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VIRTUAL HOBBING MACHINE

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Abstract: *In this paper we present preparation steps and machining for cylindrical gear teeth. In this respect, we elaborate the followings: verification of geometrical elements of the gears, changing gears determination for adjusting machining cinematic chains, setting parameters for tool-part positioning, adjusting and functioning the virtual machine, comparing the virtually machined gear with the designed gear. This methodology can also be applied for gear teeth profiles other than involutes.*

Key words: *spur gearing, generator profile, flanks line and profile, generation movements, adjustment parameters, manufacturing errors.*

1. INTRODUCTION

Machines and modern technology are characterized by flexibility, simulation possibilities and adaptation to manufacturing complex parts, one of a kind or limited series. Gears with cylindrical serrated wheels represent an important part in many machines and equipments. Gear manufacturing takes an important place in researchers' area of work both from the technological point of view as well as from the point of control and of testing. When the manufacturing process for teeth cutting is established, the following factors are considered: the purpose of the gear, it's type, shape and size and, the preciseness of the cutting machine and of the splintering tool, the production type and economic efficiency of the manufacturing process. The manufacturing process of teeth in most cases consists of applying the cutting process using the gear hob-module, also being productive and economical.

Although this procedure is intensely used in production there are many aspects that can be improved in order to increase performance regarding vibration, noise level and life cycle. To this purpose the method to calculate technological parameters and settings have a certain limit, especially in order to establish the size of manufacturing errors; this is the reason why the virtual machine described below was created. The concept of virtual machine tool presented in this paper is applied for the hobbing machine. Sandu [7] created a new concept, Sandu and Sandu [8] developed the numerical application by between 1990 and 1994 and the interface was finished together with specialists in gear designing and manufacturing [9, 10, 11]. According to this concept, their form is analytically defined: the form of the cutting edges, the position and the movements of the machine, the display in time of the generating movements. The generating movements are mainly performed along or around of an axis (couple shaft bearing or slide guide ways) of the coordinates system attached to each fixed or mobile element, which takes part into the generating process [7, 8, 9, 10, 11].

2. THEORETICAL ASPECTS

The basic elements of generating a curve are briefly presented in Fig. 1, where T represents the cutting edge placed in its initial position (T_0), at moment w (T_w) and namely at moment $w + \Delta w$ ($T_{w+\Delta w}$), P – piece, [S_T] – topographic area, $M_w M_{w+\Delta w}$ – fragment generated on surface [S_T] by the cutting edge, between moment w and 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 a rotation couples of the machine.

Generating the teeth of the wheel is performed using a hob (Fig. 2), for which cutting edges of the hob tooth were analytically defined. The second element is represented

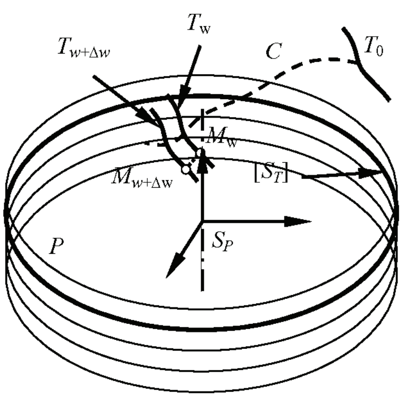

Fig. 1. Generation elements.

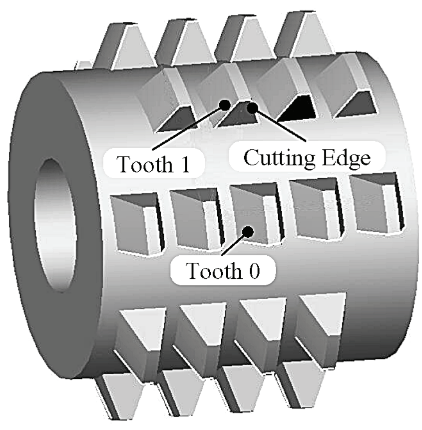

Fig. 2. Hob.

by the coordinate system. In the concept of the machine this element is make up of two branches, namely: the tool and the piece. The third element which supports the virtual machine in its performing is represented by defining the topographic plans of the piece with the help of which the generated surface is generated; the wings of the wheel's teeth.

3. PERFORMING ON THE VIRTUAL MACHINE

The basis of the virtual machine construction consist in an ample calculating program [7, 8], elaborated and checked in time on various practical applications. The program is modularly created, having interfaces communicating with the operator and with the machine type main windows. The main windows open successively, for entry and exit data, for representations and results of the performance of the respective machine tool. In the main window there may be windows that appear as the program specially developed for this purposes rolls-on.

• **Main window I:** defining certain parameters of the wheel to process (Fig. 3).

Windows 1...7, used for the introduction of certain geometrical parameters, are having four layers of display each. First of all the parameter is mentioned and secondly there is one or two buttons according to the fact that the namely parameter is unique (distance between axes), or has several localizations (module – normal or frontal). In the latter two cases, or in the latter case, the values introduces in the subsoil or indications that help to choose the appropriate value appear. In Fig. 3.b window 2 is exemplified.

After the introduction of the parameter, the specific departure (window 7), in window 8 other calculated parameters of the gear appear, with known relations [6], with values, as the case may be, in mm. In Table 1 several of the calculated and parameters displayed in window 8 are presented.

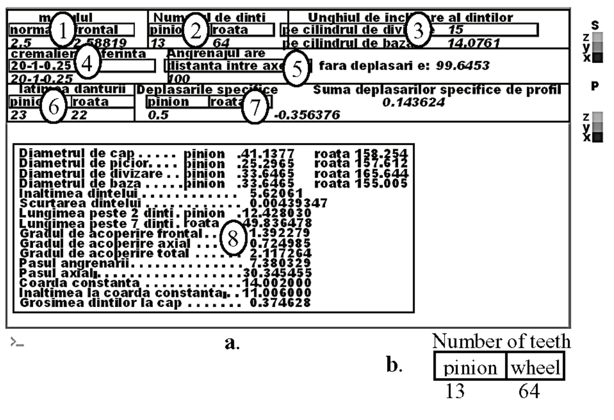

Fig. 3. Parameters of the cylindrical gearing 13/64:
a – main window 1; b – detail window 2.

Table 1

Calculated parameters of the cylindrical gearing 13/64

Diameter pinion split . . . 33.646 *wheel* 165.644
Diameter internal pinion 29.896 *wheel* 157.612
Height of the tooth 5.620
Shortage of the tooth 0.004
Diameter external pinion 41.137 *wheel* 168.853

• **Main window II:** frontal profile of the pinion and of the wheel. With the introduced and calculated data (Main window I) the tooth of the pinion and of the wheel are represented in frontal section (Fig. 4). There are used keys of the computer, which animate the gearing movement, in one-way or the other. The drawing gets bigger or smaller or moves on the display using other keys.

Certain details, out of which contact between the teeth on the gearing line and the singular contact points, can be presented in this way.

• **Main window III:** date for the setting of the cinematic threading chain. Window 1 indicates the spare wheels given the machine book depending on the way and bending angle of the tooth. The spare wheels are displayed on rows up to 15 seconds degrees, depending on the size of the bending angle error. On each row the number of four or tow wheels to spare is indicated 5 seconds degrees, hereinafter referred to as group, which determines the same angle error.

For the considered example there were calculated 306,627 groups, which fulfill the condition of setting on the machine. Those with the smallest error are indicated in window 2 (Fig. 5.b). On each row on the left there is indicated the number of wheels to spare which give the same angle error, and on the right there is the selecting button. In the selecting button there is written the deviation of an angle from the direction to be made of the tooth. Pressing a button, out of 2 or 3, window 5 respectively 6

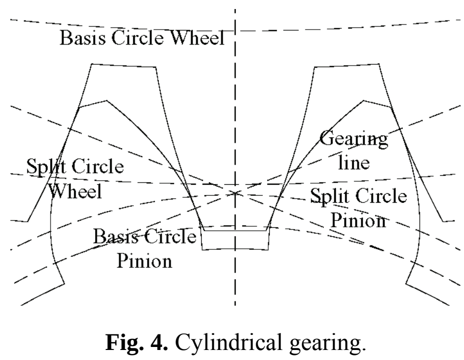

Fig. 4. Cylindrical gearing.

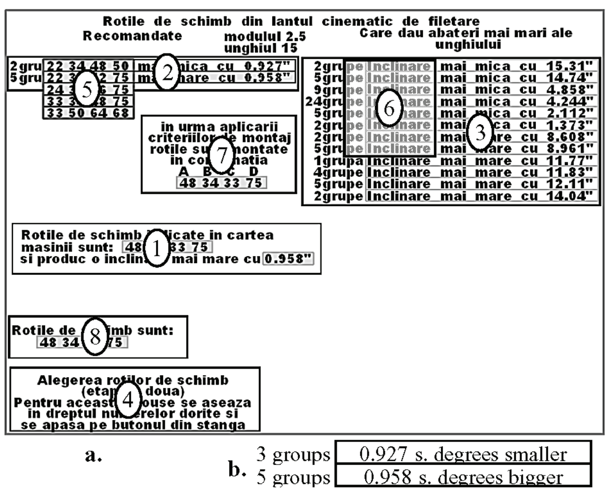

Fig. 5. Choosing spare wheels to thread:
a – main window 3; b – detail window 2.

appear, from all groups of wheels, them too as buttons. By selecting one up to four variants of setting the spare wheels of the previously selected group are transferred in window 7. If there is only one variant the session ends, unless pressed the chosen variant button. The spare wheels to be set in the cinematic threading chain appear in window 8. Window 4 is used for the selection instructions, which are changed after pressing a button.

• **Main window IV:** 3D drawing of the wheel. The wheel has 13 teeth with the frontal profile, except filet to bottom of the tooth (Fig. 6). The wheel is enlarged, diminished, spin or moved by pressing certain keys from the computer.

• **Main window V:** parameters of the hob and the setting of the other chains of the machine. The respective data is registered in six created windows, whose content is indicated in Fig. 7. Window 1 displays the parameters that characterize the hob STAS 3092/1-86. Window 2 is used to display data, characteristic to the main cinematic chain: spare wheels, rotation, the domain of the cutting speed, and the validation of the couple of spare wheels chosen by pressing the two buttons from window 3. Window 4 presents the spare wheels of the rolling cinematic chain and namely, those chosen out of them to process the 13 teeth wheel. In window 5 there are registered the ahead speeds performed by the cinematic chain of heading axis and there are given data regarding the choice of the heading on the tooth (technological parameter). Depending on the number of teeth, in window 6 there are displayed the buttons with advancing speed,

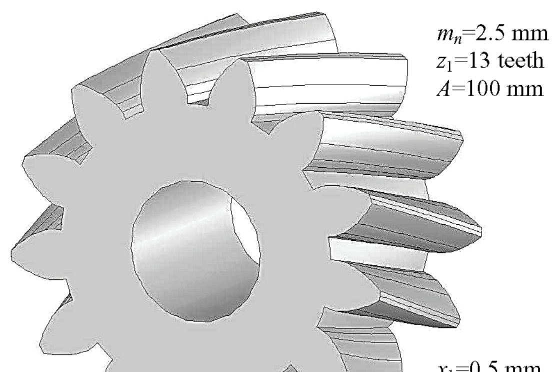

Fig. 6. Cylindrical wheel.

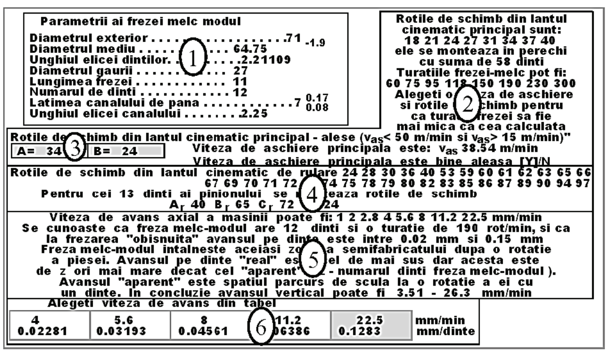

Fig. 7. Data regarding the hub and the setting of the other cinematic chains of the cars.

which may be defined by the operator. By pressing one of these buttons, the session ends and it is considered that the virtual hobbing machine is prepared for processing, by generating certain cinematic program files of the machine.

• **Main window VI**: representing the virtual hobbing machine (Fig. 8). In the superior frame of the window there is the menu, when the mouse extends by pressing one of its buttons. Pressing a button of the extender menu leads to the performance of sequences to the program.

At the block sketches of the machine there is to add: the piece, the cutting edges of the hob and the coordinates system. The axis of tool O_sY_s coincides with the axis of the main branch of the machine. As a rule, one of the axes of each ax system is on a direction in which a movement of a couple slide guide ways or on a rotation axis for couple shaft bearing can be performed.

There are represented all the coordinating systems from the brunch of the tool: $S(x_s, y, z)$, of the machine and of the tool $S_s(x_s, y_s, z_s)$, and those from the branch of the piece: of the machine $S_m(x_s, y, z)$ and of the tool $S_p(x_p, y_p, z_p)$. In representing the program (one cannot notice from Fig. 8 due to the overlaying) in the branch of tool there are four coordinating systems in succession: translation on axis O_sz_s; rotation around axis O_sx_s with the angle of the helices of the hob; rotation around axis O_sx_s with the bending angle of the teeth; rotation (main movement) around axis O_sx_s. In the branch of the piece there are two coordinating systems in the succession: translation on axis O_sx_s with O_sO_p; rotation around axis O_pz_s with one angle corresponding to the rolling and unrolling.

The drawing zooms in and out, rotates or moves in the windows using the keys. Keys "Page Up" or "Page Down" simulate the void functioning of the machine by its time evolution of the mutual position of the ax systems of the two branches: of the piece and of the tool. After a while (15 s) through its menu the piece may by virtually processed. There are two virtual processing ways: with or without moving the tool and the piece. From the point of view of the rolling time the former option lasts longer.

Main window VII: generating the void of the wheel. The result of the virtual generation (Fig. 9) and implicitly of the frontal profile of a void of the tooth results as a

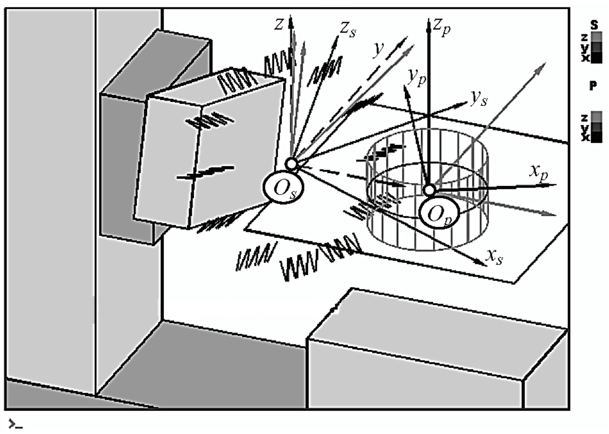

Fig. 8. Virtual hobbing machine set to process.

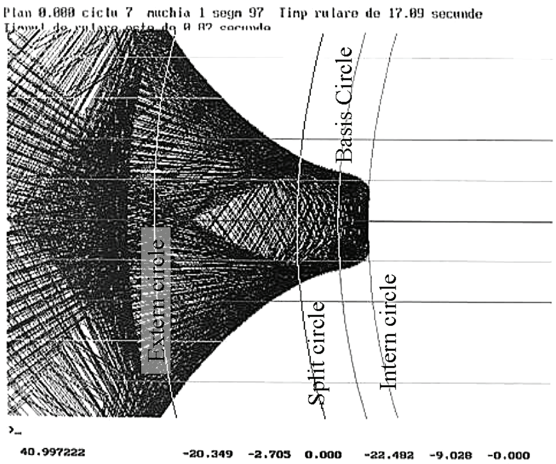

Fig. 9. Generating the void of the wheel.

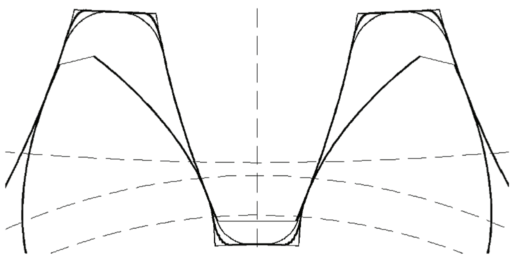

Fig. 10. The working gearing.

crossing of each cutting edge with a frontal plan (in this case $y_pO_px_p$), during the axial movement of the tool, with the chosen advancing movement, from the beginning moment of the generation and up to the ending. Finally, there is the definition of the frontal profile of the basis circle.

Main window VIII: frontal profile of the generated wheel. For the comparison with the generated profile by processing on the virtual hobbing machine is overlaid, on the frontal section (Fig. 4) of the wheel and of the pinion. Processing on the virtual hobbing machine it is noticeable that it mostly coincides with its theoretical profile. There is a difference in the recordation area in bottom of the tooth.

The profile at the bottom of the tooth has a shape determined by the profile hob in the top area of the teeth. Just as expected for a number of teeth, under 30, if the specific movement was not correctly chosen, this is noticed in bottom of the tooth.

4. CONCLUSIONS

Applying the concept virtual machine tool, with particularities for the processing on the hobbing machine, allows the rapid graphic and numerical determination of various basic aspects of cinematic generation of the flanks.

Several aspects are emphasized graphically, namely: geometric elements of the gear, the profile of the flanks, and the form of the connection to the bottom of the teeth. Therefore, the approach of the problematic of toothed wheels processing may be possible starting from the execution drawing, by viewing the wheel. This step is necessary for the in order to check the accuracy of the geometrical parameters, up to the viewing to a very large scale, in which the measure of ruggedness for the generated surfaces is identified.

The used program is in modular conception and has a wide flexibility. For instance, chamfering, connection, flanking, protuberance, and others may modify the form of the cutting edges. By appropriately choosing the movements and of the modules, the virtual hobbing machine shall also process toothed wheels. With other modules of the program the variation of transmittance report or aspect of the flanks contacts may be studied.

If in the cinematic programming files of the machine, when defining movements, harmonic functions are introduced to determine the shape of the wheel generated [7] in vibration conditions.

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