Aspects Regarding the Motion Possibilities of a CNC Multifunctional Machine-Tool

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\textbf{Abstract:} This paper presents some theoretical aspects related to the numerical command of the machine-tools and also it presents as application, a machine-tool which has a multifunctional character because it allows the accomplishment of several cutting operations, on the same machine, due to its large number of axes which are numerically commanded and do to suitable equipment of the machine with tools and devices which are specific to the cutting operation which is to be done.

\textbf{Key-Words:} machine-tool, numerical command, multifunctional, numeric axes, cutting operations.

1 Introduction

The automation of a machine-tool, after a numeric program, means the command of the machine on the base of numbers. This mean that all the information which must be transmitted to the machine in order to process a certain part, are numerically determined, and the machine-tool will “understand” the language of these numbers and based on them, it achieve the processing of the part, automatically, without the intervention of the human operator.

“Numeric” presumes that the input data are numbers. These are represented in binary code and can be directly processed by the controller. The numbers have to be introduced in order to describe the part geometry (trajectory’s data) and the technological specifications related to the tools and work speeds and other parameters.

2 Numerical command of the machine tools

A machine-tool is formed by the machine itself and the numerical command equipment. The CNC equipments of the machine-tools are available in a large number, being conceived after the principle of numerical commands of positioning or of shape. The CNC equipments are mainly used for cutting operations and for electroerosion. Any machine-tool accomplish motions, function to some axes, which are specific to each of them.

The correct determination of the axes is very important for the CNC machines, because the program will consider those axes. In the numerical command area, the axis represents a linear or rotational displacement.

The coordinate axes are assigned to various guides by certain rules, as follows:
- Z axis is parallel to the axis of the main shaft of the machine. Thus, at drilling or milling operations, the main shaft is actuating the tool while at turning operation, Z axis coincides with the axis of the part.
- The positive direction of Z axis corresponds to the movement which increases the distance between the piece and tool.
- X axis is generally horizontal and parallel to the settlement surface of the part. It is the main axis of motion in the plane in which the piece is positioned over the tool.
- Y axis is chosen to form together with the others an orthogonal system.

The getting of the motions is done by moving part or by the displacement of the tool.

The programs of a CNC machine - tool consist of a series of codes that define the phases of processing of a part. A program consists mainly of phrases that are written in a logical sequence. Each phrase is composed of more CN words. A word is composed of an address followed by a group of numbers. Address defines memory or execution circuit, from the control unit, that needs to get command and the group of numbers defines the control.
3 Information required by the program of a CNC machine

Information that are contained by a program and which are from the drawing of the part and from the technological file, are classified in geometric, technological and auxiliary information [2].

3.1 Geometrical information

Through this type of information there are transmitted to the machine-tool data regarding the direction of displacement and the position in which the tool reaches and / or the weight of the machine tool.

They are information related to the shape of the part, so they are data that determine the trajectory of the point, line or area of action between the tool and the part, at its processing. This information is determined by the design engineer.

In order that numerical equipment can command the starting of a motor by which they can be achieved some motions (linear and / or circular) there is necessary that the motions be identified. At the identification of these motions, they are taken into account both geometrical and the physical support. The physic support of the displacement is represented by the guide elements of the machine and the geometric one by the type of motion: linear or circular. Any direction of motion, linear or circular, which can be achieved by the mobile controlled elements of the machine-tool, is called the axis. These axes on a machine tool can be totally or partially numerically commanded.

Geometric information transmit to the CNC machine-tool data related to the direction and sense of displacement, and also the size of these displacements. Any relative displacement, after a specific direction, is positive if the motion is done in the positive sense of that axis and negative if it is to the contrary.

On the modern equipments they can be programmed not only the coordinates, but also some other geometrical information related to the length compensation of the tools’ diameters. With this information, they can be corrected, from the exterior of the program, the coordinates from the magnetic band, function to the length or diameter of the tool.

3.2 Technological information

They are information related to the processing technology, through which to reach the desired shape of the part: the cutting regime parameters (cutting speed or main shaft speed, feed rate, cutting depth), the tool number, its type, the individual work sequence of phases. These data are determined by the technological engineer on the base of the execution drawing.

Information with technological character are programmed by specific addresses followed by a group of numbers. Thus, using such address it can:

- command the selection of a certain tool coded in a shop tool and specify, if there is need, the existence of a tool adjustment;
- Control the rotation f the head of the port tool in order to bring the necessary tool in the work position;
- Signs need to change a tool in case of a machine without a tools shop.

3.3 Auxiliary information

Besides the technological and geometric information, in order to command a machine-tool equipped with a CNC system, they are needed also other information, known as ancillary information.

By such categories of information they are encoded commands for starting and stopping the main shaft, for determining the direction of rotation, the cycle of processing (turning, threading, drilling, etc.), the mode of cooling, etc.

Another category of information allows encoding the way of displacement (absolute or incremental), the type of interpolation, the programming system (point to point or shape), different stops, etc.

This information, in numerical command, is represented by addresses. These addresses are used in numerical control unit in order to prepare the machine tool to execute a particular type of operation, in a certain way, by certain axes.

The generation of the surface of a part on a machine-tool is accomplished by relative displacements between tool and part. Depending on the shape of generator and directory curves, the relative motion involves the execution of two or more motions of the machine elements (sliding elements, supports, tables) after different directions (the coordinate axes of the machine).

4 Multifunctional CNC machine-tools with large number of axes

Present paperwork presents like application in domain of machine tools with numerical control a multifunctional machine with large number of axes, numerically controlled [1].

Multifunctional machine, in the basic concept developed, have a complex structure, modular, and composed by 8 axes numerically controlled, with possibility to choose any axis like principal movement axis together with inter-correlation of relative motion between two, three, or more axes, depending on kinematics of surface that needs to be generated [1]. In the same time, there is the possibility that some of the axes, grouped in two, with identical movement, can be synchronized.

Below is presented general kinematics scheme of multifunctional machine for the representative structure chosen (Fig.1).
Fig. 1. General kinematic scheme

Legend:
- M1, M2 – main motor to drive part tool
- Mx1, Mx2 - advance motor on X axis with encoder
- My1, My2 - advance motor on Y axis with encoder
- Mz1, Mz2 - advance motor on Z axis with encoder
- Sbx, Sby, Sbz – ball circulating screw for advance axes X, Y, Z
- gx, gy, gz – linear guides for axes X, Y, Z
- Sx1, Sx2 – advance slide plates on X axis
- Sy1, Sy2 – advance slide plates on Y axis
- Sz1, Sz2 – advance slide plates on Z axis
- C1 – resilient coupling on principal motor
- C2 – advance slide plates on Z axis
- C1 – resilient coupling for advance axes motors

From technical point of view, multifunctional machine is build such as, on machine cradle, on the same guide ways oriented after X axis there will be mounted two longitudinal slide plates CNC controlled which can move individually and/or concomitant with keeping some pre-determined force between them.

Each of these longitudinal slide plates is equipped with a transversal slide plate oriented after Y axis, CNC controlled, and these can move individually and/or concomitant with keeping some pre-determined force between them.

Z axis is perpendicular to OXY and will intersect X axis at half distance between extreme limits of longitudinal slide plates, and origin point of machine reference system, O, is located at intersection of Z axis with XZ plane. On Z axis there are placed two slide plates: one superior, above plane XY, and one inferior, below this plane, each of them being equipped with one machine tool shaft, preferable milling shaft (superior shaft, respective inferior shaft)

The two vertical slide plates, CNC controlled, can move individually and/or concomitant with keeping some pre-determined force between them. Also, axes of the two shafts are coaxial, and speeds independent.

At this basic structure, other accessories are added, needed to make needed machining operations in normal and optimal conditions (supports for turning tools, slotting-toothing tools, rolling tooling, milling-toothing-grinding tooling, reducing gear, amplifying gear, tooling for profiling and grinding wheel sharpening, lathe chuck, index head, spindle sleeve, running centre – rotary and fixed – plus different parts clamping tooling’s.

Basic structure slide plates and supplementary one drive together with rotation of one of the shafts – superior or inferior – are realized in CNC, resulting more moving axes droved simultaneously, on which we add specific command for each process, done through computer.

Moving of principal shaft together with longitudinal and transversal slide plates is realized with the motors (M1, M2, Mx1, Mx2, My1, My2, Mz11, Mz12, Mz21, Mz22) and screw-nut systems (Sbz, Sby, Sbz).

Machine is equipped with a CNC command with large number of axes, which allows: production of wide range of machining, large diversity of surface type’s generation, optimal principal axis choosing for processing type needed.

Principal motors will have a continuous variable speed with frequency changers. Advance axes motors will be driven through numerical command, to synchronize kinematics chains depending on surface processed.

5 Conclusion

By equipping the CNC multifunctional machine-tool with different accessories and tools, it allows the accomplishment of various operations: turning, milling, drilling, boring, mortising, toothing, helicoidally or cylindrical interior and exterior rectification. All the operations, due to the machine, can be supervised and controlled by the numerical command and by the program which is specific to each operation.

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