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A GRAPHIC VARIANT TO PROFILE TOOLS FOR THE GENERATION BY WINDING OF SURFACES -PROFILING OF THE ROTATIVE-CUTTER -

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ABSTRACT

This work presents a graphic variant to study the winding problems of the wires of profiles, specific when generate by rotative-cutters. It is underlined the cinematic of the generation process by rotative-cutters and are presented the motion equations. There are treated two examples of application using the numerical identification programme of the resulted enveloped profile:
- rotative-cutter's profiling for the generation of a trapezoidal thread;
- rotative-cutter's profiling for the generation of a screw with balls.
The programmes used to determine the relative positions of the generating flank and the "numerical identification" were realized in AutoLISP programming language.

1. INTRODUCTION

The rotative-cutters are tools especially used to generate by winding the axial profiles of screws on specialized lathes – lathes to process the guide-screws of tool – machines – or on auto-lathes to generate the threads of small depth and coarse. As well as that of the revolution surfaces profiles, see figure 1.

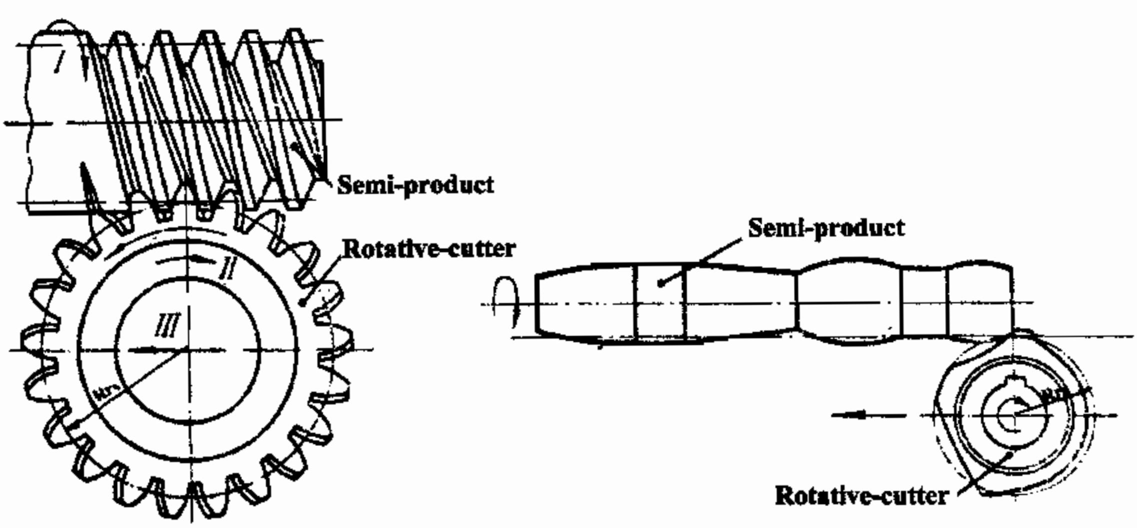

Fig.1. The principle of generation by the rotative-cutters

Based on the fundamental theorems of generation by winding – GOHMAN method, Willis theorem, [1], - and those of the analytic methods – " minimum distance "

[2], the family of " substituting circles " [3], trajectories method [4]- are known the specific algorithms to profile tools like the rotative-cutter.

On the following lines, it is suggested a graphic variant to study the problems of winding the wires of profiles, specific when generate with rotative-cutters, based on AutoLISP programming medium, combined with original soft-products – created especially on this purpose.

2. THE GENERATION'S PROCESS SPECIFIC KINEMATIC

As it is known, at the generation of threads axial sections by rotative-cutters are defined two centroids in rolling:

- C_1 is the rectilinear centroid, associated to the wire of axial profiles of the thread to be generated;
- C_2 – circular centroid associated to the rotative-cutter, see figure 2.

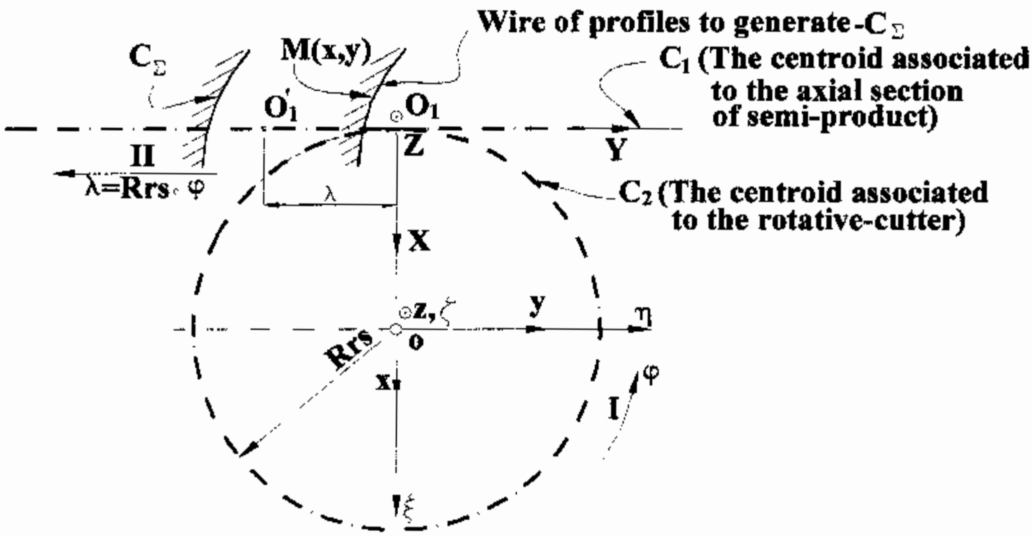

Fig. 2. Centroids in rolling, systems of reference

There are defined the systems of reference:

xyz is the fixed system of reference, having axis **z** as rotation axis of the centroid C_2;

XYZ – mobil system, solidary to the wire of profiles **Σ**, having the plane **XY** superposed to **xy**;

$\xi\eta\zeta$ – mobil system, solidary to the centroid C_2 of the rotative-cutter.

The generation process supposes the achievement of the ensemble of motions:

I – rotation of the rotative-cutter around his own axis (axis ζ), of parameter φ;

II – translation of profiles wire representing the semi-products axial section, of parameter λ.

The rotation motion of the system $\xi\eta\zeta$, and solidary to it, of the rotative-cutter, is described by the transformation:

$$x = \omega_3^T(\varphi)\cdot\xi. \tag{1}$$

Translation of the system **XYZ**, solidary to the centroid C_1, is

$$x = X + a\ ,\quad a = \begin{Vmatrix} -R_{rs} \\ -R_{rs}\cdot\varphi \\ 0 \end{Vmatrix}, \tag{2}$$

The matrix " **a** " represents, the point O_1 coordinates, after translation, in the fixed reference system.

In this ensemble of absolute motions, can be established, taking into consideration the specific condition of rolling of two centroids

$$\lambda = R_{rs}\cdot\varphi\ , \tag{3}$$

the relative motion of the profile to generate C_Σ face to the reference system of the rotative-cutter,

$$\xi = \omega_3(\varphi)\cdot\left[X + a\right], \tag{4}$$

or, by development,

$$\begin{Vmatrix}\xi\\\eta\end{Vmatrix}=\begin{Vmatrix}\cos\varphi & \sin\varphi\\-\sin\varphi & \cos\varphi\end{Vmatrix}\cdot\left[\begin{Vmatrix}X\\Y\end{Vmatrix}+\begin{Vmatrix}-R_{rs}\\-R_{rs}\cdot\varphi\end{Vmatrix}\right],$$

(5) and, in continuation,

$$\begin{aligned}\xi&=[X-R_{rs}]\cdot\cos\varphi+[Y-R_{rs}\cdot\varphi]\cdot\sin\varphi;\\ \eta&=-[X-R_{rs}]\cdot\sin\varphi+[Y-R_{rs}\cdot\varphi]\cdot\cos\varphi.\end{aligned}\tag{6}$$

The equations of motion (6), in the conditions of knowing, in discrete expression, the profile to generate C_Σ, as

$$C_\Sigma=\begin{Vmatrix}X_1 & X_2 & . & . & . & X_n\\Y_1 & Y_2 & . & . & . & Y_n\end{Vmatrix}\tag{7}$$

(with X_1, Y_1, X_2, Y_2, ... coordinates of the points belonging to the profile Σ) allow the description in AutoCAD programming medium of the trajectories family C_Σ, in the reference system of the tool – the rotative-cutter .

The numerical identification of the rotative-cutter's profile, resulted as an envelope of profile's C_Σ relative positions in motion (6), is made on the basis of an original soft [6], that determines, with sufficient accuracy, coordinates all along the profile **S** of the tool.

If, now, it is considered a geometrical place in the space **XY** , be it formed by all the points belonging to a surface of the profiles wire Σ ,

$$\Sigma: X=X(u); Y=Y(u),\tag{8}$$

with **u** – variable parameter, then, the equation (6) can be retranscribed as:

$$(T_u)_\varphi\begin{vmatrix}\xi=[X(u)-R_{rs}]\cdot\cos\varphi+[Y(u)-R_{rs}\cdot\varphi]\cdot\sin\varphi;\\ \eta=-[X(u)-R_{rs}]\cdot\sin\varphi+[Y(u)-R_{rs}\cdot\varphi]\cdot\cos\varphi.\end{vmatrix}\tag{9}$$

The equations (9), represent the trajectories family of points belonging to the profile Σ of the wire, in the relative motion of the reference system of the profile to generate face to the reference system of the tool.

The envelope of this family of profiles is the rotative-cutter's profile – profile **S** unrepresented in figure 1. Profile **S** represents the cross profile of the rotative-cutter, used to lathe the repeatable or helix profiles of revolution.

2.1. Algorithm of graphic identification

In order to determine the enveloping profile, it can be realized in AutoLISP programming medium, a calculus programme, dedicated to this problem, which, for a known profile, by equations as (5), to permit, for a sufficiently small pitch of the variable "ξ" and a satisfactory large interval of parameter φ , to trace the trajectories (6), and, then, to "identify" the enveloping profile.

"Identification" of the enveloping profile, is made using subroutine AGI (Algorithm of Graphic Identification) especially created, in an AutoLISP language.

The subroutine logic is based on "space ξη scanning", associated to the rack-tool, space where is defined the profiles family Σ , too. See figure 2.1.

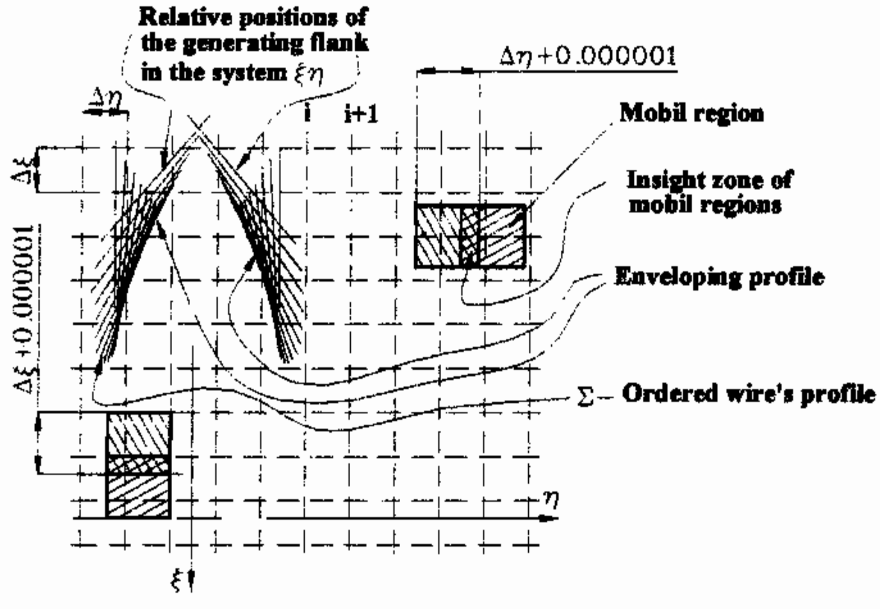

Fig.3. Scanning the ξη space with AIG

On an imaginary "grid", of pitches $\Delta\xi$ and $\Delta\eta$, small enough, it is searching for the "first contact" with one of the profiles Σ. The line **i**, of the grid, is run through, the positive direction of the axis $O\xi$, by a rectangle zone, of sides
$l_1 = \Delta\xi + 10^{-6}$ **mm** and $l_2 = \Delta\eta + 10^{-6}$ **mm**. It is checked, to each change of place of $\Delta\xi$ ($\Delta\xi = 10^{-3}...10^{-4}$ **mm**), for the existence in this region of the **"Polyline"** entity, by who was traced the profiles family Σ. If the existence of this entity is confirmed the coordinates of the respective point are introduced in **"scan1.txt"** file and restarts the scanning on the next line, the line **i+1**.

Due to the fact that the field that forms the mobil region is of sides bigger with 0,000001mm than the size of displacements $\Delta\xi$ and $\Delta\eta$ we are certain that the entire space $\xi\eta$ is rigorously ran and there is no possibility of an error in the enveloping profile's identification (see insight zones, figure 2.1.).

The existence of insight zones certifies that to each displacement $\Delta\xi$, is scanned again a portion of the region previously scanned. So, there will be no surface in the space $\xi\eta$ to contain a portion of the enveloping profile left unsubjected to the identification process.

The coordinates $\xi\eta$ from the file **"scan1.txt"** representing the abscissas, respective the ordinates of points placed the enveloping profile are counterized, following than, by reading the file **"scan1.txt"**, may be traced the enveloping profile.

3. EXAMPLES OF APPLICATION

There are suggesting in the following lines, two examples of graphic algorithm, **coupled** with the numerical identification programme of the resulted enveloped profile.

3.1. Profiling the rotative-cutter in order to generate a trapezoidal thread

In figure 4, are presented the axial section form of threads profile, and the reference systems.

Are defined in parameter form, the equations of the axial section's profile to generate:

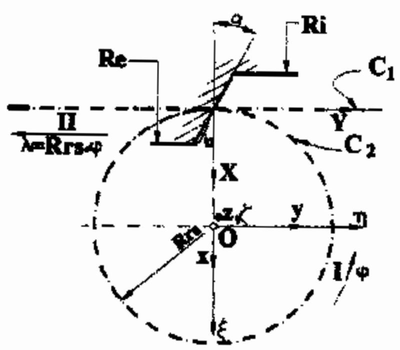

Fig.4. Axial section's profile of the trapezoidal worm

$$X = u \cdot \cos\alpha; \quad Y = -u \cdot \sin\alpha. \qquad (10)$$

that, for an incremental variation, conveniently chosen, of the paramêter "**u**" between limits

$$u_{max} = \frac{R_e - R_i}{2 \cdot \cos\alpha}; \; u_{min} = -\frac{R_e - R_i}{2 \cdot \cos\alpha}, \qquad (11)$$

establishes the coordinates matrix (7) of the axial profile - C_Σ - of the trapezoidal screw.

Based on the presented algorithm and on the " numerical identification " programme of the profile enveloped by C_Σ, in figure 6 and table 1, are presented both the rotative-cutter's profile form and its coordinates, for the case R_e=42 mm; R_i=36 mm; α=20^0;R_{rs}=50 mm.

The rolling radius R_{rs} of the centroid associated to thê tool,

$$R_{rs} = \frac{p_{ax}}{2 \cdot \pi} \cdot z, \qquad (12)$$

is established knowing:

- p_{ax} is the axial coarse of the screw to generate;
- **z** – number of teeth of the cutter-wheel.

The antiomolg flank is obtained by symmetrization of the identified profile of the tool, figure 5.

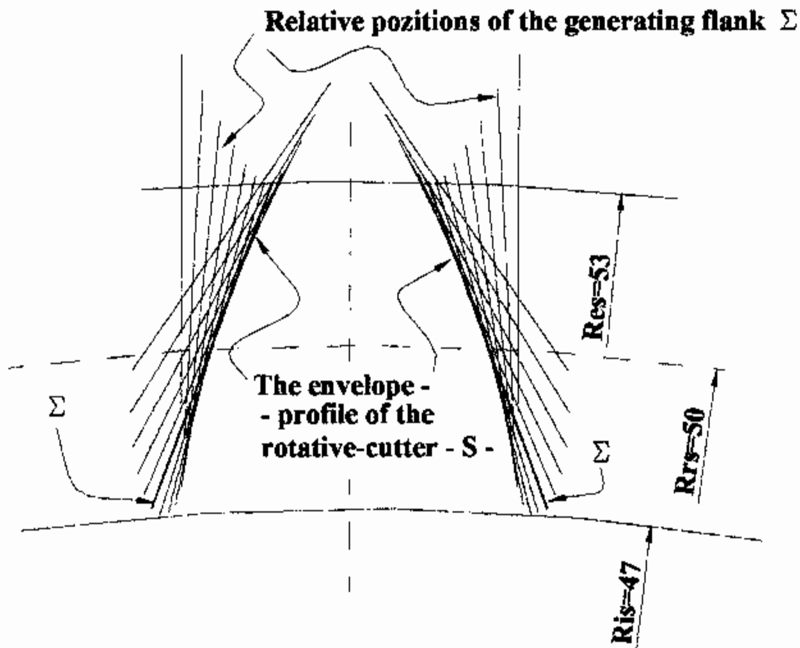

Fig. 5. Rotative-cutter's profile form

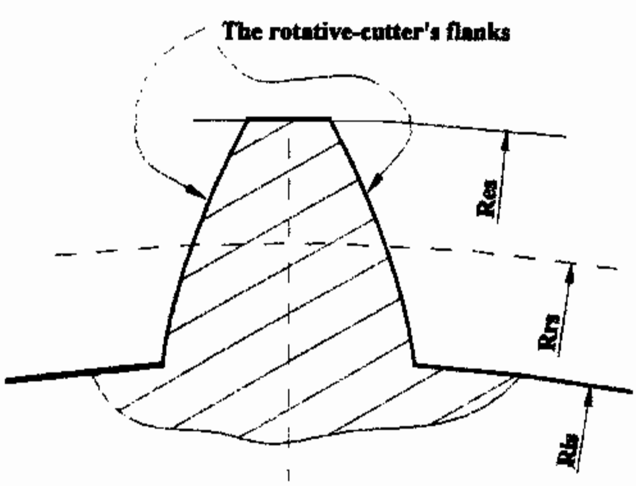

Fig.6. "Numerical identified" profile of the rotative-cutter

Table 1

Nr.Crt.	Identified coordinates of the rotative-cutter flank	
	ξ[mm]	η[mm]
0	-52.972	-1.27816
50	-52.343	-1.57584
110	-51.6252	-1.88769
170	-50.9511	-2.153
230	-50.3224	-2.3752
290	-49.7418	-2.55789
350	-49.2105	-2.70472
410	-48.731	-2.81939
470	-48.3043	-2.9057
530	-47.9319	-2.96755
590	-47.6049	-3.01042

3.1.1. Interference of profiles

A specific problem of generation by winding of profiles associated to some centroids in rolling is the problem of profiles interference (primary or secondary).

Next, it is examined the interference defined as an intersection of the profile to generate Σ of the semi-product and the trajectory of tool's peak **V** -the rotative-cutter, figure 10.

In consequence, knowing the equations of the profile Σ

$$\Sigma: \; X = X(u); \quad Y = Y(u). \tag{14}$$

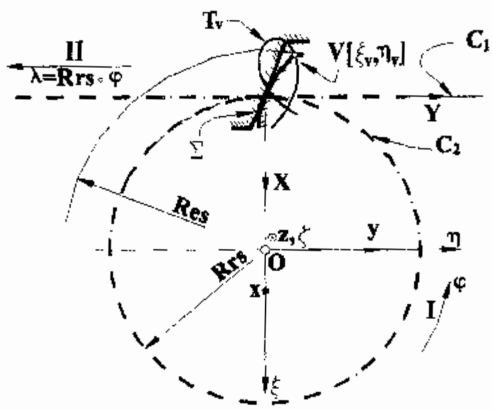

Fig.7. The trajectory of interference

as well as the rotative-cutter's peak trajectory **V**[ξ_v,η_v], in the relative motion of the tool face to the semi-product,

$$X = \omega_3^T(\varphi)\cdot[\xi - a]. \quad (15)$$

or,

$$\left\|\begin{matrix}X\\Y\end{matrix}\right\| = \left\|\begin{matrix}\cos\varphi & -\sin\varphi\\ \sin\varphi & \cos\varphi\end{matrix}\right\| \cdot \left\|\begin{matrix}\xi_v\\ \eta_v\end{matrix}\right\| - \left\|\begin{matrix}-R_{rs}\\ -R_{rs}\cdot\varphi\end{matrix}\right\|, \quad (16)$$

results the interference trajectory of the rotative-cutter's peak.

$$T_v\left|\begin{aligned}X &= \xi_v\cdot\cos\varphi - \eta_v\cdot\sin\varphi + R_{rs};\\ Y &= \xi_v\cdot\sin\varphi + \eta_v\cdot\cos\varphi + R_{rs}\cdot\varphi.\end{aligned}\right. \quad (17)$$

The interference conditions of the two profiles are determinated:

$$\left|\begin{aligned}X(u) &= \xi_v\cdot\cos\varphi - \eta_v\cdot\sin\varphi + R_{rs};\\ Y(u) &= \xi_v\cdot\sin\varphi + \eta_v\cdot\cos\varphi + R_{rs}\cdot\varphi.\end{aligned}\right. \quad (18)$$

The ensemble of the two equations, graphic interpreted, establishes the intersection point (if exists), of the trajectory $\mathbf{T}_v$ of tool's peak and the semi-products profile- Σ .

In figure 8, it is presented, for the analyzed case, the relative position of the profile Σ as well as the trajectory $\mathbf{T}_v$ of tool's peak.

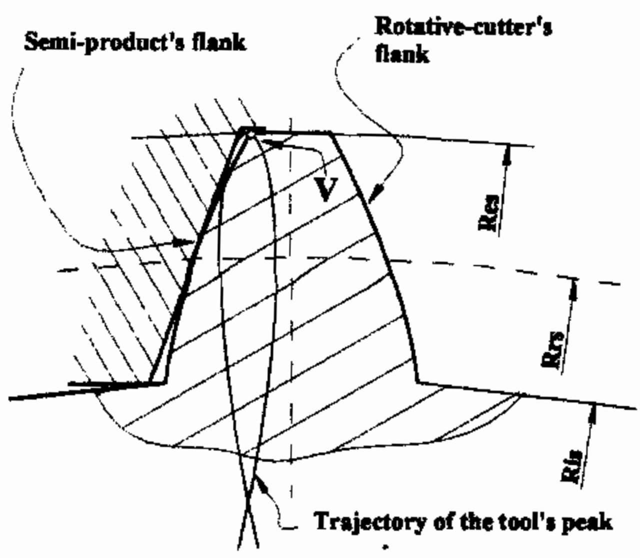

Fig.8. Trajectory T_v of the tool's peak.

It is obviously, after the numerical identification of the contact point of Σ and $\mathbf{T}_v$ that there is no interference but at the base of the profile to process appears a passing curve - $\mathbf{C}_v$.

Observation:

For the real tool, the depth of the tooth peak is bigger than ($\mathbf{R}_{es}$-$\mathbf{R}_{rs}$)=**a**. In consequence, the point representing the tool's peak represents the intersection between the determined profile of the tool and the circle $\mathbf{R}_{es}$.

$\mathbf{R}'_{es} = \mathbf{R}_{es} + \Delta$, Δ - a value representing the tolerance.

3.2. Profiling the rotative-cutter in order to generate a screw with balls

In figure 9, is presented the axial profile of the screw with balls – pointed profile.

Also, in figure 10, are presented the reference systems and the centroids associated to the profile to generate.

The parameter equations of the pointed profile's flank of the ball-screw (screw with balls) are:

$$X = e - r \cdot \sin v; \quad Y = n - r \cdot \cos v. \qquad (19)$$

that for an incremental variation of parameter "v" between limits

$$v_{min} = \arcsin\left[\frac{e-(R_e-R_i)}{r}\right]; \quad v_{max} = \arccos\left[\frac{n}{r}\right]. \qquad (20)$$

with e, R_i, R_e, n, r – constant, it is established the matrix of coordinates for the profile to generate - C_Σ (7).

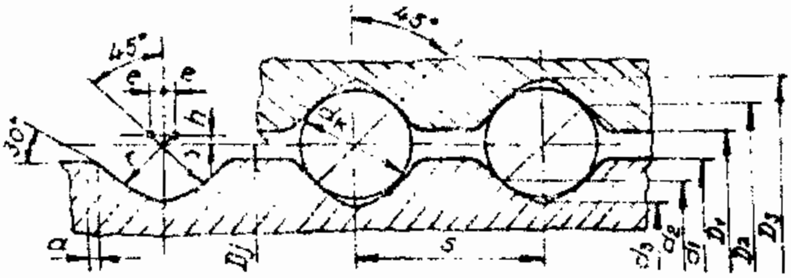

Fig.9. Profile of the screw with balls

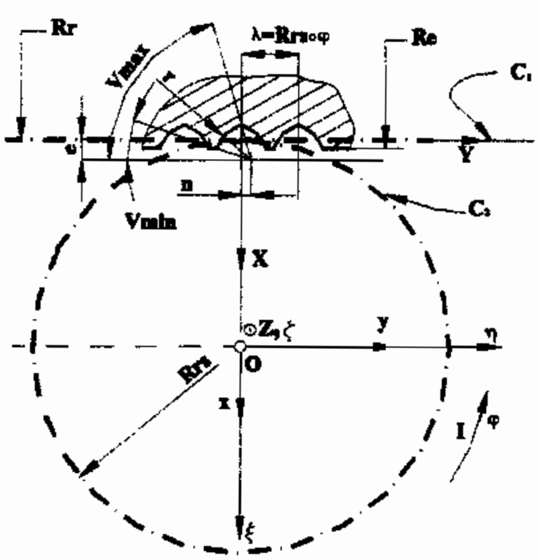

Fig.10. Reference systems for the processing of ball-screw

In figure 11, are presented the relative positions of the profile C_Σ in the system ξη of the rotative-cutter. In figure 12, is represented the " numerical identified " profile of the cutter-wheel, obtained by symmetrization, for the case: e=0,17 mm; n=0,155 mm; R_e=24 mm; R_r=25 mm; r=5,4 mm.

In table 2, are given the results from the numerical identification of the rotative profile.

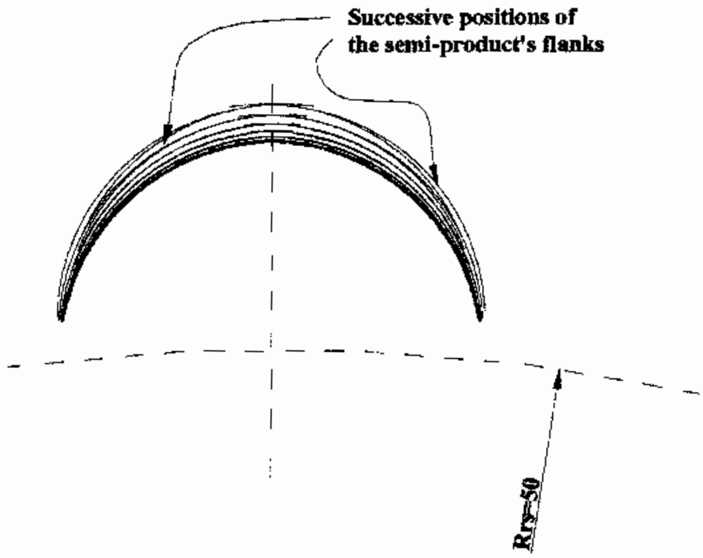

Fig.11. Relative positions of the profile C_Σ in the tool system

Table 2

Nr. Crt.	Identified coordinates of the totative-cutter's flank	
	ξ[mm]	η[mm]
0	-51.02641	-5.113637
9	-51.469378	-4.991821
21	-52.055633	-4.765834
33	-52.61808	-4.469743
45	-53.145785	-4.107042
57	-53.627842	-3.683378
69	-54.057333	-3.204299
81	-54.427437	-2.677105
93	-54.731965	-2.109176
105	-54.967168	-1.508508
117	-55.129008	-0.883596
132	-55.224679	-0.083175

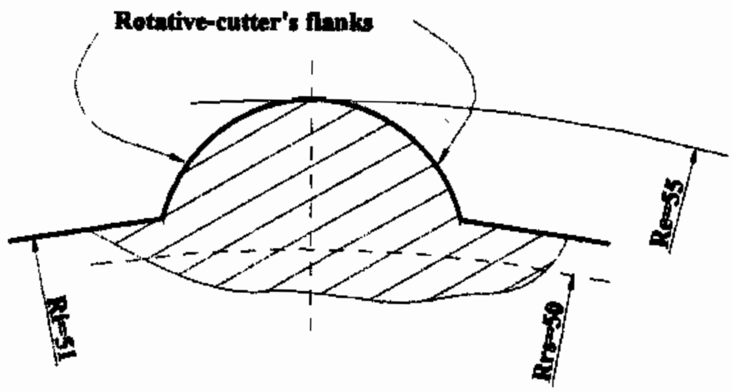

Fig.12. Numerical identified profile of the rotative-cutter

4.CONCLUSIONS

The graphic method for the study of winding processes specific to the generation with rotative-cutters allows the establishment with a precision of 10^{-4} mm of the rotative-cutter's profiles.The method can be used for the cases where the profiles to generate are given by a finite number of points (coordinates) that doesn't belong to a curve of known analytic expressions, too.

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O VARIANTA GRAFICA A PROFILARII SCULELOR PENTRU GENERAREA PRIN INFASURARE A SUPRAFETELOR - PROFILAREA CUTITULUI ROTATIV-

(Rezumat)

Lucrarea prezinta o varianta grafica pentru studiul problemelor de infasurare a vartejurilor de profiluri, specifice generarii cu cutite-rotative.

Este pusa in evidenta cinematica procesului de generare cu cutite-rotative si sunt prezentate ecuatiile de miscare.

Sunt tratate doua exemple de aplicare utilizandu-se programul de "identificare numerica" a profilului infasurat rezultat:

-profilarea cutitului-rotativ pentru generarea unui filet trapezoidal;

-profilarea cutitului-rotativ pentru generarea unui surub cu bile.

Programele utilizate pentru determinarea pozitiilor relative ale flancului generator si "identificarea numerica" au fost realizate in limbajul de programare AutoLISP.

UNE VARIANTE GRAPHIQUE POUR PROFILER DES OUTILS POUR LA GÉNÉRATION PAR DES SURFACES D'WINDING OF - PROFILAGE DU ROTATIVE-COUPEUR –

(Resume)

Ce travail présente une variante graphique pour étudier les problèmes d'enroulement des fils des profils, détail quand produisez-vous par des rotative-coupeurs.

Il est souligné le cinématographique du procédé de génération par des rotative-coupeurs et est présenté les équations de mouvement. On traite deux exemples d'application en utilisant le programme numérique d'identification du profil enveloppé donné droit:

- rotative-coupe profilant pour la génération d'un filet trapézoïdal;

- profilage rotative-cutter`s-cutter`s pour la génération d'une vis avec des boules.

Les programmes employés pour déterminer les positions relatives du flanc se produisant et "de l'identification numérique" ont été réalisés en langage de programmation d'AutoLISP.