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# VIRTUAL MACHINE FOR PROCESSING OF CUTTING TOOLS

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***Abstract**: In the first part of the paper are presented the basic stages that define the structure of the machine. It is studied the machine's destination, as following: the generation of the cylindrical or conical helical spatial surfaces, with different profile shapes. These shapes are personalized for cutting tools of type: cylindrical mills with helical teeth and helical drills. For the processing stage it is considered the technological rectification process with disk type cutting tools. In the paper are also presented the machine's adjustment parameters, generation motions and the link between the form of generating profile and that of the generated surface. In the final part of the paper are presented some results of the virtual machine's utilization: the form and the numerical definition of the generated surfaces, the adjustment's imprecision influence for the form and for the cutting tool's position.*
***Key words**: virtual machine tool, generating profile, generated surface, coordinate system, machine tool setting value.*

## 1. INTRODUCTION

The exactingness concerning the building and the exploitation of the cutting tools in the durability limits, the cutting productivity and costs did as the cutting edges processing to be a case of generation for complex surfaces. The diversity and the destination of the cutting tools are determined in the stages: calculus, design, technology, control etc., to constitue a preoccupation as much for the producers of processing cutting tools machines and for those who are using them. For the design purposes, the actual theories concerning the generation of the geometric surfaces [1], [2] and [3] are well covering the interest area. A shortcoming of the actual theories is that usually there are defined theoretical surfaces without abbots and not the real ones. In the generation process on machines appear deficiencies in the determination of the machine's adjusting parameters influence for the form of real surfaces. In the purpose of decreasing these deficiencies there is established a new generation approach, presented in the papers [4], [5], [6] and [7]. That approach is described afterwards.

## 2. THEORETICAL ASPECTS

The basic elements of generating a curve are briefly presented in figure 1, where $T$ represents the cutting edge placed in its initial position ($T_0$), at the moment $w$ ($T_w$) and at the moment $w+\Delta w$ ($T_{w+\Delta w}$), P – the piece, [$S_T$] – the topographic area, $M_w M_{w+\Delta w}$ – the fragment generated on surface [$S_T$] by the cutting edge, between the moment $w$ and the moment $w+\Delta w$, $S_P$ – the coordinates system attached to the piece. In the analyzed case this has one of the axes, as axis of rotation couples of the machine. The cutting edge ($T_0$) is in the following parametric equation:

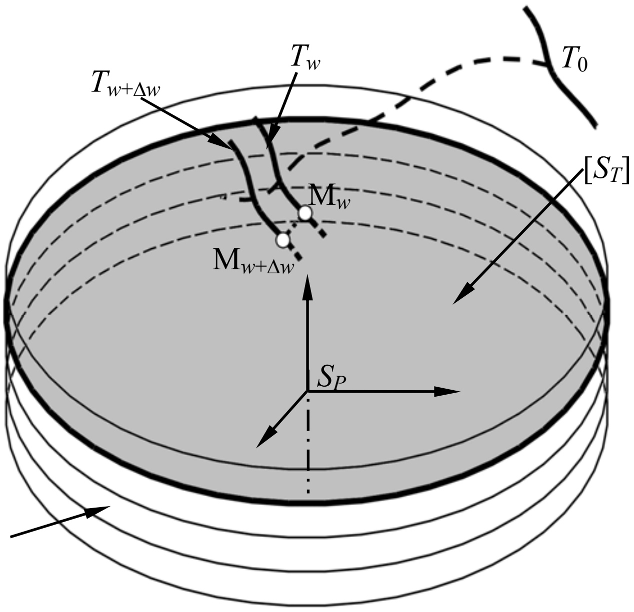


**Fig. 1.** *Generation elements of topography part*

$$\begin{cases} x_t = x_t(u) \\ y_t = y_t(u), \\ z_t = z_t(u) \end{cases} \quad (1)$$

where $u$ is the parameter.

There are considered the machine's coordinates systems, with the axis oriented on the kinematic couple's directions. Also, it is defined the transformation and moving matrix (2) of the coordinates systems under this form:

$$\begin{cases} x_p = x_p(w, x_t(w), y_t(w), z_t(w)) \\ y_p = y_p(w, x_t(w), y_t(w), z_t(w)), \\ z_p = z_p(w, x_t(w), y_t(w), z_t(w)) \end{cases} \tag{2}$$

in which: $x_i$, $y_i$, $z_i$, represents values of the translation along the axis $x$, $y$, respectively $z$, of the coordinate system $S_i$, regarding the coordinate system $S_{i-1}$; $M_1$, $M_2$, $M_3$ … $M_n$ shows the transformation between systems (if $M_i$ is $tx$, representing the translation along the axis $x$ of the coordinate system $S_i$ regarding $S_{i-1}$, respectively if $M_i$ is $rz$, representing the rotation around axis $z$ of the coordinate system $S_i$ regarding $S_{i-1}$). Also, $F_1(w)$, $F_2(w)$, $F_3(w)$ … $F_n(w)$ are parametrically ($w$), defining the motions along the indicated axis by the element from the respective line of the 4th column (e.g. if $M_i$ is $tx$, $F_i(w)$ will define the translation motion along the axis $x$ of the coordinate system $S_i$ regarding $S_{i-1}$, respectively if $M_i$ is $rz$, the rotation motion will be defined around the axis $z$ of the coordinate system $S_i$ regarding $S_{i-1}$).

The topographic surface $[S_T]$ is defined by the coefficients $A, B, C, D$ of the following equation:

$$A \cdot x_p + B \cdot y_p + C \cdot z_p + D = 0. \tag{3}$$

The transformations imposed to the equations (1), by the application of matrix (2), drives to obtaining the parametrical equations of the generated curve, in the form:

$$\begin{bmatrix} x_1 & y_1 & z_1 & M_1 & F_1(w) \\ x_2 & y_2 & z_2 & M_2 & F_2(w) \\ x_3 & y_3 & z_3 & M_3 & F_3(w) \\ \ldots & & & & \\ x_n & y_n & z_n & M_n & F_n(w) \end{bmatrix} \tag{4}$$

The generated curve (4) is composed by segments ($M_w M_{w+\Delta w}$) and belongs to the topographic surface (3).

## 3. THE STRUCTURE OF THE MACHINE

The studied sharp tool cutter machine is built by the WALTER company. It has 6 axes in its structure, numerically commanded (X, Y, Z, A, B, C) and other 3 axis manually driven

(X`, Z`, D). The axis notation is made with respect to the WALTER standard. The generation programs are supplied by the company and can not be modified by user, which has access only to the program's parameters. The manufacturer has only the task to choose the tool and the adjusting level for different elements of the machine. The necessary time for determination of the machine's parameters of a specified tools type is notably long and requires specially financial efforts. After the disposal on the machine of the translational and rotational kinematic couples (fig. 2), the coordinate systems are placed.

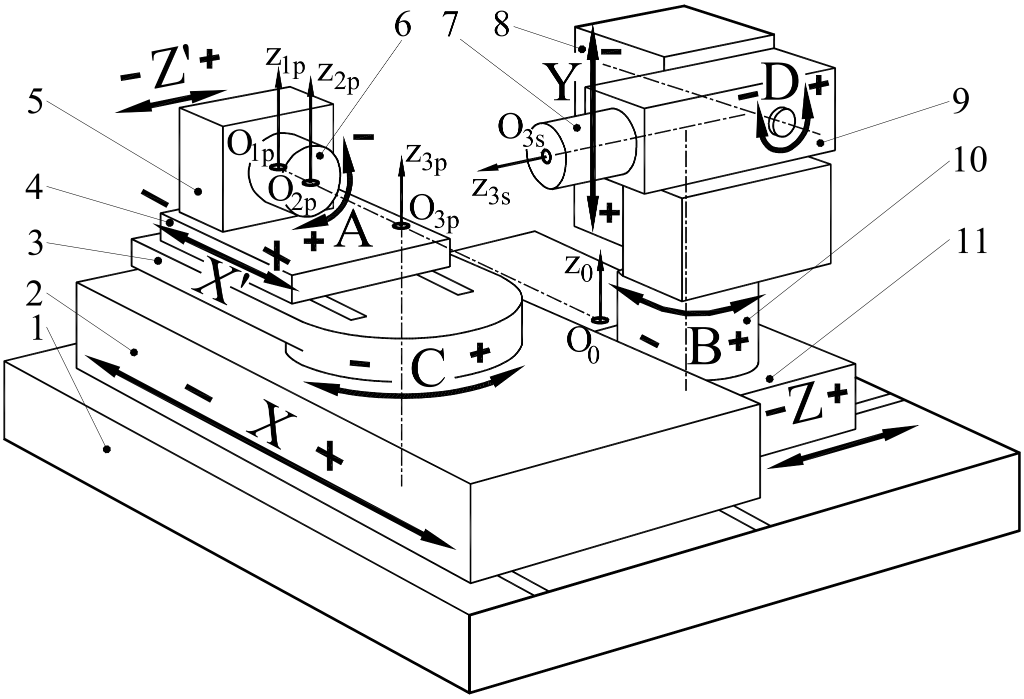


**Fig. 2.** *The block scheme of the sharp tool cutter machine* (WALTER):
1 - *Bed*; 2 - *Table*; 3 - *Rotative slide*; 4 - *Radial slide*; 5 - *Puppet holding the piece*;
6 - *Shaft piece*; 7 - *Main spindle*; 8 - *Vertical slide*; 9 - *Grinding head*; 10 - *Column*;
11 - *Transversal slide*.

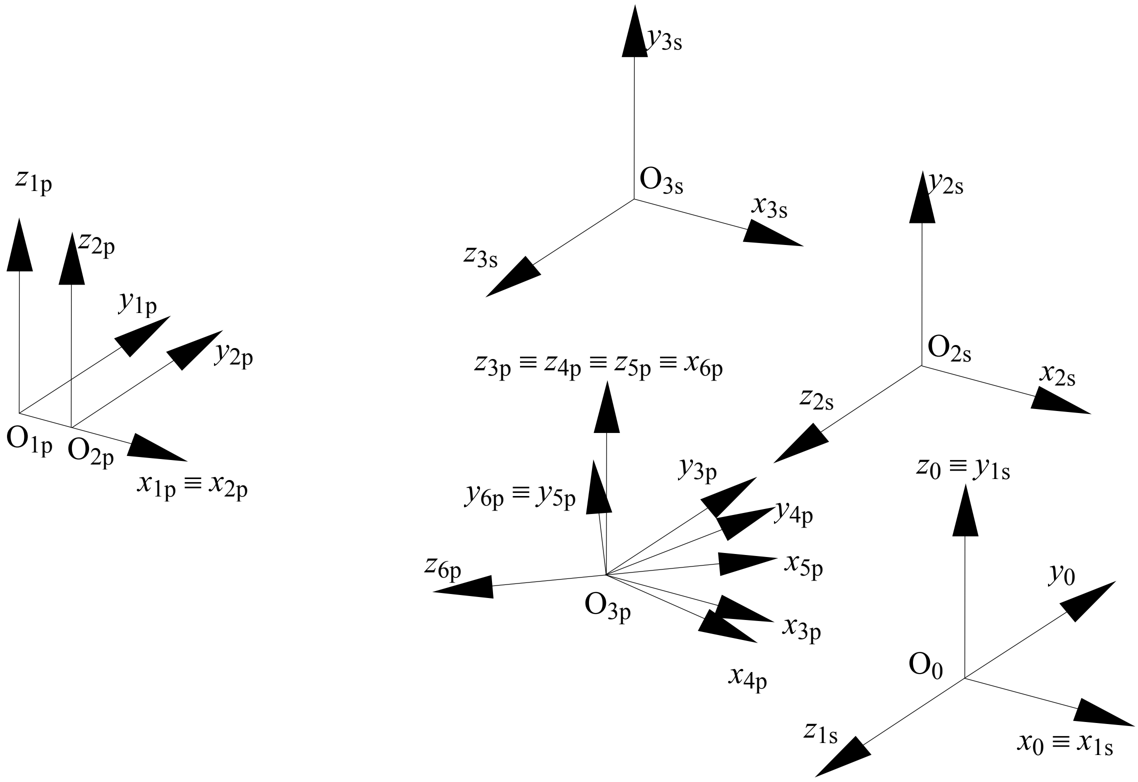


**Fig. 3.** *Coordinates systems of the sharp tool cutter machine* (WALTER)

It is choose one of these systems (marked with the index 0) as reference. As a rule, for a virtual machine, this system is linked to the bed frame, but in the current case, for programming reasons, it was preferred to be linked to the table. From the system start two branches of coordinate systems, for the piece (a number of 6, marked with the *p* index) and for the tool (a number of 3, marked with the *s* index).

The correspondence between the kinematic couples and the coordinate systems is indicated in the scheme shown in figure 2 by marking the points $O_0$, $O_{1p}$, $O_{2p}$, $O_{3p}$ and $O_{3s}$, as origins and the $z_0$, $z_{1p}$, $z_{2p}$, $z_{3p}$ and $z_{3s}$, as axes. The kinematic couples' motions are expressed for the tool's branch, and also for the piece, by a file having the following format:

$$\begin{array}{l} n-1 \\ x_1 \quad y_1 \quad z_1 \quad (\text{transf\_axa})_1 \quad (\text{functia})_1 \\ \ldots \\ x_n \quad y_n \quad z_n \quad (\text{transf\_axa})_n \quad (\text{functia})_n \end{array} \tag{5}$$

where: ***n*** is the number of coordinate systems from the respective branch (tool or piece);

$x_1, y_1, z_1$ - the origin coordinates of the new system in the old coordinate system;

**transf_axa** - is composed by two letters: the first letter signifies the transformation type (translation *t*, rotation *r*) and the second one is the transformation axis;

**functia** - is the motion time dependent function for the second coordinate system regarding the first coordinate system.

The virtual machine, alike the real one, is used for processing the cutting tools and precisely for the surfaces of the active part (figure 4). There can be enumerated: the helical channels, the facets, the placement and emission faces. In figure 5 are presented the tool positions in different generation cases.

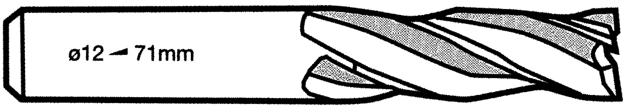


**Fig. 4.** Shank end mill

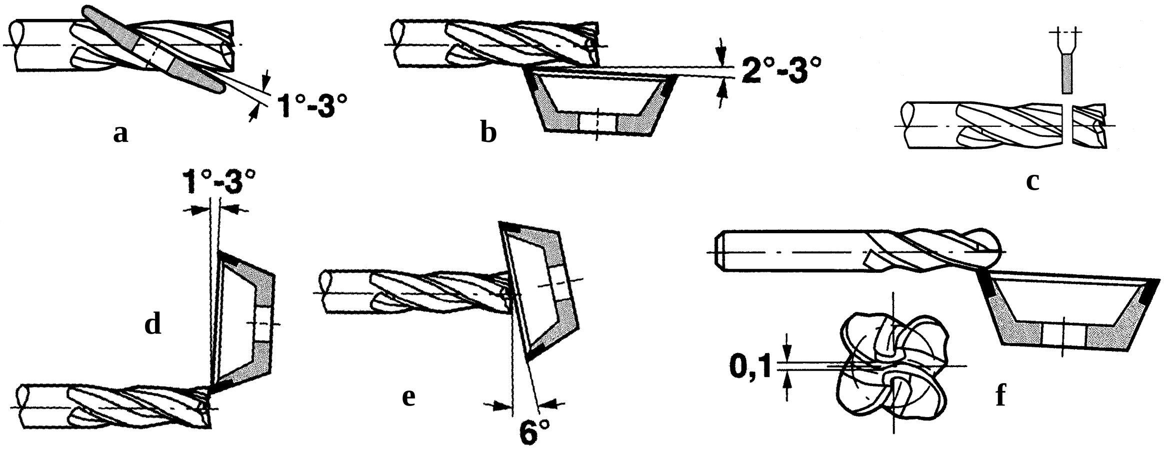


**Fig. 5.** *Processing possibilities*: a – *evacuation channel*; b, d – *placement faces*; c – *shortening*; e – *sharp central face*; f – *profiling faces*

**4. APPLICATION**

The exemplification is done for the processing of the helical channels, but not with a profiled tool. That tool is inclined with another angle than that indicated in figure 5.a. The abrasive tool (figure 6) used to process the piece channels have a tronconic shape with the width of 6.4 mm and the angle of 36.8°. With the virtual machine are generated: the channel of a cylindrical mill with 3 teeth and the diameter of 10 mm (figure 7); the channels of a cylindrical mill with 4 teeth and the diameter of 6 mm (figure 8), respectively, the frontal section (figure 9) of the mill shown in figure 8.

The adjusting elements of the abrasive disk are represented by the translation of the $S_{p2}$ system regarding the $S_{p1}$ system and the rotations of the $S_{p4}$ regarding the $S_{p3}$ and, respectively, of the $S_{p5}$ regarding the $S_{p4}$ from the piece branch, respectively, by the

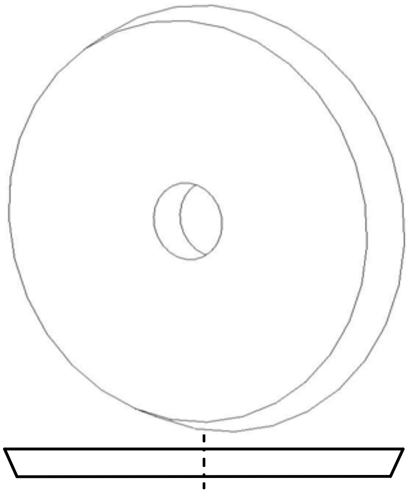

**Fig. 6.** *Abrasive Tool*

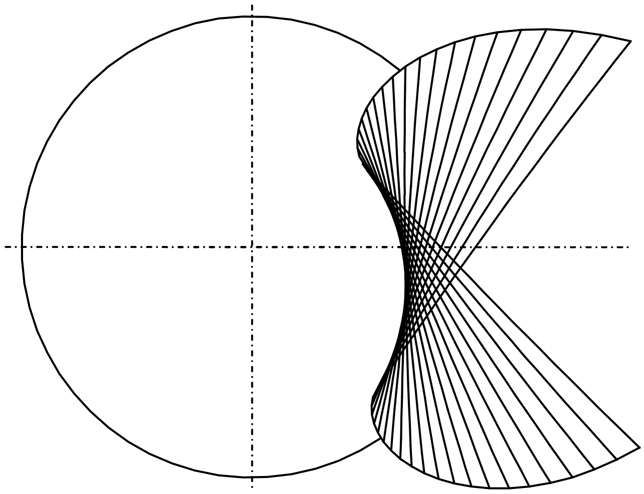

**Fig. 7.** *The generation of a helical channel*

translations of the $S_{s2}$ system regarding the $S_{s1}$ system and of the $S_{s3}$ system regarding the $S_{s2}$ system from the tool branch.

**Fig. 8.** *Generated surfaces*

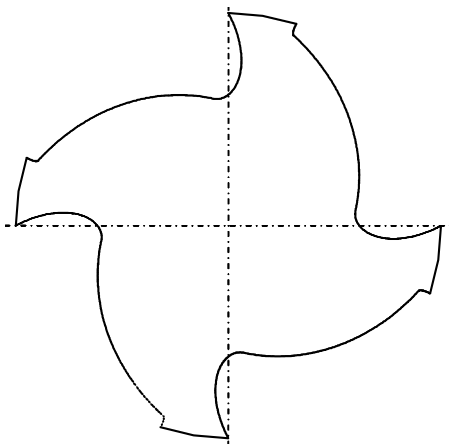

**Fig. 9.** *Frontal section of the end mill with four teeth*

## 5. CONCLUSIONS

The utilization of the virtual machine offers the possibility to generate the complex surfaces of the cutting tools without consumption of materials, energy and machine processing times. Thus, if in the real case, the introduction time for fabrication of the monobloc end mills from carbide was a year, in the case of using the virtual machine, this time is reduced by 5...10 times.

The transformation and motion matrix of the coordinate systems easily permit the introduction of the real machine's adjustments, such as: the positions for the abrasive tool and piece, the profile of that tool and even the vibrations.

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