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NEW TECHNOLOGICAL SOLUTION FOR MANUFACTURING PRECESSIONAL GEARS WITH NON-STANDARD PROFILE

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Abstract: All fields of science do not stand still and develop. The industrial revolution involves a new approach to production, based on the mass introduction of information technologies, this also refers to mechanical transmissions with gears and more specifically to planetary precessional gears. The implementation of these gears involves the study of scientific research in the field of precessional gear manufacturing technology. Several technologies have been created, for mass and large series production. The given article presents a new step-by-step method for manufacturing gears for small-scale production on CNC machining centers. The results of the proposed technology and the next steps that were followed in the design of the precessional gear machining process are presented. CAM Parts were identified which were made in CAD software, then with the help of CAM, a new gear processing technology was obtained.

Key words: *precessional planetary gears, product, manufacturer, technology, implementation, technological design, quality*

1. INTRODUCTION

The increasing demands of consumers for gear mechanical transmissions to increase torque, reduce weight and size indicators can only be satisfied by two directions of development, namely, the creation of new types of mechanical transmissions based on new principles of operation or an increase in the load capacity of the contact of the teeth of the wheels, using the example of a long type of engagement, investigated in works [1 - 4].

The first patent of precessional planetary transmissions appeared under the name "Precessional transmission" [4] gradually he perfected himself [5]. The shape of the precessional transmission shown in figure 1, (a, b, c) is conical with variable tooth height, consisting of a satellite wheel with two rows of convex-straight teeth and a convex-concave central wheel, thus we get improved contact characteristics of the sides with the contact surface of the teeth of the central wheel.

Using this geometrical aspect, the possibility of the shape of the tooth, implicitly the performance characteristics of the contact, is ensured by shortening its height to the level that would ensure only a convex-concave contact (see figure 1).

Figure 1 (d, e, f) shows the profilograms of the teeth of the left central wheel Z_1, described by $\zeta=(\xi)$, correlated with the trajectory of movement along the envelope radius of the profile of the satellite teeth of the row Z_2 in the form of a circular arc $\zeta 1= f(\xi_1)$. The profilograms are obtained by selecting the configuration of the parameters [Z_1, Z_2, θ, δ, and r], wheels, while it is proposed to make a decision on the engagement of a part of the teeth with a convex or straight geometric contact, in order to achieve a contact surface of the teeth with a convex-concave engagement [4 - 5].

The reduction in rotational speed and the transmission of torque in the precessional transmission occurs by rolling with some slippage between the sides of the contacting teeth. The rolling motion is a function of the nutation angle, and the displacement between the side surfaces of the teeth depends on the value of the parameters [Z_1, Z_2, θ, δ, *and r*] of

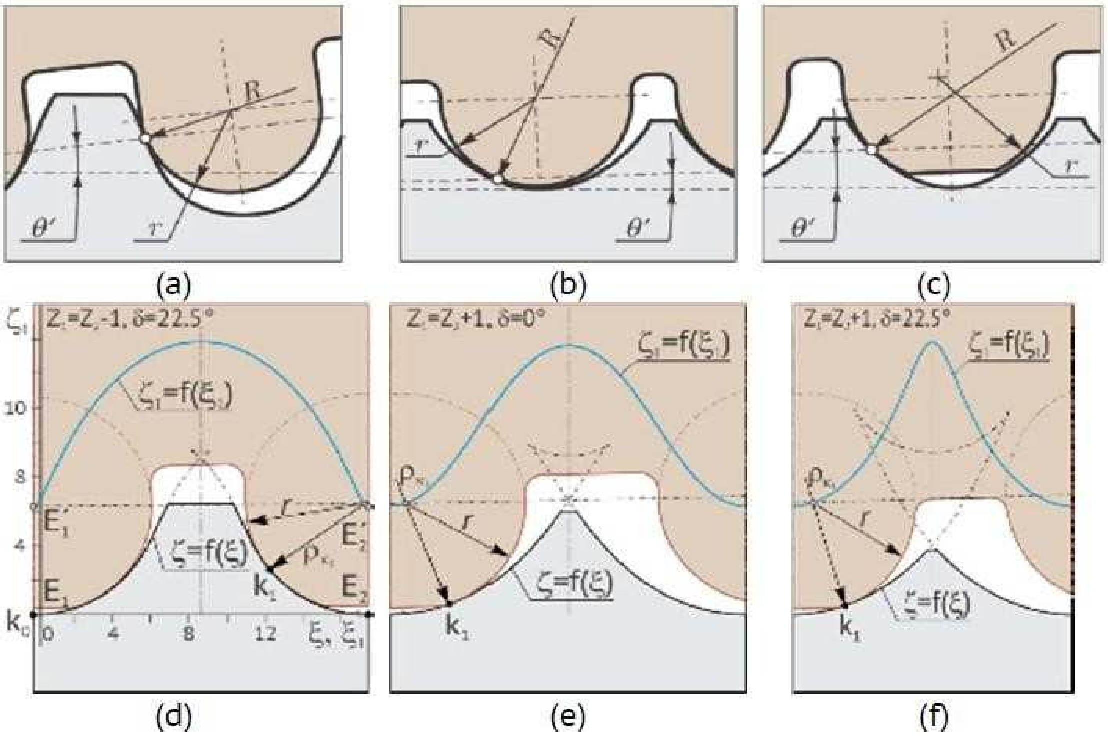

Figure 1. The geometry of the gear contact in the precessional planetary gear: a, b, c - where the contact occurs along the profile of the teeth along the radius of the circle and convexity-concavity; d, e, f – contacts the surface with a convex-concave shape with the smallest difference in the curvature of the conjugated profiles for the corresponding configuration parameters [Zg–θ;±1].

the wheel. The slippage in the mesh reduces the mechanical efficiency of the gear wheel, the tightening of restrictions on the physical and mechanical properties of the wheel material, the imposition of expensive construction and operating solutions.

The rapid development of technologies for manufacturing gears on machined centers (CNC) with program control, as well as technologies for rapid prototyping with 3D printing, is changing approaches to obtaining contact surfaces of teeth based on mathematical models that describe surfaces and allow computerizing the design process on a CAD/CAM/platform CAE and in the final to make.

This work is aimed at checking, using this method, previously developed technologies for obtaining gears designed for precessional gears of the 2K-N and K-H-V types with different types of gearing, including those with different curvature of the lateral surfaces of the contacting teeth, which make it possible to obtain various gear ratios.

When creating a tooth contact in the above-described engagement of a stationary wheel with precessionary motion of the satellite teeth, it is possible that the teeth on its left side can be described by an LEM curve with a radius r (Figure 2).

Trajectory of movement along the circle with radius r from the beginning during the precessional movement of the satellite wheel is represented by the function $\zeta = (\xi)$, and the profile of the engagement of the teeth of the central wheels - by the function of the arc of the circle - LEM $\zeta_1 = f\ (\xi_1)$ [1, 7].

Knowing the kinematic Euler equations and their relationship between the angles φ and ψ, taking into account the expressed kinematic formula $\varphi = -Z_1/Z_2\psi$ [2], we obtain the trajectory of the LEM motion $\zeta_1 = f(\xi_1)$ with the origin G of the circle arc radius, using the coordinates X_G, Y_G, Z_G depending on the rotation angle of the input shaft ψ:

Equations (1) [1] are necessary for the design the center of the central wheel teeth in two ζ and ξ coordinates in the P_1 plane we draw the

$E_1\zeta\xi$ coordinates system originating at point E_1, whose E_D axis passes through point E_2 (figure 2). From the X_N, Y_N and Z_N coordinates we move to the coordinates ζ and ξ using the relations:

$$\xi = \frac{(E_1E_2)^2 + \nu_1^2 - \nu_2^2}{2(E_1E_2)}, \zeta = \sqrt{\nu_1^2 + \nu_2^2}. \qquad (1)$$

where

$$(E_1E_2)^2 = \left(X_{E_2} - X_{E_1}\right)^2 + \left(Y_{E_2} - Y_{E_1}\right)^2 + \left(Z_{E_2} - Z_{E_1}\right)^2,$$

$$\nu_1^2 = (E_1E_N)^2 = \left(X_N - X_{E_1}\right)^2 + \left(Y_N - Y_{E_1}\right)^2 + \left(Z_N - Z_{E_1}\right)^2,$$

$$\nu_2^2 = (E_2E_N)^2 = \left(X_N - X_{E_2}\right)^2 + \left(Y_N - Y_{E_2}\right)^2 + \left(Z_N - Z_{E_2}\right)^2.$$

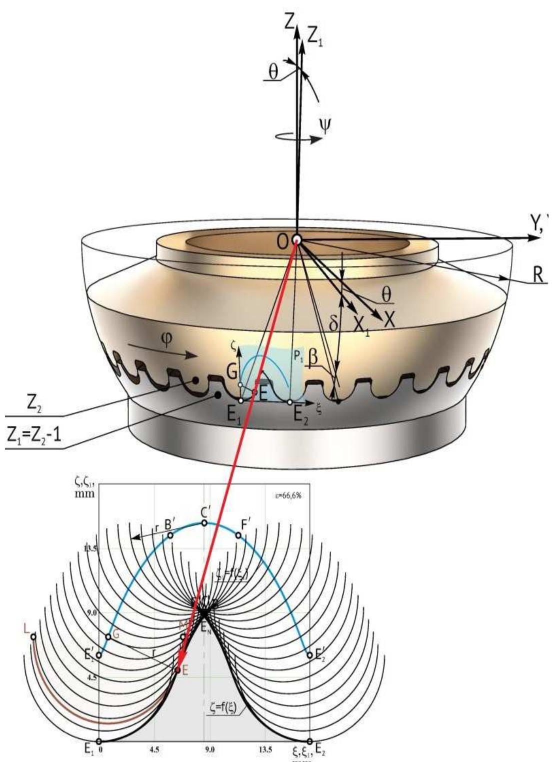

Figure 2. Description of wheel tooth profile through families of circular arcs in the $O\overline{XYZ}$ system.

2. CREATE TECHNOLOGY CNC

Knowing the equations describing the profile of the teeth [1-7], a technology was developed for manufacturing teeth with a tool that performs precessional movement [8-10], first with a tool in the form of a truncated cone. and then a tool in the form of a profiled disk. Methods for processing gears, tools, fixtures and methods for obtaining blanks are patented, approx. 50 patents. The developed technology is carried out on an aggregate type machine and is intended for mass and large-scale production.

Starting to create CNC technology, having analyzed the input data (materials, technical drawing, characteristics of CNC machines, cutting tools, fixtures), knowing the necessary: processing accuracy, production time, costs [11-19]. After that, we define the technological process: knowing the parameters of the work piece, technological transitions, sharpening parameters of cutting tools, and the control system. The next step will be the creation of a workflow for design, production and the creation of technological documentation.

Steps that have been used:

Definition and creation of the CAM part

Step 1: Find the component of the CAD program and use the CAM program (Figure 3).

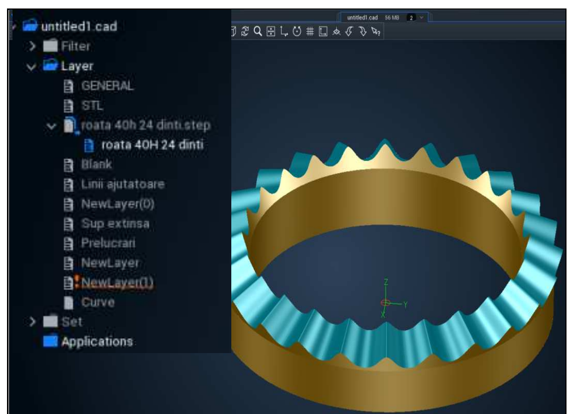

Figure 3. 3D model of a gear wheel with precessional gearing.

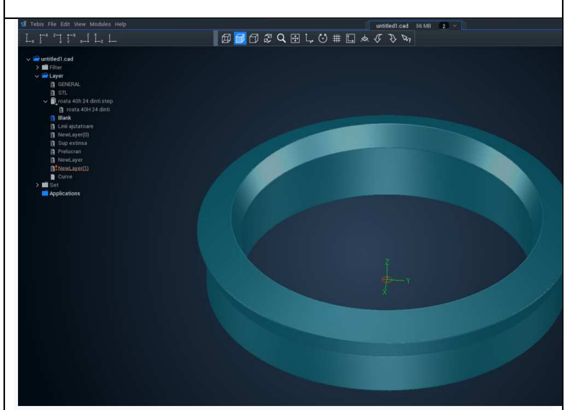

Figure 4. 3D model of a gear blank.

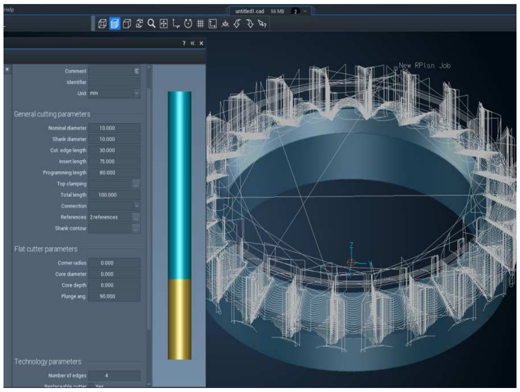

Figure 5. Implementation of the recommended wheel processing strategy.

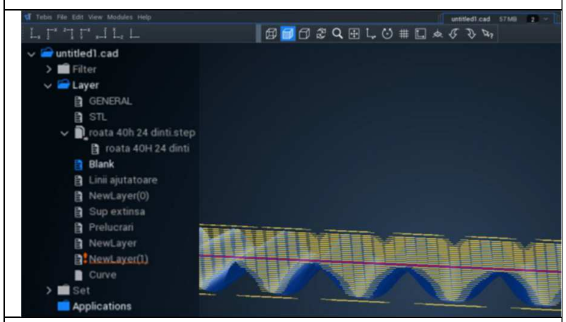

Figure 6. Technological phases of the roughing operation.

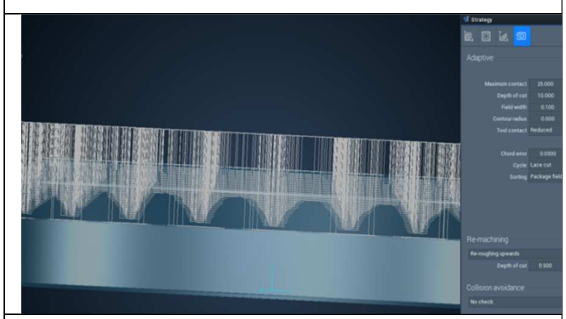

Figure 7. Working and idle strokes of the tool in the black operation.

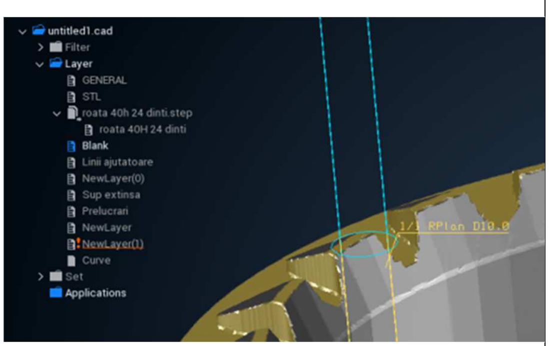

Figure 8. The first roughing pass.

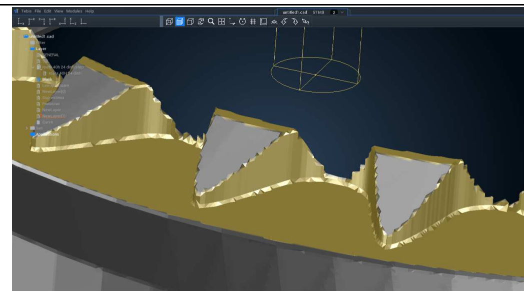

Figure 9. The result of first roughing.

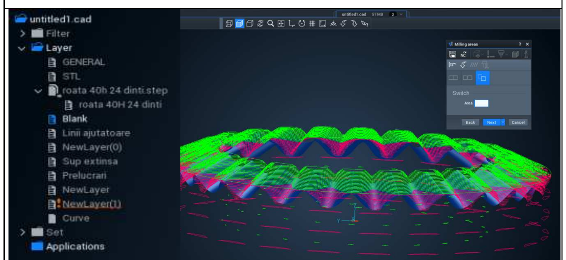

Figure 10. The two-separate surface of the teeth.

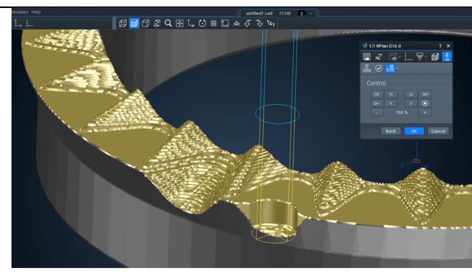

Figure 11. 3D image of the method of forming teeth in the elements.

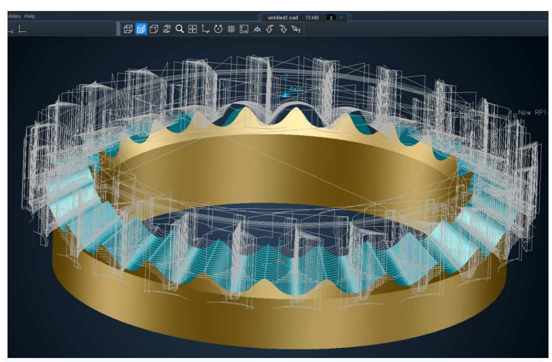

Figure 12. Cutting tool paths.

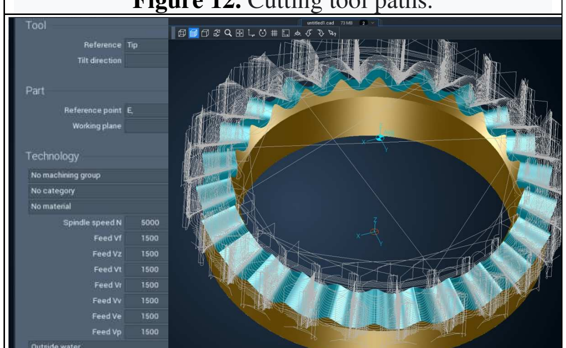

Figure 13. The cutting tool parameters.

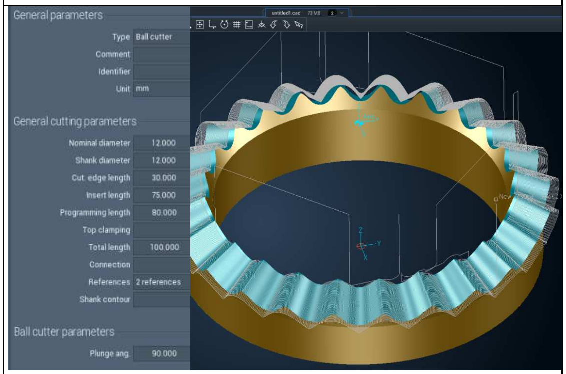

Figure 14. "Equidistant milling" strategy and the ball mill cutting tolls definition.

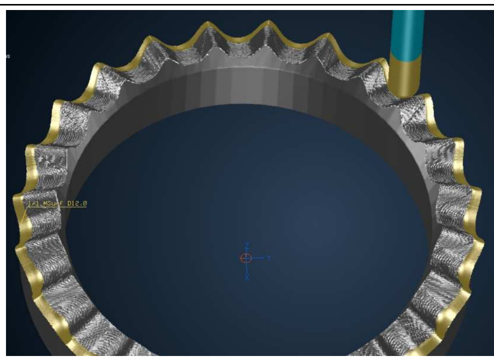

Figure 15. The tool path generation

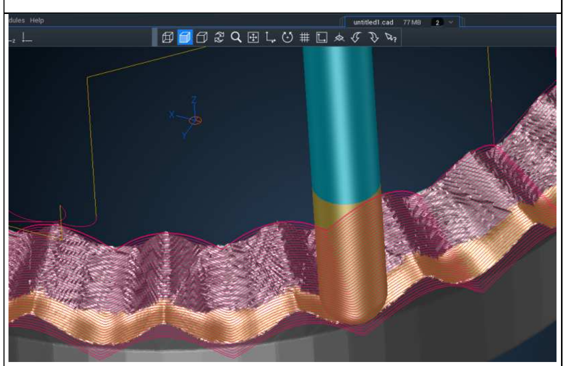

Figure 16. Detail of a second operation: semifinishing.

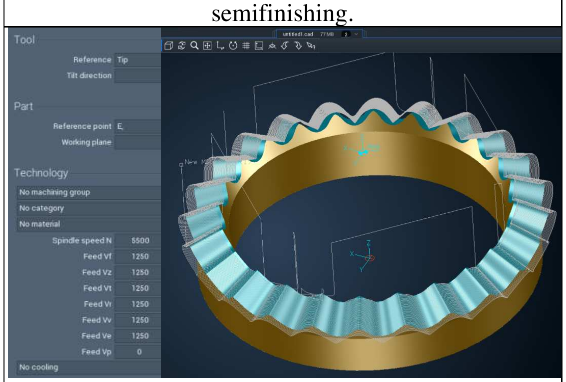

Figure 17. The cutting tool paramenters using at semifinishing operation

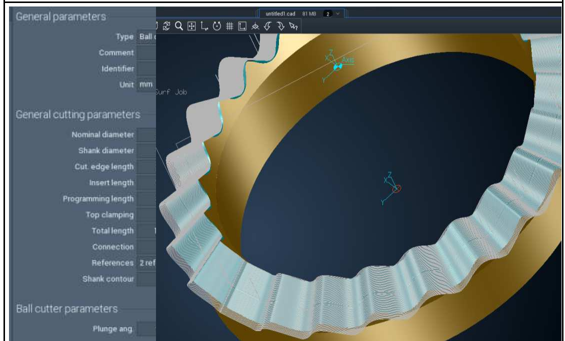

Figure 18. Finishing tool.

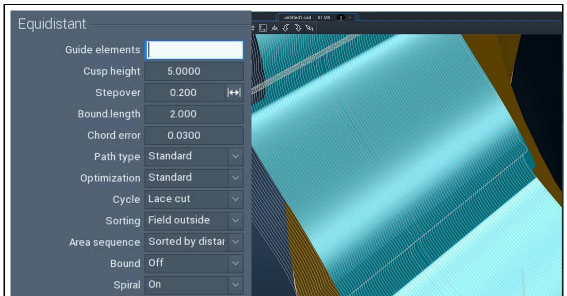

Figure 19. Definition of the "Equidistant milling" strategy with the step over 0.2 mm.

Determining the Directory for Saving the CAM-Part.

Step 2: Determine where the CAM data will be stored and create the CAM-Part.

Selecting the CNC-Machine Controller.

Step 3: Having determined the CAM part, we select the machine controller. In our case, was HAAS milling center in three axes, with HAAS numerical control. Defining the Machine Coordinate System.

Step 4: Create a coordinate system.

To define the CAM steps needed to define the coordinate system. The machine system determines the origin for all operations on the CAM part. This will allow the controller function to be defined (eg G54). The constant Z coordinate system is restored. Defining the Stock and Target Models.

Step 5: Define the Stock and Target models. The stock model was imported after this was scanned before (Figure 4).

Adding the firs Milling Operation (1st Setup).

Step 6: Add the operations required to machine the part.

As a rule, the tool contact width plays an important role in the choice of cutting speed and work piece feed. Machining across the entire width of the tool is often unavoidable, despite the design of the part. The feed per tooth of the tool during stock removal increases where the edges on the internal contours are located.

a) Contour processing is associated with tool path calculation with parallel contour technology where it is possible to create discontinuous (curved) surfaces and tool paths with maximum tool loads.

This technology has been specially developed for the tool when removing the maximum allowance of material. This technology allows you to choose the optimal value of cutting conditions to achieve the specified value of the parameter R. Using the maximum contact of the tool. Avoid overloading the tool. This allows maximum use of the entire active surface of the tool without exceeding the maximum loads.

One of the advantages of this technology is the highest cutting speed, which allows an increase in tool life, which affects the settings and determines the strategy setting.

The cutting tool what was used was : carbite end mill with 4 teeth and Ø 10 mm diameter. (Figure 5).

This technology uses a method of processing a part, which is based on the division of the transitions of processing the teeth into two phases in depth with a maximum allowance: 10 mm - using milling technology. (Figure 7 and Figure 8) to reduce tool wear. The result of this first transition is presented in (Figure 9). The contact between the tool and the work piece is 25% in diameter; we will use this data for the next roughing transition to remove machining errors. (Figure 10)

In Fig. 11 was presented with two colors (green and red) the two surfaces of teeth and the modality how was manufacturing. In (Fig. 12) the 3D print view of the manufacturing. In (Figure 13) is present the trajectories of the cutting tool and in (Figure 14) the cutting tool parameters:

Rotation speed -5000 rot/min;

Feed - 1500 mm/min;

Depth of cut - 10mm;

Finger milling cutter 2, with radius R6, with tooth finish selected for milling this surface (Figure 15).

In (Figure 16) the semi-finishing operation is presented and in (Figure 17) the cutting tool parameters using at semi-finishing operation.

Because a high surface quality can be achieved with a maximum machining allowance, this surface quality can be achieved in one continuous machining step, even for complex parts. The load on the tooth does not affect the bending of the cutter.

The finishing operation is a finishing operation, where the machining is done using an R3 radius end mill with two teeth (figure 18) and the “incremental milling” milling technique is used, but this time the pitch was defined as 0.2 mm. (Figure 19).

3. CONCLUSIONS

A method for shaping the lateral surface of the teeth of gear wheels with disk and finger sphero-conical cutters has been developed (Figure 20).

A tool has been developed for the implementation of the profile modification of the gear teeth, which makes it possible to take into account the following errors in the manufacture and deformation of the teeth under load in the shape of the cutting edge of the tool: gear profile error, error in the pitch of the teeth, radial and tangential deviation of the gear, roughness of the lateral surface of the teeth, displacement of the teeth under load.

The technological feasibility of practical implementation of shaping by milling teeth of precession gears with variable tooth height on three-axis CNC processing centers has been proved. Control programs have been developed for processing teeth on a three-axis milling processing centers using the proposed shaping kinematics for gear.

Generally, the basic treatment of a wheel depends on the specific gearing geometry, material, surface heat treatment, and available tools and equipment. Machining allowances, as well as cutting data, must be precisely matched to the online machining strategy.

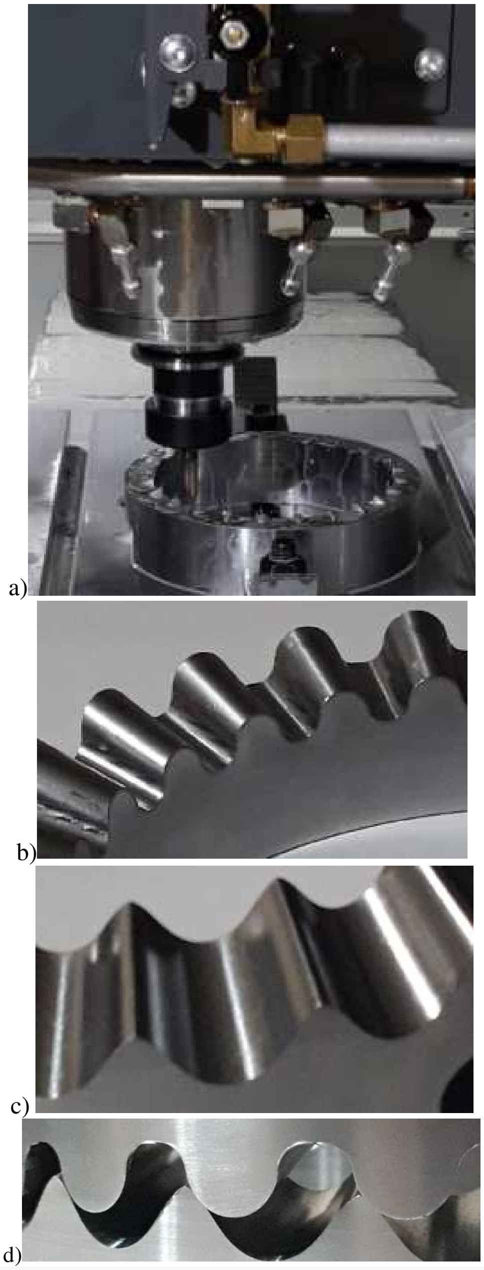

Figure 20. CNC machining center for milling gear teeth with a finger mill (a), internal gear wheel (b) external gear wheel (c), meshing gears (d).

In the experimental research, it was compared different ways processing under consideration of part geometry and the technology parameters.

As results, one may say that the right consecutive order is critical.

The processing technology presented above with the help of a finger cutter with a radius at the top comes on the basis of the technology of grinding the engagement with a profiled disc-like coating, which provides precessional movement, as in the first engagement [20], in terms of processing accuracy, roughness and productivity. The final grinding of teeth with precessional heat treatment mechanisms provides an accuracy of 5-6 in:

- deviations that allow the profile of the teeth f_f;
- Tooth end runout tolerance F_f:
- minimum deviation of the f_{pb}. engagement pitch.

Grinding with precessional engagement easily provides a roughness of about 0.2 µm, depending on a variety of cutting data parameters, with a finger cutter this roughness is difficult to achieve

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O soluție tehnologică nouă pentru fabricația angrenajului precesional cu profil nestandard

Toate domeniile științei nu stau pe loc și se dezvoltă. Revoluția industrială presupune o nouă abordare a producției, bazată pe introducerea în masă a tehnologiilor informaționale, aceasta se referă și transmisiilor mecanice cu angrenaje și mai precis angrenajelor planetare precesionale. Implementarea acestor angrenaje presupune studiul cercetării științifice în domeniul tehnologiei de fabricare a angrenajului precesional. Au fost create mai multe tehnologii, pentru producția de masă și de serie mare. Articolul dat prezintă o nouă metodă pas cu pas pentru fabricarea angrenajelor pentru producția la scară mică pe centrele de prelucrare CNC. Se prezintă rezultatele tehnologiei propuse și pașii următori care au fost parcurși la proiectarea procesului de prelucrare a angrenajului precesional. Au fost identificate Părțile CAM care au fost realizate în software CAD, apoi cu ajutorul CAM, s-a obținut o nouă tehnologie de procesare a angrenajului.

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