WAYS OF CREATING NC PROGRAMS

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This article comprises several sections that analyze the NC program designed for machine tools. The first section focuses on characterizing the program and highlights the differences between external and internal programming. In the subsequent section, the program's structure specifically tailored for the Fanuc control system is described. It delineates the distribution of words within individual commands, elucidates their structure, and expounds on their significance. Additionally, it elucidates the interpretation of individual addresses, preparatory functions, and auxiliary functions. The final section describes programming methods and provides a concise characterization of each.

KEYWORDS

NC programming, Fanuc, programming, manual programming, workshop programming, automatic programming, StepNC programming

1 INTRODUCTION

The transition from conventional machines to digitally controlled machines leads to the need to digitize the production process. CNC machines use a series of commands during a work cycle, with each word in the command having a unique role. Each piece of equipment must be equipped with a control system that controls every single step during production [Balara 2018, Duplakova 2018, Flegner 2019 and 2020, Monkova 2013, Murcinkova 2018, Baron 2016, Mrkvica 2012, Chaus 2018, Vagaska 2017 and 2021, Straka 2018a,b, Modrak 2019, Michalik 2014, Olejarova 2017].

In the first part of this article, we will explain the basic composition of the NC program. In the second part, we will briefly present the structure of the program for the Fanuc control system.

2 DEFINITION OF NC MACHINE PROGRAMMING

Under the terms NC machine, we can imagine a machine whose all work steps are controlled using a program created for a given machine control system and for a given unique component [Rimar 2016, Panda 2011a,b, 2012, 2013, Jurko 2011, 2012, 2013, Valicek 2016, Duplak 2011, Sedlackova 2019, Kurdel 2014, Kurdel 2022, Labun 2017 and 2019, Pollak 2019 and 2020, Svetlik 2014, Zaloga 2020, Zaborowski 2007].

Such a program contains all the information necessary for the production of the given part.

Programming includes two areas of activities and concepts:

- External processing,
- Internal processing.

ISO G-codes are most often used for programming NC and CNC machines [Sorocin 2022].

2.1 EXTERNAL PROCESSING

The preparation and processing of the machining program can take place directly on the machine tool using the control system or outside it using a simulation program.

Several types of information are required to set up a machining program, which can be divided into the following categories:

- Geometric: describe the machining geometry, i.e. the path of the tool relative to the workpiece,
- Technological: they describe the machining technology, i.e. they characterize all the operations that the machine must perform, Auxiliary: they describe the organization of machining, i.e. they characterize all the auxiliary functions necessary for the proper functioning of the program.

2.2 INTERNAL PROCESSING

All entered information is coded in the control system and transformed into individual control pulses. These impulses are subsequently sent to individual movement mechanisms that execute the given command. After executing a given command, they send feedback to the comparison member. This series of commands is repeated until the actual position of the tool is identical to the programmed value [Sorocin 2022].

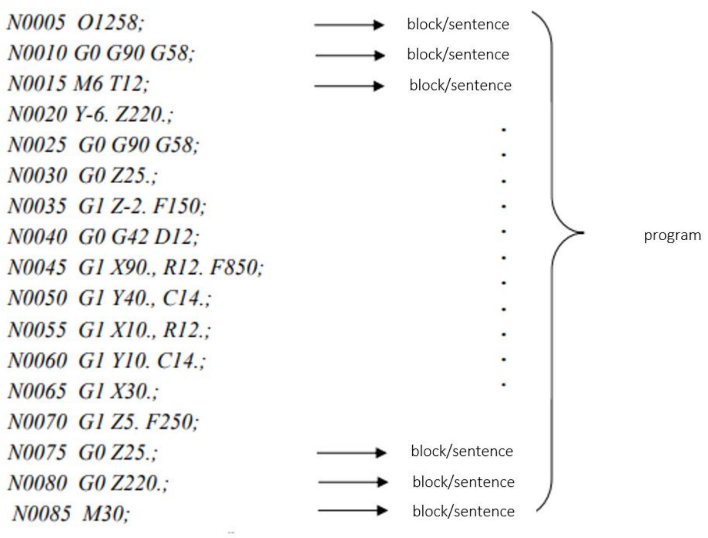

Figure 1. Structure of a numerically controlled machine program

3 PROGRAM STRUCTURE FOR CS FANUC

Figure 1 shows the program structure of a numerically controlled machine. Each full program intended for CS must be separated from other programs at the beginning and end. In CS Fanuc, the beginning and end of the program is marked as follows:

- The beginning of the program marked with the capital letter "O" and the program number (e.g. O1234),
- The end of the program is determined by the auxiliary function code "M30".

The program code itself is composed of individual blocks (sentences), while the blocks themselves are composed of words. Each block is terminated by a semicolon (";"). Each block starts with a unique number, which can only occur once in each program.

Each word in the program block consists of two parts:

- Adress part,
- Meaning part.

Figure 2 shows the block structure of a numerically controlled machine.

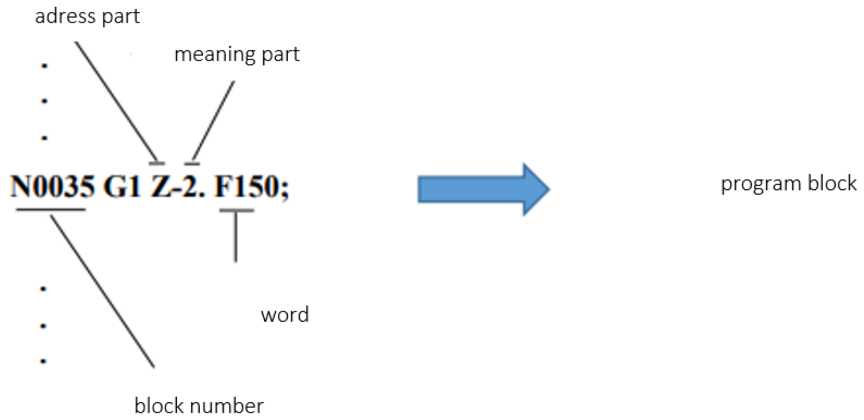

Figure 2. Sentence structure of numerically controlled machine

We divide the words in the program into:

- Dimensional,
- Dimensionless.

The meaning part of dimensional words is a physical quantity; therefore they have a physical dimension:

- Shift in the direction of the axes X, Y, Z, U, V, W, I, J, K, R,
- Rotation around axes A, B, C,
- Spindle speed S,
- Feed F.

4 MEANING OF ADDRESSES FOR NUMERICALLY CONTROLLED MACHINES

Table 1 shows the list and meaning of the most frequently used addresses for numerically controlled machines.

Table 1. List of most frequently used addresses

Address	Meaning
A	Angular dimension around the X axis.
B	Angular dimension around the Y axis.
C	Angular dimension around the Z axis.
D	Position number in the tool radius correction table.
F	Feed rate function.
G	A preparatory function.
H	Position number in the tool length correction table.
I	Incremental distance between the center of the tool and the center of the produced hole in the X axis.
J	Incremental distance between the center of the tool and the center of the produced hole in the Y axis.
K	Incremental distance between the center of the tool and the center of the produced hole in the Z axis.
L	Unspecified/ older types of control systems number of repetitions for the subroutine.
M	Auxiliary function.
N	Block number.
O	Marking the beginning of the program.
P	Number of repetitions for the subprogram, depth of cut in µm when cutting threads.
Q	Depth of cut for the drilling cycle with flushing.
R	The size of the radius of the radius for circular interpolation.
S	Spindle speed function.
T	Tool function.
U	Incremental dimension in the X axis.
V	Incremental dimension in the Y axis.
W	Incremental dimension in the Z axis.
X	The dimension of the primary movement in the X axis.
Y	The dimension of the primary movement in the Y axis.
Z	The dimension of the primary movement in the Z axis.

5 PREPARATORY FUNCTIONS

Preparatory functions, so-called G-codes (geometric functions), together with the coordinates, form the so-called content part of the program. The codes G01, G02 and G03 are most often used to change the position of the tool during machining. Table 2 lists the most frequently used G-codes along with their meaning.

Table 2. List of the most frequently used G-codes

Code	Meaning
G00	Fast forward function.
G01	Linear interpolation (advance of the tool along the segment).
G02	Circular interpolation (moving the tool along a circle in the clockwise direction).
G03	Circular interpolation (moving the tool in a circle counter-clockwise).
G17	Definition of the plane for the X-Y axes.
G18	Definition of the plane for the X-Z axes.

G19	Definition of the plane for the Y-Z axes.
G54-G59	Definition of coordinate systems (definition of the starting position of the coordinate system of the manufactured part).
G90	Absolute method of entering coordinates (intersection of axes does not change its position).

6 AUXILIARY FUNCTIONS

Auxiliary functions, so-called M-codes (miscellaneous functions) have the form of logical functions and control the functions of the machine. The basic functions are the same for all control systems, but others may differ depending on the manufacturer of the control system. Table 3 lists the most frequently used M-codes along with their meaning.

Table 3. List of the most frequently used M-codes [Michalik 2016]

Code	Meaning
M03	Spindle start on the right.
M04	Spindle start on the left.
M05	Spindle speed stop.
M08	Program activation of cooling.
M09	Program shutdown of cooling.
M30	End of program.

6 WAYS OF PROGRAMMING

Perhaps the most important criterion for creating an NC program is the shape complexity of the manufactured part. Other criteria include:

- Level of programming skills of the programmer,
- Frequency of production,
- Level of production equipment [Sorocin 2022].

Currently, the following methods of creating NC programs are most often used:

- Manual programming,
- Workshop programming,
- Automatic programming,
- Step NC programming.

6.1 MANUAL PROGRAMMING

The basic way of programming is manual programming. This programming is the foundation for other programming methods (except Step programming). The result is a program created by programmers without any support of supporting programs. Programming takes place directly in the relevant G-code.

When manually creating an NC program, the following procedure must be followed:

- Studying the production drawing of the part (can choose another technology),
- The method of clamping, the tool used,
- The zero point "M" of the workpiece is selected, the coordinates of the transition points of the curves are calculated,
- The drawing is adjusted for the required programming method,
- Cutting conditions are calculated for individual sections of operations,
- The production process will be compiled,
- A program sheet is compiled with data transformed into program code,
- This is followed by a simulation phase, with the use of which the possibilities of errors in the program are minimized,
- Verification - debugging of the program on the machine - production of the first part [Michalik 2016, Sorocin 2022].

6.2 WORKSHOP PROGRAMMING

Use suitable only for simple component shapes. Unlike manual programming in simulation program, workshop programming is carried out directly on the machine tool v dialog window of the CNC machine control system. Preset functions of the machine are used (e.g. drilling, reaming, pocket milling...), in which only the machining parameters (speed feed, revolutions, depth, ...). After entering these values, the program generates its own cycle, which already are not 2-digit G-codes. To increase machining accuracy, the program generates 4-digit G-codes.

Figure 3 shows the working window of cutting conditions for a CNC milling machine.

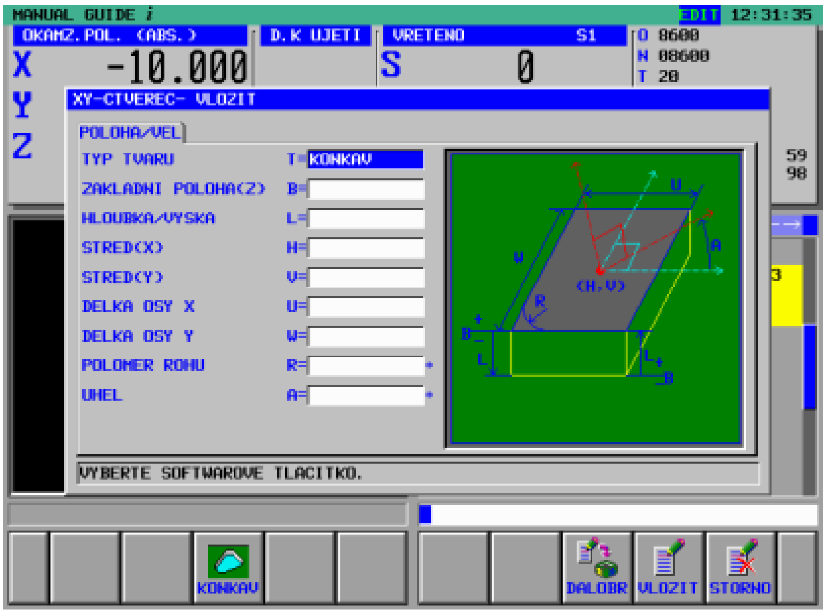

Figure 3. Working window of cutting conditions for a CNC milling machine [Michalik 2016, Sorocin 2022]

As mentioned above, this programming is only suitable for creating simple part shapes. The following problems can occur when programming more complex shapes:

- It is not possible to clearly define a semi-finished product, which may not always be block (milling), or cylinder (turning),
- Work with a real cross-section, forging, casting,
- In some systems it is possible to import the blank from external CAD systems but then there is a duplication of functions, complexity and thus lack of transparency of the program, system,
- In most cases, it is not possible to determine the beginning and end of machining, i.e. moving and moving the tool to cut [Michalik 2016, Sorocin 2022].

Figure 4 shows the working window of cutting conditions for a CNC lathe.

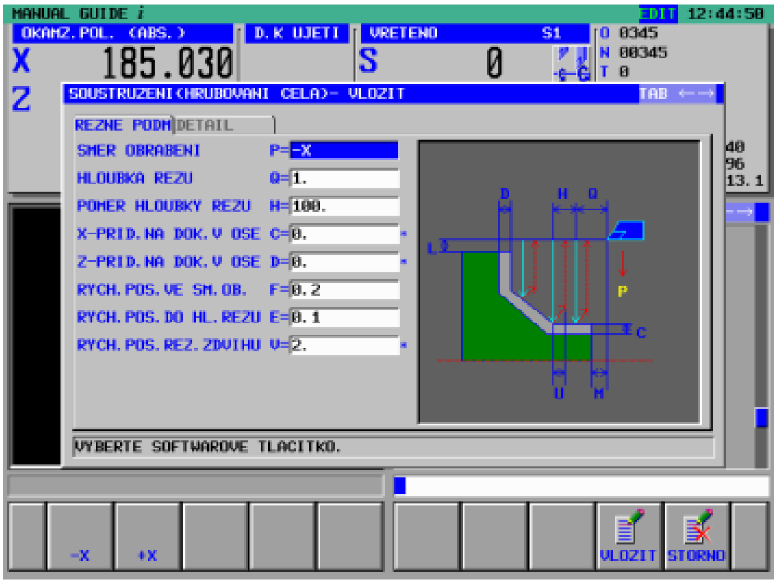

Figure 4. Working window of cutting conditions for a CNC lathe [Michalik 2016, Sorocin 2022]

6.3 AUTOMATIC PROGRAMMING

One of the modern methods is automatic programming. This method is possible easily create programs for the production of shapely complex parts, as manual or workshop programming these parts would be relatively demanding on experience and skills programmer [Sorocin 2022].

Thanks to the use of CAM programs, these requirements are eliminated. The principle of this method consists in utilization CAM programs. When using simulation, you can, among other things, use production simulation, which we will remove possible production collisions and therefore save time when debugging the program directly on the machine [Sorocin 2022].

Examples of some applications for CAM programming:

- Autodesk Inventor CAM,
- ProE, Catia, SolidWorks,
- Work NC, Unigraphics,
- Metallurgy,
- Alpha CAD/CAM,
- Edge CAM, Master CAM,
- Esprit [Michalik 2016, Sorocin 2022].

6.3.1 NC PROGRAM CREATION PROCEDURE

Each programmer has his "own" procedure for creating a program. In principle, however, the process of NC creation program consists of the following steps:

- Creating a model in any CAD application, "name.part",
- Using the CAM superstructure - generation of CL /Cutter Location Data/
- Using a suitable post-processor (for a specific control system) generating NC program with G codes,
- Entering the program into the control system of the CNC machine tool [Michalik 2016, Sorocin 2022].

6.4 STEP NC PROGRAMMING

STEP-NC for machine tools is a programming language that extends the ISO 10303 STEP standard with model for machining in the ISO 14649 standard. Supplements information about the part with geometrical information dimensions and data required for control obtained from CAM software. It is supplemented by the STEP PDM model for integration into the broader agenda of the structure of production. The combined result was standardized as ISO 10303-238 (also known as AP238).

Step NC programming is designed to replace ISO G-codes.

7 CONCLUSIONS

In this article, we explored various aspects of the NC program designed for machine tools. The first section was aimed to characterize the program and emphasized the disparities between external and internal programming. Subsequently, the article delved into the program's structure, specifically customized for the Fanuc control system. It provided a detailed analysis of the word distribution within individual commands, elucidating their structure and highlighting their significance. Furthermore, it shed light on the interpretation of individual addresses, preparatory functions, and auxiliary functions. Lastly, the article discussed different programming methods and offered a brief yet informative characterization of each approach. Thus, we defined the NC program, described the structure of the preprogram for CS Fanuc and described the methods of creating NC programs.

By examining these aspects, this article contributes to a deeper understanding of NC programming for machine tools.

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