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RESEARCH REGARDING TOOTHING KNIVES

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Abstract- This paper presents the research regarding knives used for toothing spiral bevel gears. The mathematical model employed in the research uses the space meshing method as its study method, having customized it for the technological gear formed at the rectification of the seating surfaces. The deviations of the cutting edge from a straight line that passes through its extreme points are determined using computer simulation. These deviations are assessed in different sections of the cutting tool's resharpening field. The proposed solution for the side and peak surface coincidental grinding is based on a key property of cylindrical helicoids of constant pace which states that the common screw axis is affine-invariant to the rototranslation of either helicoid. The exploitation of this property for achieving active helical edges ensures the conservation of the shape of the cutting tool's edges, and consequently of its profile. The results obtained with these cutting tools in the processing of the gear are being presented.

***Keywords*—** gears, gear cutting tools, relieving head

I. INTRODUCTION

THE relieving technology for spiral bevel gears toothing knives used by commercial manufacturers of tools and machine-tools is unknown. In our country, the attempts for profiling toothing knives through relieving, by using cam devices, have been abandoned. This is due to the fact that after a small number of sharpenings the blade profile no longer meets the imposed conditions.

The mounting of relieving devices on the cross slide of a lathe is difficult, because of the high number of blades on the head and the small space between them. During the processing of a blade on the technological head, the abrasive disc touches the nearby blades, which implies the need to use special heads with a smaller number of cutters, which in turn raises the processing cost. The high number of gear cutting machines which exist countrywide requires the identification of more economical and precise methods for relieving the knives of the cutting heads.

The tools used for toothing the spiral bevel gear differ according to the type of the teeth and the processing methods used [1]. Thusly, depending on the type of teeth, we can distinguish the tools into:

1) tools for toothing spiral bevel gears with curved teeth;
2) tools for toothing bevel gears with elongated epicyclic teeth; and
3) tools for toothing bevel gears with involute teeth.

According the processing method used, we can distinguish the tools into:

1) brooches for toothing spiral bevel gears with curved teeth;
2) cutter holder supports for processing through rolling of the spiral bevel gear teeth;
3) cutter holder supports for processing through rolling of helicoid teeth – the Spiromatic process, or of spiral teeth – the Fiat procedure;
4) worm mill-cutters for toothing spiral bevel gears with involute teeth.

The broaching of spiral bevel gears is one of the most productive processes. Either of the following types of processing can be used to this effect:

- *processing through the use frontal teeth rotary broaches with rectilinear profile; or*
- *processing through the use of frontal teeth rotary broaches with curvilinear profile.*

In the first case, the knives are arranged alternatively, for the outer flank processing, and for the inner processing of the gap. Due to the rectilinear shape of the blades, the normal profile of processed teeth comes out rectilinear too (the Formate profile). This makes the method particularly suitable for the processing of gears with a high number of teeth or for roughing.

The second type of processing, which implies the use of curvilinear profile knives, is more suitable for large scale production from an economic standpoint. In the case of using cutter holder supports or worm milling machines, the knife cutting process is achieved through milling, while the execution of teeth is achieved by using a generating flat gear, havind the teeth of the tool materialize the generating flat gear teeth [6].

II. THE RELIEVING PARAMETERS

The numerical research used in this paper is based on an algorithm which is the result of the geometrical modeling of the relieving technology used for the profile of spiral bevel gear toothing knives. The modeling itself is based on a custom version of the spatial meshing method of researching gears [8].

The implementation of the side edges of the knife is of great importance because it must satisfy all of the following conditions:

1) preserve the cutting-edge straightness after re-sharpening;
2) maintain the α_e and α_i cutting edge inclination constant in any transverse section;
3) maintain the generating diameters D_e and D_i constant, so as not to influence the size and the placement of the conjugated points contact area;
4) maintain the seating angle constant in any transverse section.

These conditions can be achieved through the relieving of the side and peak surfaces of the knife. The working side surfaces of the knife are processed according to an Archimedean spiral.

The coordinate transformation matrices are used as operators that help us in determining the equations of the relieving movements, the relative speeds of said movements, as well as the tangents to the cutting edge, and the normal lines to the surfaces. They are also useful in establishing the links between the systems [5].

The coordinates of the origin are considered to be equal to zero for the transformations of the vector projections onto the coordinate axes, in accordance with the rules of vector translation.

The reciprocal arrangement of the systems [8] is related to:
1) the A_x and A_z displacements;
2) the φ and δ angles of the device's tool axes to the z_i axis;
3) the relative rotation angle θ.

The A_x and A_z displacements of the systems in relative motion are characteristic of all relieving trajectories.

The following equations describe the transition from the x_k y_k z_k system to the x_i y_i z_i system:

$$\begin{aligned} \mathbf{x_k} &= \mathbf{x_i \cos\theta\cos\varphi + y_i \sin\theta - z_i \cos\theta\sin\varphi - A_x \cos\theta\cos\varphi} \\ \mathbf{y_k} &= \mathbf{- x_i \sin\theta\cos\varphi + y_i \cos\theta + z_i \sin\theta\sin\varphi + A_x \sin\theta\cos\varphi} \\ \mathbf{z_k} &= \mathbf{x_i \sin\varphi + z_i \cos\varphi - A_x \sin\varphi + A_z} \end{aligned} \quad (1)$$

The trajectory of these movements is determined by the relieving direction and the shape of the clearance cam. When relieving the cutters which equip the cutting heads for spiral bevel gears with curved teeth we can use any of the following processing methods:
1) radial relieving with an Archimedean cam:

$$\mathbf{A_x = A_0 - [kn\theta/(2\pi)]} \quad (2)$$

where k is the relief cam dimension and n is the cam's number of rotations;
2) oblique (angular) relieving with an Archimedean cam:

$$\mathbf{A_x = A_0 - [kn\theta/(2\pi)] \sin\tau} \quad (3)$$

$$\mathbf{A_z = [kn\theta/(2\pi)] \cos\tau} \quad (4)$$

where τ is the angle that characterizes the relieving direction.

The relieving direction angle is considered to be positive if the axis rotates towards the z_i axis in anti-trigonometric direction when observing the motion from the side of the positive direction of the y_i axis.

For the process of relieving after a helical trajectory on cylindrical helix:

$$\mathbf{A_z=\theta[\, P_e]} \quad (5)$$

where P_e is the cylindrical helix pitch, the relieving motion can be described using any other trajectory if the A_x and A_z parameters are expressed as a function of the θ angle [8].

The cutter is positioned with the generating curve definition section in an axial plane. When processing relieved surfaces it is necessary to take the following into account:
1) the calculation section position for which the generating curve is defined;
2) the cutter adjustment parameters in the relieving device;
3) the relieving process parameters;
4) the adjustment and form parameters of the abrasive disc;
5) the cutting edge profile, which will suffer modification after the re-sharpening is complete.

Because of the alteration to the cutting edge profile, the calculations will be done for various angles of cutter sharpening, so that for ε=0, the cutting edge will be situated in the calculation section, and for a variable ε ($\pm$ 5°) it will land in different sections of the cutting tool.

During the generating process, the φ and β angles can take different values, so that for the following case:

$$\mathbf{\varphi=0;\ \beta=0} \quad (6)$$

the processing will be done with a conical abrasive stone as seen in Fig. 1. The advantage of using the conical disc lies in the fact that the relieving tool's axis need not be inclined.

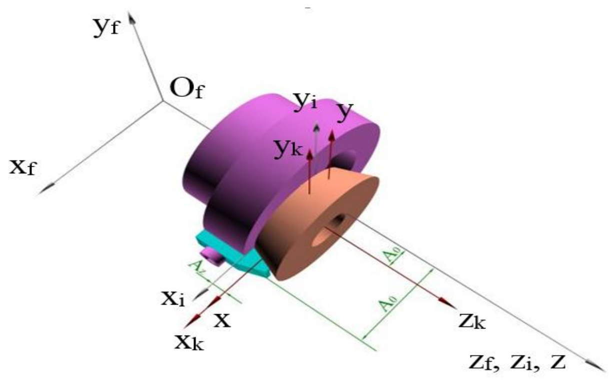

Fig. 1. Inner axial relieving with conical abrasive stone

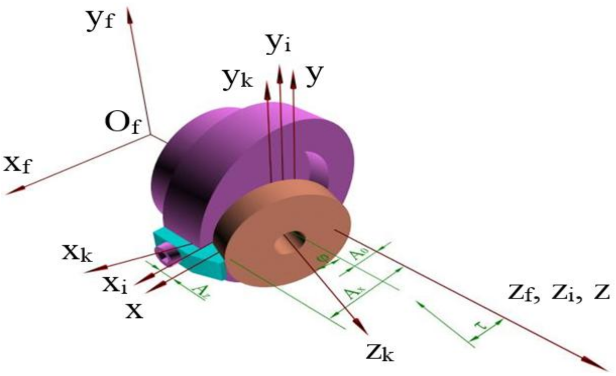

Fig. 2. Inner axial relieving with a cylindrical abrasive stone

The process of relieving the tip of the knife is shown in Fig. 3.

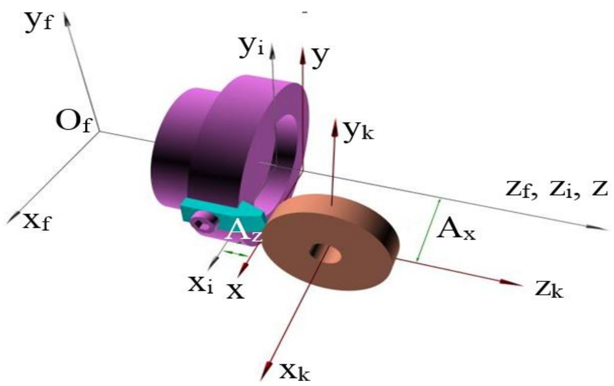

Fig. 3. Knife tip relieving

When processing and re-sharpening the side surfaces, the blades are assembled in the technological device, and the length is adjusted in the console after each re-sharpening.

III. NUMERICAL RESEARCH

The purpose of the numerical research is to determine the deviations of the relieved seating surface of spiral bevel gears toothing knives. It is to this effect that we have written software whose purpose is to simulate the technology involved in the process.

The computational software is used for the process cases which involve outer cutting tools with a straight cutting edge. We have chosen the module m = 5mm knives which equip the 6” Hardac – Gleason gear cutting heads.

The finishing relieving of the blades is done by rectfication using a conical grinding stone, on the axes of the Niles-type worm cutter-rectifying machine or on the thread rectifying machines, on a cylindrical helix path.

In order to attain the coordinate display functions of the cutting edge, of the abrasive tool coordinates, and of the real cutting edge deviations from a straight line passing through its extreme points, a software program was written by the author in VC++, as seen pictured in Fig. 4.

The relieving wheel profile is dependent upon the relieving schema, the cam profile, and the cutting edge in the calculation section. In order to determine the theoretical profile, the abrasive tool’s surface is

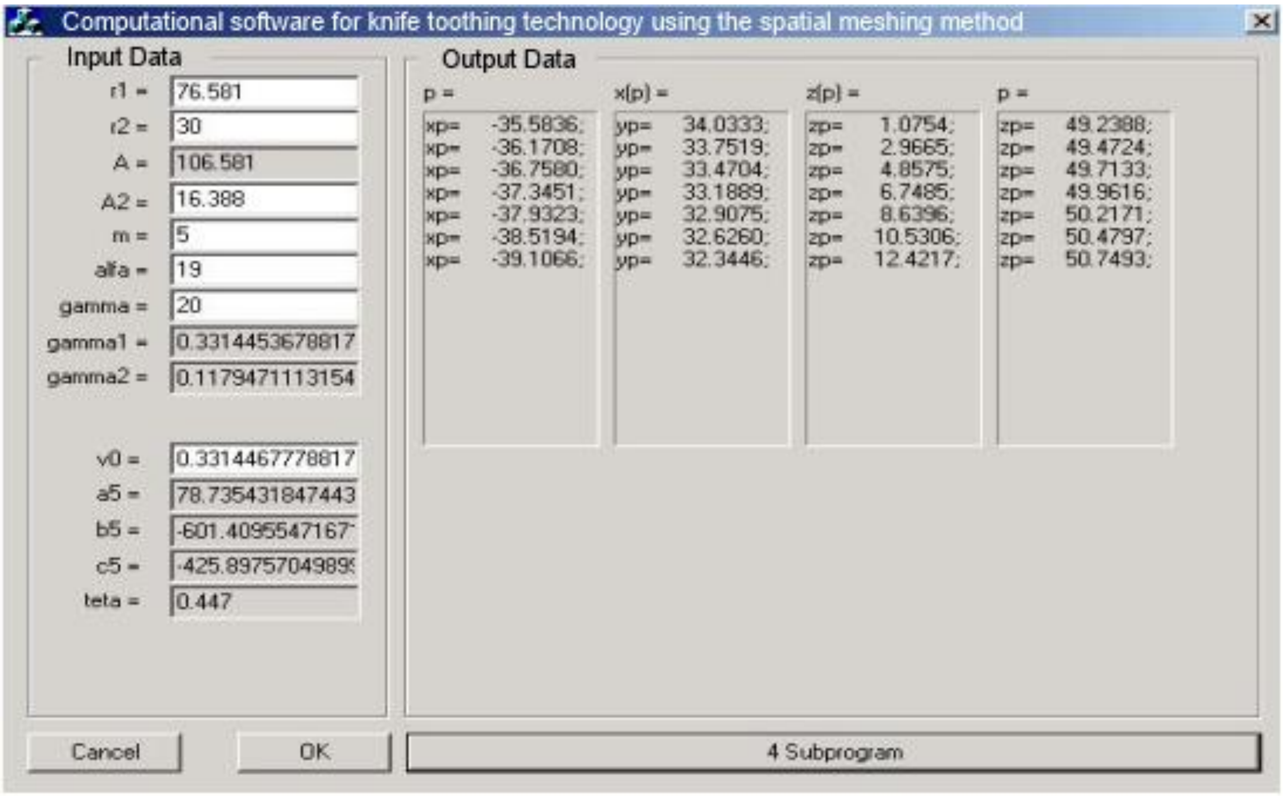

Fig. 4. The computational software program interface