MODEL OF GENERALIZED MACHINE TOOL

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Rezumat. *Lucrarea de față prezintă un concept revoluționar şi modern în care calculatorul poate modela o maşină-unealtă determinând şi forma suprafețelor pieselor prelucrate pe aceasta cu o precizie mai mică de 0.01µm. Acest concept a fost verificat în numeroase cazuri: prelucrarea roților dințate cilindrice cu freză melc, prelucrarea roților melcate cu determinarea liniilor de contact dintre melc şi roata melcată, prelucrarea melcilor de la pompa de noroi; maşina de rectificat fără centre, unele aspecte ale prelucrării de finisare a roților dințate cilindrice prin şeveruire etc.. Totodată, cu ajutorul lui se poate determina un model de prelucrare a pieselor în condiții de imprecizie reale ale maşinii şi/sau de vibrații.*

Abstract. *This paper presents a revolutionary and modern concept according to which the computer can mould and shape a machine tool, generating surfaces of the machined parts with an accuracy of less than 0.01µm. This concept has been verified in many cases such as: machining of cylindrical spur gears; machined worm wheel; parallel type worm manufacturing of solids handling pump; centreless grinding machine, some aspects of finishing cylindrical gears by shaving cutter, and so on. Also with the help of this concept can be determined the machining of the parts in conditions of real inaccuracy of the machine and / or vibration.*

Keywords: machine tool, surfaces, machining, model.

1. Introduction

The surface treatment of the complex parts such as gears flanks led to the concept of generalized machine tool. Machining with the gear hob is regarded as among the most productive and economical methods [1,2,3]. Yet the technological process that is extended in production has still many aspects that can be improved to ensure increased gear performance in terms of accuracy and behaviour in operation. In practice, calculation methods and adjustment of process parameters of the technological system have limitations, especially in determining the size of processing errors and their classification in the step precision prescribed.

This article presents theoretical aspects of generalized machine tools [1,4,5]. According to the concept, they have been defined: the shape and position of the cutting edges and the cutting edges of the tool, the movements of the machine

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elements and assemblies, the timing of the movements, the part of the topographic surface and generating conditions.

The cutting tool is one of the main elements of machining. It is processed on a machine tool that is also modelled. In conclusion, the cutting edges of the tool are determined by the generalized machine-tool.

2. Theoretical Aspects

The specialised literature presents theoretical and numerical rating on generating complex surfaces [6,7], referring to the teeth flanks cylindrical spur wheels, inclined or curved. These are based on the establishment and application of computer programs that determine the shape of various surfaces for reasons of machine parts without defining them by working on machine tools. Important aspects of processing the desired parts are presented that would be difficult to put out without any extensive time and money.

The theoretical generation of surfaces received a boost particularly by defining their two theoretical curves: generating curve (G) and guiding curve (D).

The application of the generalized machine tool highlights the influence of geometrical parameters of the tool and of the gear, their position, cinematic errors, the influence of vibrations on the machined surface, machine control errors and elastic deformations [1,8].

The accuracy of machined surfaces [9,10] is influenced by the type adjustment items that are considered as input data.

2.1. Part definition

Part definition is performed by shaping the outer surface of the blank and "topographic" surfaces. The topographic surfaces are flat surfaces, cylindrical, spherical, etc., as defined within the blank.

2.2. Basic elements

Being given a part where there is a cylindrical shape blank and where are defined topographic surfaces such as perpendicular planes to the cylinder axis (Fig. 1). Other forms of topographic surfaces are cylinders, cones, spheres and so on. It is considered a cutting edge (T0), defined by a number of points (A, B, C, D, E), where the relative movement of the tool from the piece intersects topographic surfaces successively in points (A1, B2, C3, D4, E5). The point E of the cutting edge describes de curve (C) (E0, E1, E2, E3, E4, E5) called the guiding curve. The curve (A1, B2, C3, D4, E5) cannot be assimilated in most cases to the guiding curve. The curve represents the intersection of the cutting edge with the topographic surface and will be called “trace” and is a component of the cutting scheme.

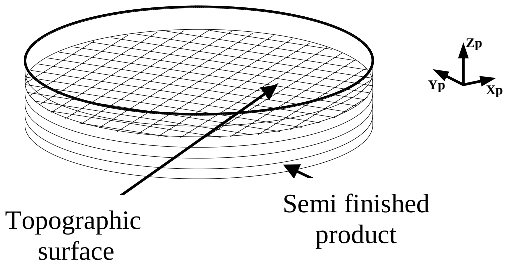

Fig. 1. Topographic surface of the cylindrical blank.

2.3. The tool

If the cutting tool is in the initial position (T0), during the relative movement performed during time (w) will occupy the positions (T1), (T2), (T3), (T4) and (T5) at the time w1, w2, w3, w4 and w5 (Figure 2).

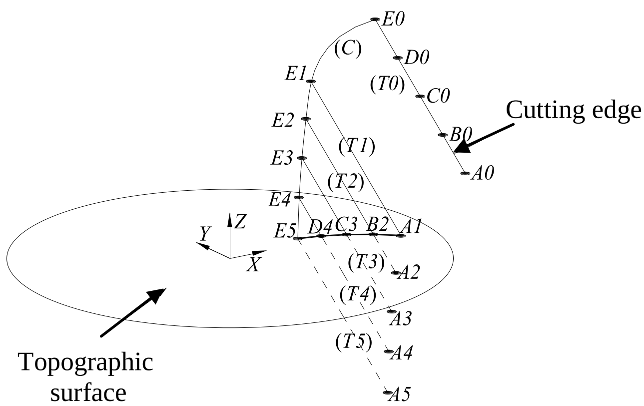

Fig. 2. Traces of machining the topographic surface.

To define the cutting edges we give as example the lathe tool (Figure 3). The cutting edge is in this case the curve ABCD where AB is the main cutting edge; BC is the cutter bit and CD is secondary cutting edge.

In this case the cutting edge of Figure 2 (T0) becomes the ABCD curve that defines a lot of waypoints which define the final curve that determines the tracks in the topographic surface.

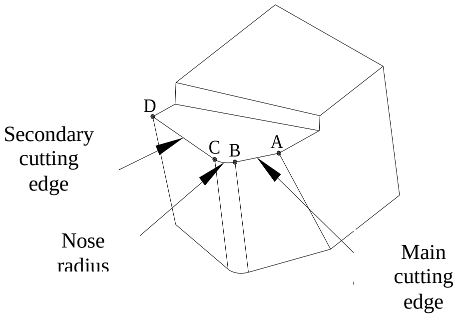

Fig. 3. The cutting edge of the lathe tool.

Cutting tools like cutters, drills, broaches and so on have a similar number of cutting edges similar to the ABCD curve in Figure 3, which is called tooth (Figure 4).

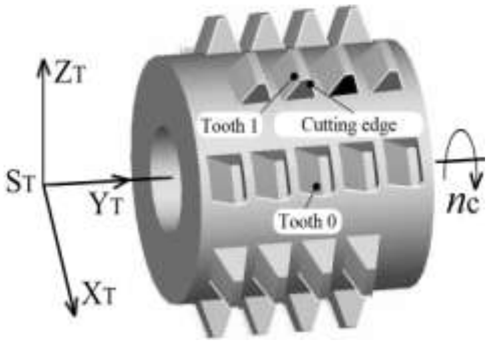

Fig. 4. Tooth and cutting edges of the spline hob.

Conceptually, for the spline hob above, the file for 33 tooth contains the following:

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720  30.625 -17.68277  .2168031  39.375 -20.86354  5.776781E-02
720  39.375 -23.1737 -5.774027E-02  30.625 -26.35447 -.2167817
675  21.80845 -16.30661 -21.50184  27.88318 -19.48738 -27.80148
675  27.8015 -21.79754 -27.88316  21.50186 -24.97831 -21.80843
 ….
0  30.625  4.335847  .2167924  39.375  1.155081  5.775404E-02
0  39.375 -1.155081 -5.775404E-02  30.625 -4.335847 -.2167924
….
-675  21.50186  24.97831  21.80843  27.8015  21.79754  27.88316
-675  27.88318  19.48738  27.80148  21.80845  16.30661  21.50184
-720  30.625  26.35447  .2167817  39.375  23.1737  5.774027E-02
-720  39.375  20.86354 -5.776781E-02  30.625  17.68277 -.2168031
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2.4. The machine structure, coordinate systems, axes and generating movements

The real machine tool for milling spur gears, which is used for generalized machine tool modelling, has a number of subassemblies, where: 1- frame; 2 - pillar; 3 - vertical slide; 4 - hub slide; 5 - weight slide port; 6 - generation plane with z = 0; X_f, Y_f, Z_f- fixed coordinate system (Figure 5).

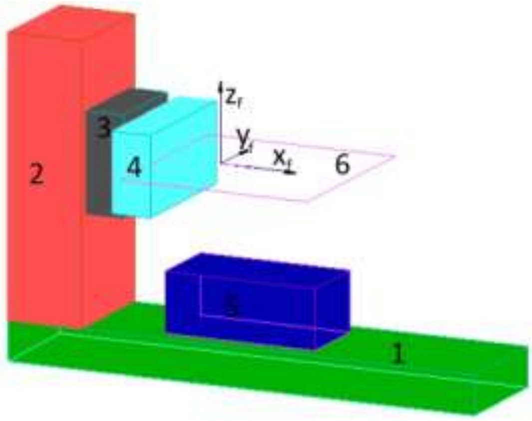

Fig. 5. Cylindrical gear milling machine structure with fixed coordinate systems.

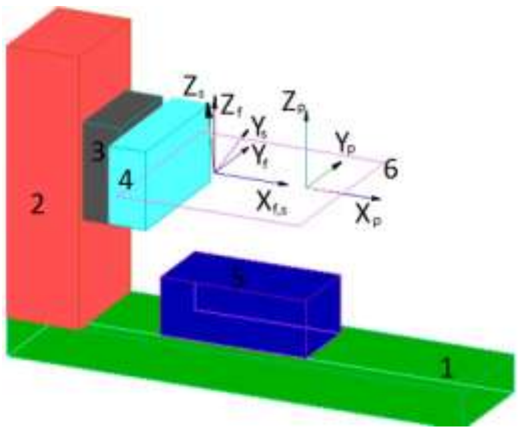

Fig. 6. Cylindrical gear milling machine structure with coordinate systems.

2.5. The reference systems and movements

For working with generalized machine tool, three coordinate systems are used: the machine (O_f ,X_f, Y_f and Z_f); the tool (O_s, X_s, Y_s and Z_s), and the part (O_p, X_p, Y_p and Z_p) (Figure 6). The coordinate system of the machine is fixed against the machine, and the others are programmed with shift their origin (O_s or O_p) from O_f and / or translational parameterized while the origins O_s or O_p along axes: X_f, Y_f, or Z_f. The coordinate system is programmed with parameterized rotation around its own axis.

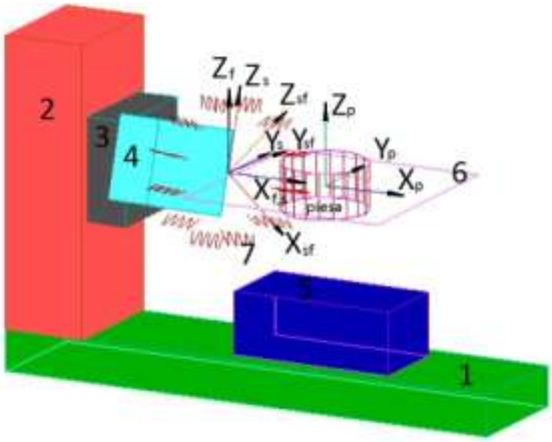

Fig. 7. Cylindrical gear milling machine structure with processing coordinate: 1 - frame; 2 - pillar; 3 - vertical slide; 4 - hub slide; 5 - weight slide port; 6 - generation plane with z = 0; 7 - cutting edges; X_f, Y_f, Z_f- fixed coordinate system; X_s, Y_s, Z_s - coordinate system of the tool X_p, Y_p, Z_p- coordinate system of the part; X_{sf}, Y_{sf}, Z_{sf} - coordinate system of the cutting tool.

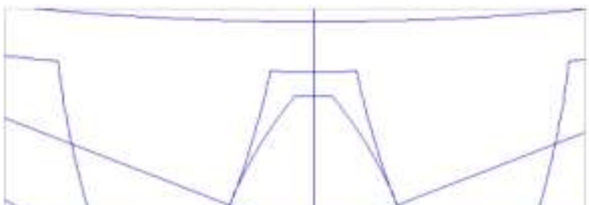

Fig. 8 The representation of the gear after data input.

2.6. Data input

To determine the tool path it is necessary to introduce the following data:

- the cutting edges and the raw material (Figure 7)

- part parameters (Figure 8).

After entering these data we can pass to the next stage, the generalized machine tool functioning.

3. Surface Generation Mathematics

The starting point is the cutting edge [1]. Its mathematical expression, in parametric form, is:

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

where the u parameter defines the points.

3.1. Transformation matrix

The characteristics and movement directions are defined (Figure 7).

For the analytical expression of the achieved trajectories, we use a matrix of the following form:

$$\mathbf{[M]} : \begin{bmatrix} x_1 & y_1 & z_1 & M_1 & F_1(w) \\ x_2 & y_2 & z_2 & M_2 & F_2(w) \\ x_3 & y_3 & z_3 & M_3 & F_3(w) \\ \dots & & & & \\ x_n & y_n & z_n & M_n & F_n(w) \end{bmatrix} \quad (2)$$

It is considered x_1, x_2, ..., x_n, y_1, y_2, ..., y_n and z_1, z_2, ..., z_n values of the displacements of the translational axes X, Y respectively Z of the current coordinate system, to the previous coordinate system. For example, x_2, y_2, z_2 are displacements of the coordinate system S_2 to system S_1.

Notations M_1, M_2, ..., M_n express the type of transformation between the considered reference systems (example: if M_2 is t_x, it represents translational movement in X system S_2 to S_1, if M_2 is r_z, performing a rotation movement around the Z axis system S_2 to S_1). The elements of the fifth column of the matrix [M] denoted F_1 (w), F_2 (w), ..., F_n (w) define the parametric (w) movements along the indicated axis by element on the line of the column to the fourth matrix.

4. The Generalized Machine Tool

The generalized machine tool functioning is based on a comprehensive calculation program developed and checked for various practical applications. Algorithms for calculating the surface generation in accordance with those described in [1] were designed, to which are added algorithms for entering data that define the part (execution document), regulatory mechanisms and characteristics of the machine kinematic chains. The output algorithms are variables or graphics on the gear and its tooth flanks.

The computation program has a modular structure with communication interfaces with the operator and machine. The communication interfaces successively open for data input and output, for representations and results of operation of the machine in question.

5. Numerical Results

Applying the concept of generalized machine tool enables rapid determination, graphically and numerically different basic aspects of the teeth gap generation. The generalized machine tool is designed with high modular flexibility. If the defining movement contains harmonic functions we can determine the shape of the generated flanks under vibration conditions.

5.1 Removing the stock left for machining

By moving the cutting tool, the traces of each tooth of the tool in the topographic surface represent the section of the cutting chips removed from the part. All of these traces represent the cutting scheme (Figure 9).

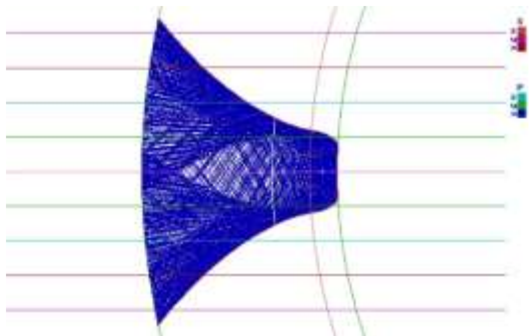

Fig 9. The milling sketch.

5.2. Tooth profile

It is the last stage of the generalized machine tool use in which is presented the sprocket profile in connection with the gear and it can easily track the gearing movement (Figure 10).

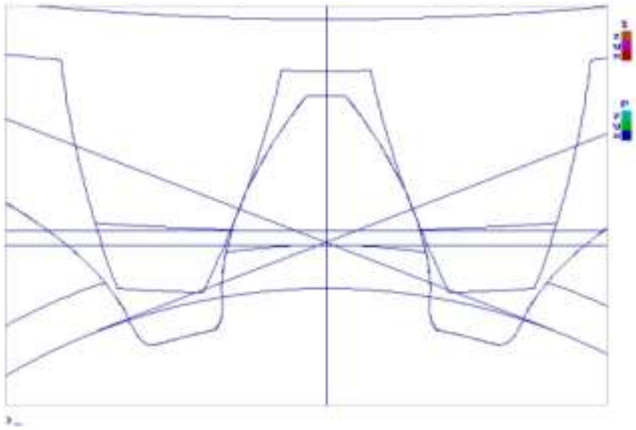

Fig. 10 The representation of the gear after data input and of the sprocket determined by generalized machine tool.

Conclusions

The generalized machine tool is an extremely useful instrument for:

- the machine tool design engineering, for machining complex surfaces and in determining the kinematics of the machine;

- the user by knowing the surfaces of the part under certain adjustment conditions of the machine, the cutting tool used with or without vibrations during the machining.

Depending on the measurement of the deviations in moving the machine elements, we can determine the correction values for the CNC machines in order to obtain the values from the nominal data.

By using different modelling and by comparing the results obtained with the generalized machine tool to those obtained in real manufacturing, the results were validated.

R E F E R E N C E S

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