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THEORETICAL ASPECTS CONCERNING SURFACE MACHINING WITH NUMERICALLY CONTROLLED MACHINE TOOLS

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Abstract: *This paper represents a study about numerically controlled machine tools and utilization of tools on these machines. Obtaining very good precisions and smallest roughness requires high performance both on machine side and on cutting tools with their fixing devices. In the paper is presented also, like application, a new virtual concept of multifunctional machine tool with large number of axis.*

Key words: *machine, tool, multifunctional, CNC, surface, machining.*

1. INTRODUCTION

In the centre of all technical, economical and managerial actions that industrial companies do to respond successfully to demands of reactivity, flexibility, competitiveness and tenacity, imposed by economical environment more and more complex and with increasing level of incertitude, are machine tools.

Along time, these evolved, today machine tool being a complex system formed by mechanical parts, fixed or mobile, analogical or numerical command, by satellite or voice, information's acquisition and processing, automatic loading/unloading of parts and tools, self-adaptation to external or internal variables, defects diagnose and automatic repair, forecasted maintenance, etc.
Is necessary to use a new high performance machine tool, capable to do machining of all surface type that we meet on parts, and to bring contribution to cycle time reduction. This requires building multifunctional high productivity machine tools, equipped with modularized elements, universal and specialized, ho can allow quick adaptation to various machining requirements [5].

2. ASPECTS REGARDING THE COMPLEX SURFACES

For majority of parts commonly used, possibilities of surface generating on basis of generator and cinematic directory are enough [4].

In actual conditions though, by using of computer aided design and numerically controlled machine tools, high complex shape parts machining, that cannot be done just by using the combination of the two curves, is becoming possible.

This surfaces have generator curves, that cannot be expressed analytically, or, if they are, will allow surface generation only with significant errors and non-economical in most cases, due to high complexity of expression.

These surfaces are known today as complex surfaces, which by the origin of complexity can be divided in functional complex surfaces, technological complex surfaces and esthetical complex surfaces.

The functional ones have complex shapes that need to fulfil some functional requirements, and technological ones represents in fact stages in final realization of the product.

Esthetical complex surfaces are provided to improve the aspect of the product, especially in automotive industry, commercial electronics, light industry, etc.

3. GENERALITIES ABOUT CNC MACHINE TOOLS

A numerically controlled machine tool is made from machine tool itself and CNC equipment. Because of this, machine tools with CNC are manufactures by collaboration of more companies, some building the classical side, others being specialized in numerical command side [3].

CNC equipments of machine tools have a large range of diversity, being built after the principle of numerical command for positioning or contouring.

CNC equipments are used mainly at following machine tools category: milling machines; drilling machines; turning machines; grinding machines; wire electro-erosion machine; pressing centres. At those is adding machining centres and some non-conventional machines such as electrical discharge machining, chemical erosion machining, plastic laminators, plasma machining.

From manufacturing programmer point of view there are some important characteristics of CNC equipments: number of axis, program keeper; memory for program storage; program input method; possibilities to adapt to a connection with an external memory, obtained precision.

Any machine tool accomplishes movements, function of some axes specific to each of them. The correct setting of the axes is very important in the CNC machine- tools; because the program takes account of these axes. In the numerically command, it was introduced the axis notion, as being a linear displacement or a rotation. These movements are accomplished by the mobile parts of the CNC machine. Theoretically, there is the general case, with 3 axes of translation (X, Y, Z) and 3 axes for rotation (A, B, C) around the three axes of translation. In this case, we have a machine with 6 axes. If the whole assembly is fixed on a support, which also can accomplish

movements, then it is considered a machine with 7, 8 or 9 axes. These machines are very complex and usually, they are designed for a certain purpose. The machines which are found practically have usually 2-5 axes, most of them having 2 or 3 axes.

The axes for linear movements form a system with orthogonal coordinates which verify the right hand rule. The coordinate's axes correspond to various guides after certain rules, as it is following:

- *Z* axis is parallel with the axis of the machine's main shaft. In this way, at a drilling machine or a milling machine, the main shaft trains the tool, but at a turning machine, *Z* axis is the same with the part's axis. If the machine doesn't have a main shaft, *Z* axis will be chosen perpendicularly on the part surface. The positive sense of the *Z* axis corresponds to the displacement by which the distance between part and tool is growing.
- *Z* axis generally is horizontal and parallel with the part surface. It is the main axis for displacement in the plane in which there is made the positioning of the part function of the tool.
- *Y* axis is chosen so to form together with the others an orthogonal system, which can be determined with the right hand rule of physics.

Rotations can be: *A*-rotation around the *X* axis, *B*-rotation around axes *Y*, *C*-axis rotation around *Z*. The movements obtaining is done by moving the part, either by moving tool. Movement means both translation and rotation.

Generally not all the axes of a CNC machine are numerically commanded. Often there are controlled two or three axes. In some complex centers of processing and milling machines, the number of controlled axes can reach up to 6 (3 translations and 3 rotations.

Any motion made by the CNC machine relates to a reference orthogonal system. Origin is the point where $X = 0$, $Y = 0$, $Z = 0$, respectively $A = 0$, $B = 0$, $C = 0$. Choice of origin is arbitrary, both for the axes of translation and the rotation axis. The origin of reference system which is associated to the machine tool has the name of the machine zero point.

On a CNC machine, the zero point represents a fixed and well established in space point, in the same time with the traductors assembling and machine testing, meaning all of the settings in numerical command. From this point there is displaced the work piece on the machine. The machine itself, the coordinate axes and the zero point are actually a rigid system from geometric point of view, with a good set axes system.

Any part that is to be processed, firstly must be positioned function to the rigid coordinate system of the machine ($O_mX_mY_mZ_m$) or absolute system and then it must be identified the point where the processing starts (the start point). But the program is written function to a reference system of the part ($O_pX_pY_pZ_p$), called also relavive system, which is chosen by the programmer. This system is related to the absolute system of the CNC machine tool through a position vector. This operation is called the part positioning and it has as effect the transformation of the parts coordinates from the system ($O_pX_pY_pZ_p$), in the system ($O_mX_mY_mZ_m$) by a translation accomplished automated by the CNC machine.

In the programming practice, the first step that must be done is the chosen of the part relative system ($O_pX_pY_pZ_p$). This system is chosen in such of way that the tool displacements determination is done as easy is possible considering the part drawing. Other criteria would be the ways of positioning the work-part on the machine table.

For the spatial parts it must be settled also the plane $Z = 0$. This chosen is very important because in the planes which are parallel with the plane ZOY takes place the displacements for the tool positioning, and an error in the program could lead to an accidentally touch of the part by the tool. As a preventing issue, it is indicated that the plane $Z = 0$ be chosen on a plane surface, at the highest altitude (in case that the main shaft is vertical).

The programs of the CNC machines are formed with a succession of codes which define the processing steps of a part. A program is mainly made from phrases which are written in a logical succession. Each phrase is composed by some NC words. A word contains an address which is followed by group number. The address is defining the memory or the execution circuit from the command unity in which it must reach the command and the number group is defining the command.

The information which a program must contain and which is coming from the part drawing and technological sheet could be classified in geometrical, technological and auxiliary information.

The geometrical information transmits to the CNC machine data related to the direction and sense of displacement and also the size of these displacements. All the equipments have the possibility of displacement in absolute or relative coordinates. On the modern equipments there can be programmed, excepting the coordinates, also other geometrical information related to the length and tools' diameters compensation.

The information regarding the part shape presents those data which determine the trajectory of the point, line or surface of the action between the part and tool. This information is known as geometrical data.

The information about the processing technology is those which lead to the wanted shape: the parameters of the cutting regime (cutting speed or the main shaft rotational speed, the advance sped, the cutting depth), the tool number, its type, the individual work phases' succession. These data are called technological data.

4. THE USAGE OF THE TOOLS ON THE CNC MACHINE TOOLS

The obtaining of some dimensional and shape high precisions, and reduced roughness, in the conditions of high productivity, is conditioned both by the machine performances and cutting tools and devices which are used for their fixing.

The efficient usage of the CNC machines id addicted by the rational choosing of the cutting tools, because:

- the processing precision depends also by the positioning precision and by the rigidity of the tools which are used;
- the processing productivity is function of the tools quality reflected by their cutting capacity;
- the accomplishment of a various number of operations requires proper tools (Fig. 1 [2]).

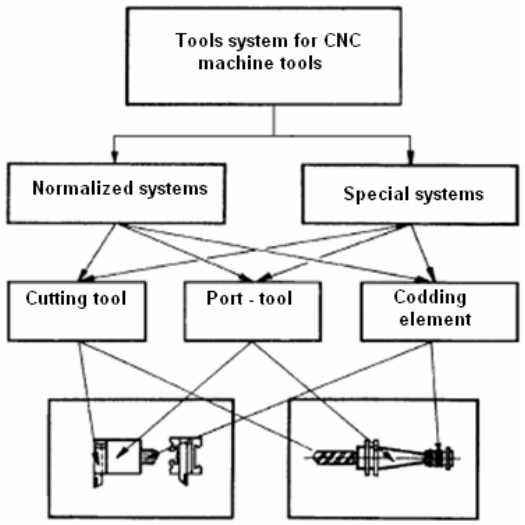

Fig. 1. Tool systems for CNC machine tools.

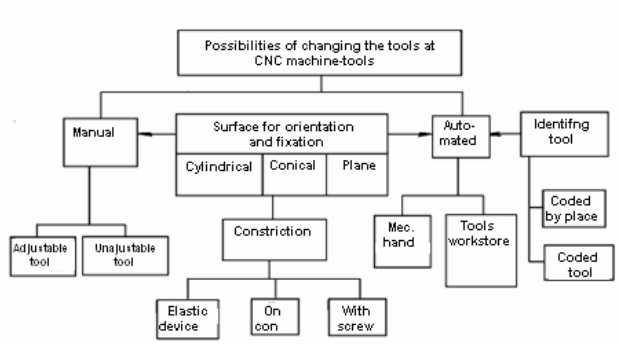

Fig. 2. Representation of the possibilities of changing of the tools at CNC machines.

Some of the NC machines' particularities, for instance: automated tools changing (at the processing centres), the tool usage compensation, the usage of the tools which were set before, etc., lead to the unitary treatment of the tools, port-tools and coding possibilities.

From the Fig. 2 [2], it can be noticed that except the constructive and geometrical characteristics, for the tools with automated changing, there must be predicted their codification and adjutancy way (axial or radial).

From the analyze of the system it can be observed that the precision and the rigidity of the tools are dependent to the number and the type of the used port-tool, by the shape and length of queues tools, and the duration and the precision of the adjustment is function to the and the type of the port-tool and also to the type of the device for adjustments.

The creation of some systems of tools for the CNC machines tools allow that using a minimum number of elements change, to serve as many machines.

The whole tool system is composed of the following elements: tool; port-tool; coding elements.

The tool is to remove the additional processing in the form of chips, in the process of generating the surfaces. The port-tool serves to catch the cutting tool on the machine-tool, to determine its position towards the piece of work in accordance with the scheme of cutting and technological process established, in order to determine the settling of the tool on the machine or external to the machine and for the tool displacement in the workshop.

The tools which are used on CNC machine-tools together with the port-tools related, must meet some special requirements:

- *High stiffness.* An increased stiffness, allows high accuracy of shape and dimensions of the parts processed only to the extent that the tool- port-tool – part and device system complies with this condition.
- *High cutting capacity at high cutting speeds.*
- *Ensure to eliminate easily the chips*. An important issue is to ensure an easy removal and fragmentation of chips from the working edge tool.
- *Simplicity of construction.* This goal is achieved by using a minimum number of components; using plane or rotational surfaces in the construction of the cutting side and of the position-fixing side; the adoption of constructive solutions to enable rapid and convenient replacement of the plates changed.
- *Interchangeability and the possibility of rapid changeability*. The rentability of a CNC machine depends to a large extent, by the minimizing or even eliminating unproductive times. In this context, the choice of cutting tools can lead to significant savings. The choice must lead to build a limited set of tools that are used regardless of the form and nature of the surface material which is to be processed, with the condition that this restriction to not affect the cutting.
- *Sharpening and control with precise devices.*
- *Short times for the previous setting.*

5. NEW CONCEPT OF MULTIFUNCTIONAL MACHINE WITH LARGE NUMBER OF AXIS

This paper is based on the development of a new concept of achievement of a CNC multifunctional machine-tool, for processing as turning, milling, boring, mortising, toothing, plane, exterior and interior cylindrical and helicoidally rectification [5].

This machine (Fig. 3.) allows the processing of cylindrical parts, which have the length/ diameter rapport ~ 5 and small diameters, diameters smaller than 200 mm for turning operations, and process the parts with dimensions less than 600×600 mm, with h = 500 mm for milling, drilling, boring, mortising, toothing, plane, exterior and interior cylindrical and helicoidally rectification.

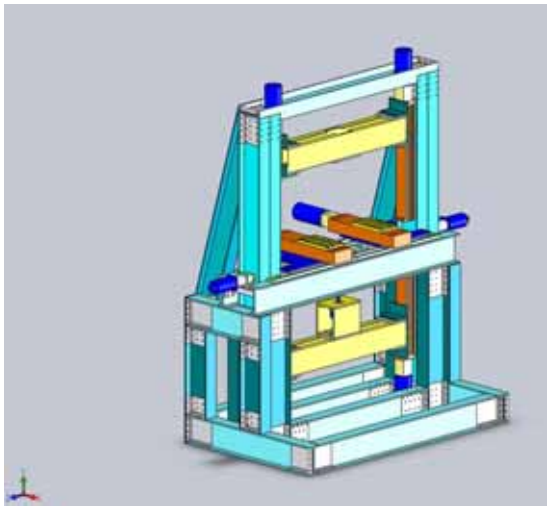

Fig. 3. Multifunctional machine with large number of axis [5].

From technological point of view, the multifunctional machine will be made in such of way so that, on the machine's frame, on the same guides oriented on the *X* axis, there will be displaced two longitudinal sliding elements, which are CNC commanded and which can individually or/and concomitantly move, but keeping a certain preset force between them.

Each of these longitudinal sliding elements are equipped with a transversal sliding element, which is *Y* axis oriented, CNC commanded, and these sliding elements can individually or/and concomitantly move, but keeping a certain preset force between them. *Z* axis will be perpendicular on *XY* plane. On Z axis, there will be displaced two sliding elements: a superior one above the XY plane and an inferior one, below this plane, each element being equipped with a machine-tool shaft, preferential is a milling shaft. The two vertical sliding elements, CNC commanded, can individually or/and concomitantly move, but keeping a preset force between them. Also, the axes of the two shafts are coaxial and the angular speeds are independent. At this base structure, they can be also added other accessories which are necessary for the normal and optimal development of the wanted technological operations. The actuation of the sliding elements from the base structure and from the supplementary structure and also at least the rotation of the inferior or superior shafts is accomplished in CNC, resulting more motion axes simultaneously actuated, to which there are added the command of each process, made by the computer.

The configuration methodology of the new concept of multifunctional machine starts with the representative parts' study, respectively of their specific surfaces, and the assurance of the possibilities for these surfaces' generation.

Those surfaces can be obtained by processes as turning, milling, drilling, and rectification. The processing processes necessary for such of parts will determine the constructive and kinematics configuration of the multifunctional machine, which means it can be obtained any type of surface of the part, without transferring the part to another machine-tool.

At the conceiving of this machine-tool, there are determined the structural elements considering the flexibility, modularisation, adaptability and multifunctionality criteria. Also, from kinematical and functional point of view, there are important aspects related to the cutting process, respectively the process parameters required by the various types of surfaces, dimensions, etc.

The diversity of the parts which are to be processed is very large, but it can be made a grouping of these on part types, function of the constructive functional and processing technology characteristics as follows: shaft, prismatic, bushing, flange, lever, plate, bearing, type, housing, and gear type [1].

Table 1 [5] presents a division of the parts in classes and types. To each class corresponds a process's type.

Table 1

Parts classification in the machine building [5]

Class	Type
Housing	- Turning, welding parts - Parts of high complexity - Covers - Shaped plates
Shafts	- Smooth and full shafts and in steps - Tubular shafts; turn shafts, cam shafts, eccentric shafts - Shafts with flanges, with gears, and with shaped surfaces
Cave cylinders (bushing)	- Of simple shape - Complex shapes, with shaped interior and exterior surfaces - With thin walls
Disks	- Simple, with think walls; gears; piston rings
Levers	- Beams; straight or curved levers
Small parts with complex shape	- Heads; - Connectors; - Shaped parts
Fixing parts	- From bars; from wire coils

6. CONCLUSIONS

The achievement of a CNC machine does not suppose only the attachment of the numerical command equipment at the conventional machine, but also there is need to come up with some new constructive solution.

The achievement of CNC machines allows the reducing of the auxiliary times because of the increasing of the positioning speed, of the automation of the cinematic chains which are auxiliary to the work cycle programming, and also because of the automated change of the tools function to the various technological operations.

The multifunctionality of the machine-tool leads to the costs reduction, by the acquisition of one machine instead of at least three machines: turning machine, milling machine and rectification machine and due to the reduction of the costs with the fabrication preparation. The new performant machines, capable to process the parts' surfaces and which should contribute to the processing cycle time reducing. Many advantages are offered by the machine-tools with high productivity and which are multifunctional and equipped with modularized, universal and special elements, which allow the rapid adaptation at the various processing needs.

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