts machined under one setup is also important in order to assess the cost of setup time. If a great number of parts are machined in one setup, the setup cost per part can be very insignificant. A very similar reduction can be achieved by grouping several different operations into a single setup. Even if the setup time is longer, it may be justified when compared to the time required to setup several conventional machines.

### ▪ **Lead Time Reduction**

Once a part program is written and proven, it is ready to be used again in the future, even at a short notice. Although the lead time for the first run is usually longer, it is virtually nil for any subsequent run. Even if an engineering change of the part design requires the program to be modified, it can be done usually quickly, reducing the lead time.

Long lead time, required to design and manufacture several special fixtures for conventional machines, can often be reduced by preparing a part program and the use of simplified fixturing.

### ▪ **Accuracy and Repeatability**

The high degree of accuracy and repeatability of modern CNC machines has been the single major benefit to many users. Whether the part program is stored on a disk or in the computer memory, or even on a tape (the original method), it always remains the same. Any program can be changed at will, but once proven, no changes are usually required any more. A given program can be reused as many times as needed, without losing a single bit of data it contains. True, program has to follow for such changeable factors as tool wear and operating temperatures, it has to be stored safely, but generally very little interference from the CNC programmer or operator will be required, the high accuracy of CNC machines and their repeatability allows high quality parts to be produced consistently time after time.

### ▪ **Contouring of Complex Shapes**

CNC lathes and machining centers are capable of contouring a variety of shapes. Many CNC users acquired their machines only to be able to handle complex parts. Good examples are CNC applications in the aircraft and automotive industries. The use of some form of computerized programming is virtually mandatory for any three dimensional tool path generation.

Complex shapes, such as molds, can be manufactured without the additional expense of making a model for tracing. Mirrored parts can be achieved literally at the switch of a button, templates, wooden models, and other pattern making tools.

### ▪ **Simplified Tooling and Work Holding**

No standard and homemade tooling that clutters the benches and drawers around a conventional machine can be eliminated by using standard tooling, specially designed for numerical control applications. Multi-step tools such as pilot drills, step drills, combination tools, counter borers and others are replaced with several individual standard tools. These tools are often cheaper and easier to replace than special and nonstandard tools. Cost-cutting measures have forced many tool suppliers to keep a low or even a nonexistent. Standard, off-the shelf tooling can usually be obtained faster than nonstandard tooling.

Fixturing and work holding for CNC machines have only one major purpose – to hold the part rigidly and in the same position for all parts within a batch. Fixtures designed for CNC work do not normally require jigs, pilot holes and other hole locating aids.

### ▪ **Cutting Time and Productivity Increase**

The cutting time on the CNC machine is commonly known as the cycle time- and is always consistent. Unlike a conventional machining, where the operators skill, experience and personal fatigue are subject to changes, the CNC machining is under the control of a computer. The small amount of manual work is restricted to the setup and loading and unloading the part. For large

batch runs, the high cost of the unproductive time is spread among many parts, making it less significant. The main benefit of a consistent cutting time is for repetitive jobs, where the production scheduling and work allocation to individual machine tools can be done very accurately.

The main reason companies often purchase CNC machines is strictly economic – it is a serious investment. Also, having a competitive edge is always on the mind of every plant manager. The numerical control technology offers excellent means to achieve a significant improvement in the manufacturing productivity and increasing the overall quality of the manufactured parts. Like any means, it has to be used wisely and knowledgeably. When more and more companies use the CNC technology, just having a CNC machine does not offer the extra edge anymore. The companies that get forward are those who know to use the technology efficiently and practice it to be competitive in the global economy.

To reach the goal of major increase in productivity, it is essential that users understand the fundamental principles on which CNC technology is based. These principles take many forms, for example, understanding the electronic circuitry, complex ladders diagrams, computer logic, metrology, machine design, machine principles and practices and many others. Each one has to be studied and mastered by the person in charge. In this handbook, the emphasis is on the topics that relate directly to the CNC programming and understanding the most common CNC machine tools, the machining centers and the lathes (sometimes also called the turning centers). The part quality consideration should be very important to every programmer and machine tool operator and this goal is also reflected in the handbook approach as well as in numerous examples.