CONSIDERATIONS REGARDING THE COMPLEX SURFACES PROCESSING BY USING CNC MACHINE TOOLS

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Abstract. This paper represents a study in the CNC machine-tools' area and on the complex surfaces processing, using these kind of machines. The paper also is based on the development of a virtual model for a CNC multifunctional machine, with large number of axis, for cutting operations. A modular structure, with 8 axis, which is meant to satisfy the requirements of a large processing area, leads to an original new machine with a high performances and a high economical efficiency but also very complex by the integration of some mechanisms and kinematics structures of high complexity. The processing axes combination, the possibility to use various types of tools, the usage of some intelligent gripping and fixing systems, the sensors' integration, CNC command and active control, seen in adaptive and modular way, allow to the new concept of multifunctional machine to generate complex geometrical surface, surface which is required by the part's functionality.

Keywords: CNC machine, complex surface, cutting operations

1. Introduction

In the methodology of configuration for a new machine tool concept, is starting from a study of representative parts, respectively specific surface of those parts and assurance of possibilities for generating the surfaces.

Respective surface can be machined by methods like turning, drilling, milling, grinding. Machining methods required for such types of parts will determine constructive and cinematic configuration of the machine, in a way that we can obtain any type of surface without transferring the part to another machine tool. In machine tool structure design is recommended to establish the structural elements based on criteria of flexibility, modularity, adaptability and multifunctionality. From cinematic and functional point of view are important also aspects related to cutting process, like parameters of cutting conditions required for multitude of surface types, dimensions, etc.

Nowadays, a machine tool is 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.

It 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

2. Aspects concerning the CNC machines and the flexibility property

Nowadays, the performance criteria are fundamental, and system flexibility is a gained internal attribute when there are created the conditions for the company to be able to adjust production without great efforts, producing the products in the required quantities, the required time, the cost imposed by market, at the level of quality set by the rules and contract conditions.

Flexibility represents the ability of a machine/ technological system to adapt quickly (in minimum time) to different production tasks. It can be appreciated that the large series products' manufacture is characterized by a reduced flexibility. Switching to the manufacture of a product to another one, takes long time and high training costs. Manufacturing productivity is however very high.

The manufacture of the small series products on classic machine-tool are characterized by reduced flexibility. Switching to the manufacture of a product to another one is achieved with big consumption of time and money. The manufacturing productivity is reduced.

In order to reduce the disadvantages of the classic small manufacture, there was introduced the flexible automation. Flexible Automation refers to machines-tools with numerical commands, equipped with high capacity tools' stores, grouped into cell lines and flexible systems in which robots and industrial manipulators are indispensable elements [2].

The automation of a machine tool, after a numeric program, means its command based on numbers. These suppose that all the information (geometric and technological information), which have to be sent to the machine, at a part processing, are numerically expressed and the machine tool have to understand the meaning of these numbers and on their base to make the part's processing, automatically, without the human operator intervention.

As it can be noticed in figure 1, the numeric command equipment (NCE) is attached to the conventional machine tool (CMT). This make possible that the same machine (turning machine, milling machine, boring machine) be attached to different numeric command equipments, which are made by different producers, but which accomplish that machine's functions.

The numeric command equipment has as components an electronic board and traductors to measure the real displacement of the mobile elements of the machine (sliding elements, tables, supports) after different coordinate axes.

The information introduced by the NC program are transmitted and processed by the electronic board and then are provided to the electric or electro-hydraulic equipment of the conventional machine which accomplish the suitable commands towards the work circuits and the auxiliary ones of the machine tool. On the other side, the information regarding the real displacement of the machine's elements are provided by the traductors, for displacement measure, by the inverse connection, which compares the real displacement with the programmed one, the movement stopping when the two values are the same.

The achievement of a CNC machine tool doesn't suppose only the attachment at a conventional machine tool of the numeric command equipment, but also there is necessary to comes up with constructive solutions towards it, and those should lead to the equality between the precision and productivity performances of the machine and the performances given by the numeric command equipment.

At the mechanical processing of a part, on a machine tool, there is necessary to provide to the machine some work information:

- Information about the shape of the part, which are those data which determine the trajectory of action point, line, or surface, between the tool and part which is to be processed. These information are named geometric data;
- Information towards the processing technology, which lead to the wanted shape: the cutting regime's parameters (the cutting speed or the main shaft speed, the advance speed, the depth of cutting), the tool number, its type, the individual work steps succession. These data are named technological data.

The surface generation of a part on a machine tool is achieved by the relative movement between the part and tool. Function of the shape of the generator and directory curves, this relative movement suppose the accomplishment of two or more movements of the machine's elements (sliding elements, tables, supports) after different directions.

Any machine tool accomplishes some movements function to some specific axes. The correct determination of axes is very important because the program takes account these axes. In the numeric command there was introduced the axis notion as being a linear or rotational movement. These movements are done by the mobile elements of the CNC machine.

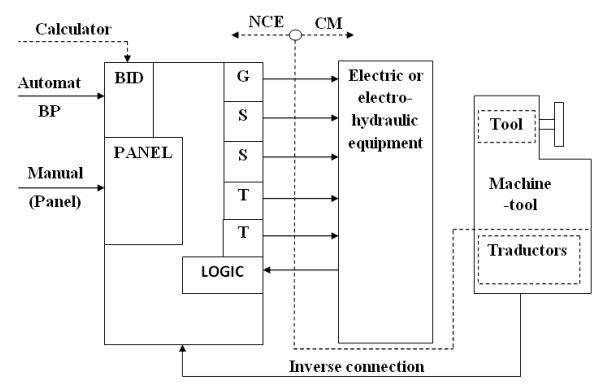

Figure 1. Numeric command machine structure [5]

3. Representative parts used in machine building industry

In the methodology of configuration for a new machine tool concept, is starting from a study of representative parts, respectively specific surface of those parts and assurance of possibilities for generating the surfaces.

Respective surface can be machined by methods like turning, drilling, milling, grinding. Machining methods required for such types of parts will determine constructive and cinematic configuration of the machine, in a way that we can obtain any type of surface without transferring the part to another machine tool. In machine tool structure design is recommended to establish the structural elements based on criteria of flexibility, modularity, adaptability and multifunctionality. From cinematic and functional point of view are important also aspects related to cutting process, like parameters of cutting conditions required for multitude of surface types, dimensions, etc.

The diversity of the parts which can be processed is huge, but they can be grouped function of their type, function of their constructive and functional characteristics and o the processing technologies as the following: parts of shafts type, parts of bushing type, prismatic parts, parts of flange type, parts of leverage type, parts of board type, part of bearing type, parts of disk type, parts of case type and, gear wheels [4].

Shaft type parts. The shafts accomplish the function of support of the components which are in rotation movement and the function of transmission of the motion and of the power between the parts that they sustain. They are requested at bending and torsion.

Constructive types of the shafts are various. Thus, they are used trim shafts, unilateral and bilateral steps shafts, shafts with groves, cross holes, wedge channels. The surfaces that need to be processed in shafts can be: cylindrical, conical, front, holes for centring, supplementary details (releases, holes, chamfers, fillets, channels) (figure 2). The processing accuracy of the shafts is determined by the functional conditions of these and also by the set adjusts.

For the trim shafts processing there is need to achieve centring holes, which are considered as the main sitting and fixing base of the shafts. For centring, they must be firstly milled the frontal faces from the shafts' ends, and then they are made holes for centring with protection cone.

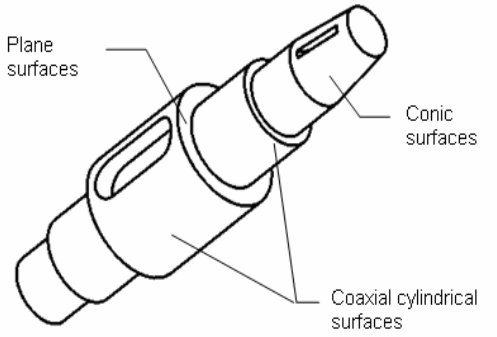

Figure 2. Representative surfaces of the shafts

Sometimes, the shafts are meant with plane surfaces, having specific functional role.

Analysing the component surfaces, it results the processing processes: cutting, milling and centring, rough and finishing turning, milling of the key groove, threading, grinding. The machining of this type of parts in serial production imposes the usage of multifunctional machine tools, which should ensure the processing accomplishment in two work places.

Bushing type parts. In the next picture (figure 3), there are presented two bushing type parts, with or without collar, and there are evidenced the surfaces types which are to be processed.

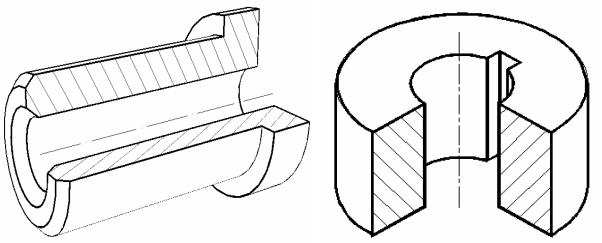

Figure 3. Bushing type parts

A technological problem, specific to the bushing processing, is the one of ensuring the concentricity of the internal surface with the external one, and also the perpendicularity of the frontal surfaces on the symmetry axes of the internal surface. This requirement can be resolved by processing the external and internal surfaces and a frontal surface with only one catch. Bushings can be provided with internal grooved surfaces. The processing of the grooved bushings with a medium complexity of external surfaces is indicated to be made on CNC machine tools, multi tools, depending also on the production type.

Prismatic parts. From constructive point of view, the geometrical shape and parts' dimensions are various (figure 4).

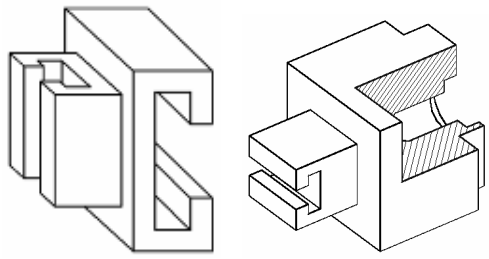

Figure 4. Prismatic parts

The main characteristic of these parts is that they have relatively large plane surfaces, disposed in parallel, perpendicular or under various angles one with each other and various bores, whose axes are also disposed at various angles.

Flange type parts. The flanges have a central bore and assembling holes, which are smooth or threaded and circularly ordered. Sample pieces with flanges are represented in the figure below (figure 5), highlighting the types of surfaces that can be processed by turning or milling and drilling.

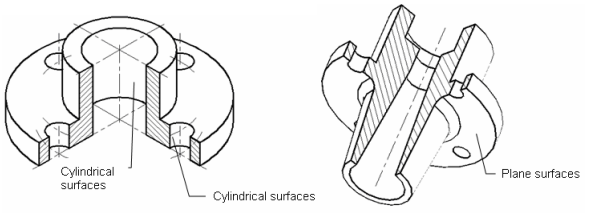

Figure 5. Flange type parts

Switching to another constructive form of the same class, involves the rapid reconfiguration of machine tools, which means it is characterized by a high degree of flexibility.

Leverage type of parts. The parts from this class have various shapes, function of the functional role in the assembly from where they belong. They are provided with flat, cylindrical or profiled surfaces (figure 6) to ensure fixed or movable links with shafts or axes, imposed by the functional and position conditions.

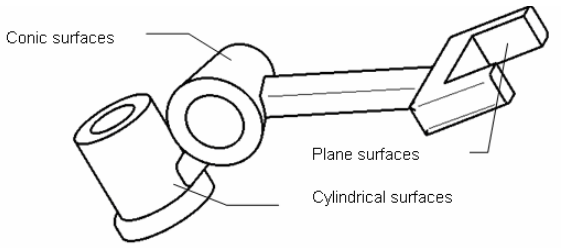

Figure 6. Surfaces for the leverage type parts

The variety of the geometric and dimensional configuration and also of the operational conditions require the use of several technological processes, which means the use of machine tools with high degree of universality, flexibility and productivity, especially in case of series production.

Board (plate) type parts. The basic feature of these parts lies in that the plane surfaces are arranged parallel, perpendicular or under different angles from each other and for different bores for bushings, bearings, etc. The next figure (figure 7) presents examples of plate-type parts.

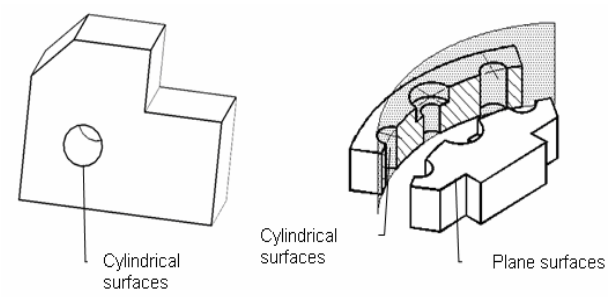

Figure 7. Board type parts

Bearings type parts. The bearings are in a great variety (Figure 8), shape and dimension, serving as supports for shafts and axles, and having as roles the reception and transmission of the tasks on the machine body. They allow movement of rotation or translation, maintaining the relative position of surfaces in contact.

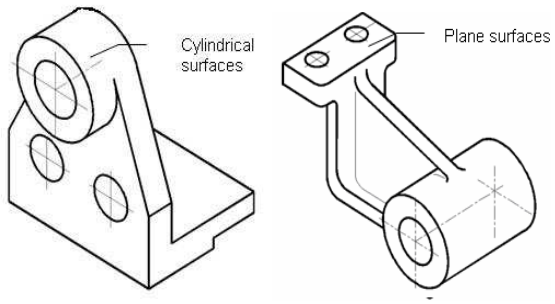

Figure 8. Bearing type parts

It must be ensure the coaxiallity of the internal and external surfaces. The processing of the bore is recommended to be done in one higher precision step, with a quality of the surface.

Disk type parts. In the group of disk type parts, there are included the parts which have the ratio between length and diameter smaller than the unity. As shape and size disks are very diverse: cylindrical, conical gears, belt wheel, flywheel, turbine disks, wheels of wagons, etc. Disks can be with or without blocks, with unilateral or bilateral blocks, symmetrical or asymmetrical, with pierced or stuffy bore.

Case type parts. The main characteristic of the cases (figure 9), from functional point of view, is to ensure a determined accuracy of the relative position of parts and mechanisms of assembly units, both in static and in the operation.

The cases take over the loads to which they are subjected during the operation of various organs of machines, ensuring a smooth operation by the vibration dissipation.

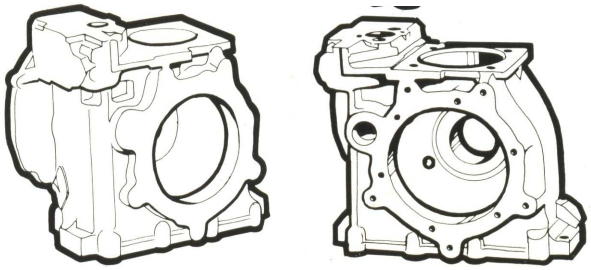

Figure 9. Case type parts

The groups of processed surfaces for most of the case type parts are:

- External plane surfaces which partially constitute the main bases and are surfaces of secondary importance, serving in this case for assembling of parts such as covers for the visiting holes etc;
- The surfaces of the main bores for the important elements from the viewpoint of the unit assembly operation to which the case belongs (bores for the shafts' bearings, the cylinders of the engines or compressors, the bores of the rotating element of the pumps etc);
- Surfaces, generally cylindrical – with or without thread - which are used for assembling other parts to the considered case or for its assembling on the machine or equipment to which it belongs (cylindrical or oblong holes for the screws' crossing, holes for centring studs, threaded holes for screws).

For most of the parts which are normally used, the possibilities of generating surfaces on the base of generator and directory curves are enough [1].

At present, however, using the computer aided design and the machine tools with numerical control becomes possible also the realization of parts with complex surfaces, which can not be achieved only by combining the two curves.

These curved surfaces have generator curve, which either can not be expressed analytically, either this expression is very complex and it only allows obtaining surfaces with very large errors, and in most cases very non-economic. These surfaces are known today as complex surfaces, which according to the complexity origin, are divided into functional complex surfaces, complex technological surface and complex aesthetic surfaces.

The functional ones have complex shapes, which must meet certain functional requirements and the technological ones actually represents stages in the final making of the product [3]. Complex aesthetic surfaces are provided to improve the appearance of the object, especially for the automotive, consumer electronics, light industry, etc.

4. New concept of multifunctional machine with large number of axes

The configuration methodology of this new concept [4] of multifunctional machine starts with the representative parts' study, respectively of their specific surfaces, and the assurance of the possibilities for these surfaces' generation.

The machine, (figure 10), 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 600x600mm, with h=500mm for milling, drilling, boring, mortising, toothing, plane, exterior and interior cylindrical and helicoidally rectification.

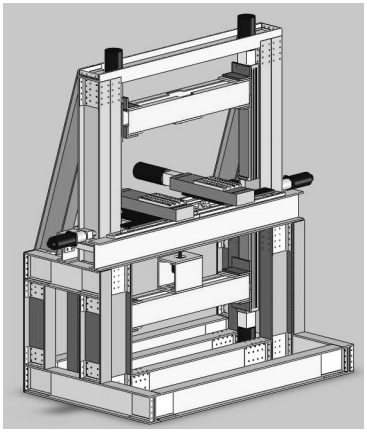

Figure 10. Multifunctional machine with large number of axis [4]

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 and will intersect the X axis at the middle of the distance between the extreme limits of the longitudinal sliding elements, and the origin point of the machine's reference system, O, will be found at the intersection of Z axis with 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, there can be also added other accessories which are necessary for the normal and optimal development of the wanted technological operations (supports for the turning knifes, for the mortising-toothing knifes, for the rolling device, for the milling-toothing-rectification device, angular speed demultiplier, angular speed multiplier, device for shaping and acute the rectification stone, turning universal and fixe and rotational tops sets). 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 machine is equipped with a CNC system with large number of axis, which allows: the achievement of a various types of cutting processing, the generation of a very large diversity of surfaces, practically unlimited, the determination of the main optimal axis for the processing type which is need to be accomplished at that moment. The structure with 6 sliding elements and 2 main axes, impose the achievement of an unusual frame, which has to allow the intersection of the movements of these sliding elements and also the facile access of the human operator in order to assembly and to set the tools and the parts which are to be processed.

In order to obtain a multifunctional machine with a minimum necessary complexity, its main structure contains only the movements which are common to the operations which are mentioned above. Other movements specific only to certain operations, are accomplished by equipping the machine with other specific devices. The synchronization of all these movements, in order to obtain the wanted surfaces, is achieved by the CNC command in correlation with proper software programs.

5. Conclusions

In the machining process of various types of surfaces, many benefits are offered by the machine tools of high productivity, with multifunctional character, equipped with modularized elements, universal and specific, allowing rapid adaptation to various processing needs.

The processing axes combination, the possibility to use various types of tools, the usage of some intelligent catching and fixing systems, the sensors' integration, CNC command and active control, seen in adaptive and modular way, allow the generation of complex geometrical surfaces, surfaces which are required by the part's functionality.

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.

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