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Method of the Generation Trajectories Comparison Between the Gohman Method and the Generation Trajectories's Method

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ABSTRACT

The profiling of the revolution peripheral primary surfaces edged tool may be made from various methods (GOHMAN [1], [2], NIKOLAEV [2], "minimum distance" [4], "substitutive circles family" [5], [6], solid modeling [7]). In this paper, we made the comparison between the results obtained from Gohman method and the method of "the generation trajectories". It was considered the rack-gear tool for profiling a squared crossing shaft, a circle's arc profile, the gear-shaped cutter tool used for profiling a squared bush and the rotary-cutter tool used for profiling an Archimedes's screw.
***Keywords**: profiling, the generation trajectories, the revolution peripheral primary surfaces.*

1. Introduction

Regarding that the method of the generation trajectories is a new method, we proposed to verify the results obtained from this methods by comparing the results with those obtained from a classical method (the GOHMAN method). The comparison was made for the following types of tools:

-the rack-gear tool; it was generated the tool's profile for a square crossing section of a shaft and for a circle's arc zone profile;

-the gear-shaped cutter tool; it was generated the tool's profile for the square bore of the bush;

-the rotary-cutter tool; it was generated the tool's profile for the Archimedes's screw.

The software that was used for the generation trajectories method was own software, which allows the calculation of these 3 types of tool above presented for the general case. The software was elaborated in AutoLISP language, and allows running inside of the AutoCAD software.

For this method we proposed a discreet representation of profile, based on the linearization of the curve's segments between two successive points of this, see figure 1, were M_i, M_{i+1}, M_{i+2} are successive points determinates on this curve.

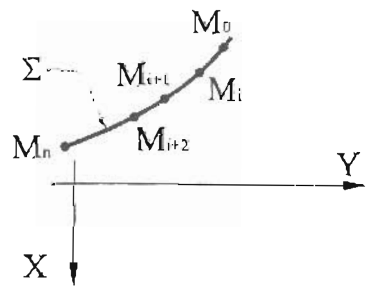

Figure 1. The curve's segment linearization

If in XY reference system are defined the "discreet" coordinates of the profile, as a matrix with form

$$\Sigma = \begin{Vmatrix} X_1 Y_1 \\ X_2 Y_2 \\ \vdots \\ X_i Y_i \\ X_{i+1} Y_{i+1} \\ \vdots \\ X_n Y_n \end{Vmatrix} \qquad (1)$$

where

$$\left|\sqrt{(X_{i+1} - X_i)^2 + (Y_{i+1} - Y_i)^2}\right| \le \varepsilon;$$
$$(\varepsilon = 10^{-2} \cdots 10^{-3})$$

with enough small value for ε, then, according with the enunciated idea, the arc between $M_i(X_i,Y_i)$ and $M_{i+1}(X_{i+1}, Y_{i+1})$ points can be linearized as a segment, as see in figure 2.

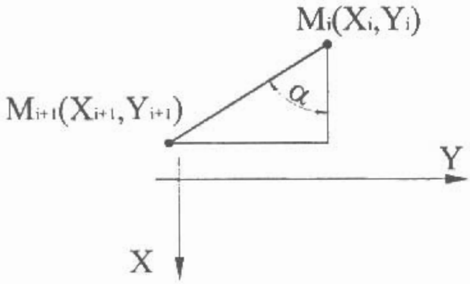

Figure 2. Replacement by straight segment

The flank of the piece's profile is divided into segments with equal length, and the equation of each segment will be:

$$\Sigma : \begin{vmatrix} X = X_i + u \cos\alpha; \\ Y = Y_i - u \sin\alpha, \end{vmatrix} \qquad (2)$$

with u variable parameter, between

$$u_{min} = 0;$$

$$u_{max} = \left| \sqrt{(X_i - X_{i+1})^2 + (Y_i - Y_{i+1})^2} \right| \qquad (3)$$

$$tg\alpha = \frac{|Y_{i+1} - Y_i|}{|X_{i+1} - X_i|}.$$

For the tool's profiling from the Gohman method was elaborated characteristics software for each type of tool, using the PASCAL language.

For each profile was obtained two suits of values which represent the tool's points coordinates.

We consider as reference the points obtained by Gohman method and we calculated the distance between this points and the points calculated by generation trajectories method. This distance was considered as error of the method, see figure 3.

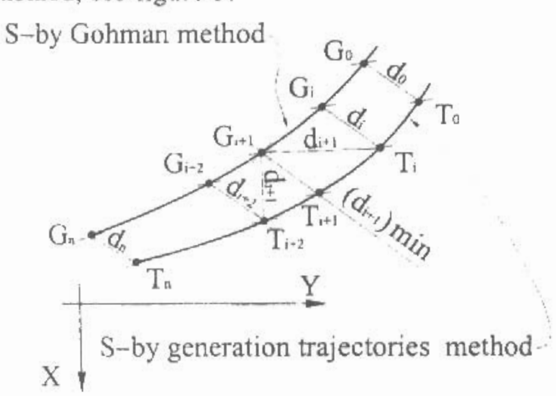

Figure 3. The errors representing

II. The rack-gear tool's profiling

II.1. Rack-gear tool's for straight segment profiling

In figure 4.a, are present the reference systems associated with piece and rack gear tool:

XY is the reference system joint to C_1 piece's centroid;

ξη is the reference system joint to C_2 tool's centroid;

xy is the fixed system.

We consider a splined shaft with this dimensions: Rr=Re=40 mm; Ri=30 mm; b=10 mm.

The flank of the spline is divided into 10 segments with equal length, and the equation of each segment will be (for α=0):

$$\Sigma : \begin{vmatrix} X = X_i + u; \\ Y = Y_i, \end{vmatrix}$$

with u variable parameter (see equation 3)

The coordinate conversion between XY and ξη coordinate systems will be:

$$\xi = \omega_3^T(\varphi) \cdot X - a;$$

$$X = \omega_3(\varphi) \cdot [\xi + a],$$

with $a = \begin{Vmatrix} -R_r \\ -R_r \cdot \varphi \end{Vmatrix}$.

In this way, we obtain the coordinates of the points which belongs of the tool's profile:

$$\Sigma : \begin{vmatrix} \xi = X_i \cdot \cos\varphi - Y_i \cdot \sin\varphi - u \cdot \cos\varphi + R_r; \\ \xi = X_i \cdot \sin\varphi + Y_i \cdot \cos\varphi - u \cdot \sin\varphi + R_r \cdot \varphi. \end{vmatrix}$$

The wrapping condition is obtained from equation

$$\frac{\xi'_u}{\xi'_\varphi} = \frac{\eta'_u}{\eta'_\varphi}$$

which, after development is

$$\varphi = \arccos\left(\frac{u - X_i}{R_r}\right).$$

The proof was made by Gohman method, based on the following equations:

$$\Sigma : \begin{vmatrix} X = -u; \\ Y = b, \end{vmatrix}$$

with u, variable parameter;

$$u_{max} = \sqrt{R_e^2 - b^2}; \quad u_{min} = \sqrt{R_i^2 - b^2}.$$

The coordinates of the points that belongs of the tool's profile will be:

$$\Sigma : \begin{vmatrix} \xi = -u \cdot \cos\varphi - b \cdot \sin\varphi + R_r; \\ \eta = -u \cdot \sin\varphi + b \cdot \cos\varphi + R_r \cdot \varphi. \end{vmatrix}$$

The wrapping condition is obtained from equation

$$\vec{N}_\Sigma \cdot \vec{R}_\varphi = 0.$$

where

$$\vec{N}_\Sigma = \begin{Vmatrix} 0 \\ 1 \end{Vmatrix}$$

and

$$\vec{R}_\varphi = \begin{Vmatrix} b - R_r \cdot \sin\varphi \\ u - R_r \cdot \cos\varphi \end{Vmatrix}.$$

After development it results

$$\varphi = \arccos\left(\frac{u}{R_r}\right).$$

The coordinates obtained from these 2 methods are showing in table 1.

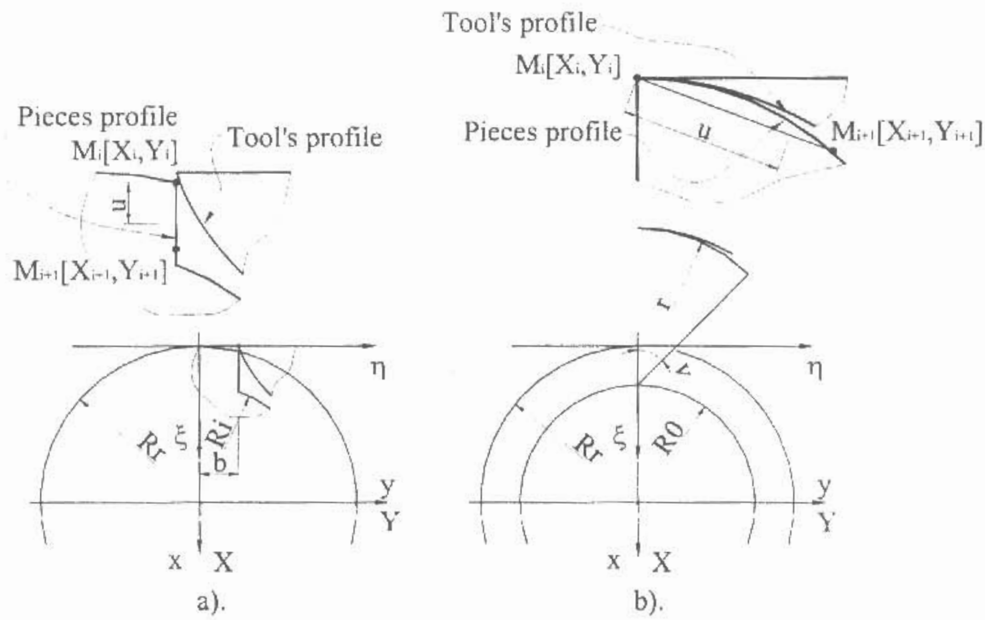

Figure 4. Rack-gear tool's profiling

Table 1.

Gohman method		Generation trajectories		Error
ξ [mm]	η [mm]	ξ [mm]	η [mm]	d_{min} [mm]
13.3833	12.1184	13.3833	12.1184	7.24129E-06
11.8965	10.918	11.8965	10.918	1.27133E-05
10.3688	9.79065	10.3688	9.79064	1.80989E-05
8.95406	8.83947	8.95404	8.83946	2.28674E-05
7.43504	7.91616	7.43502	7.91614	2.77342E-05
5.89105	7.08196	5.89102	7.08195	3.2362E-05
4.25313	6.31543	4.25309	6.31541	3.67831E-05
2.61815	5.681	2.61811	5.68099	4.02895E-05
1.03688	5.21266	1.03684	5.21265	4.11153E-05
3.5E-09	5.01311	-3E-05	5.01311	3.03368E-05

II.2. Rack-gear tool's for circle's arc profiling

In figure 4.b, are present the reference systems associated with piece and rack gear tool:

XY is the reference system joint to C_1 piece's centroid;

ξη is the reference system joint to C_2 tool's centroid;

xy is the fixed system.

We consider a circle-wise profile with this dimensions: Rr=65 mm; R0=55 mm; r=10 mm; $\nu_{min}=0°$; $\nu_{max}=20°$.

The circle's arc of the profile is divided into 10 arcs with equal length, and the extremes point of each arc will be $M_i(X_i,Y_i)$ and $M_{i+1}(X_{i+1},Y_{i+1})$. Regarding the small length of each arc, those may be approximated with a straight segment. The calculus is making similarly with the antecedent case (see equations 1-3 and figure1-2).

The proof was made by Gohman method, based on the following equations:

$$\Sigma: \begin{vmatrix} X = -R_0 - r \cdot \cos v; \\ Y = r \cdot \sin v, \end{vmatrix}$$

with v variable parameter;

$$v_{max} = 20°; \quad v_{min} = 0°.$$

The coordinates of the points that belongs of the tool's profile will be:

$$\Sigma: \begin{vmatrix} \xi = -r\cos(v-\varphi) - R_0 \cos\varphi + R_r; \\ \eta = r\sin(v-\varphi) - R_0 \sin\varphi + R_r\varphi. \end{vmatrix}$$

The wrapping condition is obtained from equation

$$\vec{N}_\Sigma \cdot \vec{R}_\varphi = 0$$

where

$$\vec{N}_\Sigma = \begin{Vmatrix} r\cos v \\ -r\sin v \end{Vmatrix}$$

and

$$\vec{R}_\varphi = \begin{Vmatrix} r\sin v - R_r \sin\varphi \\ R_0 + r\cos v - R_r \cos\varphi \end{Vmatrix}.$$

After development results

$$\varphi = \arcsin\left(\frac{R_0 \sin v}{-R_r}\right) + v.$$

The coordinates obtained from these 2 methods are showing in table 2.

Table 2.

Gohman method		Generation trajectories		Error
ξ [mm]	η [mm]	ξ [mm]	η [mm]	d_{min} [mm]
3E-10	0	0	0	3E-10
0.00021	0.06981	0.00021	0.06981	4.69E-07
0.00082	0.13962	0.00082	0.13962	9.37E-07
0.00186	0.20943	0.00186	0.20943	1.41E-06
0.00515	0.34902	0.00515	0.34903	2.34E-06
0.04333	1.01128	0.04333	1.01129	6.85E-06
0.22396	2.29203	0.22397	2.29205	1.7E-05
0.54353	3.55127	0.54354	3.5513	3.35E-05
0.6766	3.95331	0.67662	3.95335	4.19E-05
1.01377	4.81164	1.01379	4.8117	6.96E-05

III. The gear-shaped cutter tool's profiling

III.1. Gear-shaped cutter tool's for straight segment profiling

In figure 5.a, are present the reference systems associated with piece and gear-shaped cutter tool:

XY is the reference system joint to C_1 piece's centroid;

ξη is the reference system joint to C_2 tool's centroid;

xy is the fixed system.

We consider a square bored bush with the dimensions: Rr=30 mm; i=1,33.

The profile is divided into 50 segments with equal length, and the equation of each segment will be (for $\alpha = -\frac{\pi}{2}$):

$$\Sigma: \begin{vmatrix} X = X_i; \\ Y = Y_i + u, \end{vmatrix}$$

with u variable parameter (see equations 3).

The coordinate conversion between XY and ξη coordinate systems will be:

$$\xi = \omega_3(\varphi_2)\left[\omega_3^T(\varphi_1) \cdot X - a\right];$$

$$X = \omega_3(\varphi_1)\left[\omega_3^T(\varphi_2) \cdot \xi + a\right];$$

with $a = \begin{Vmatrix} -A_{12} \\ 0 \end{Vmatrix}$, $A_{12} = \left(R_r - \frac{R_r}{i}\right)$ and

$i = \frac{R_{rp}}{R_{rs}}$ (i is ratio).

In this way, we obtain the coordinates of the points which belongs of the tool's profile:

$$\Sigma: \begin{vmatrix} \xi = X_i \cdot \cos(1-i)\varphi_1 - Y_i \cdot \sin(1-i)\varphi_1 - \\ \quad -u \cdot \sin(1-i)\varphi_1 + A_{12}\cos i\varphi_1; \\ \eta = X_i \cdot \sin(1-i)\varphi_1 + Y_i \cdot \cos(1-i)\varphi_1 - \\ \quad -u \cdot \cos(1-i)\varphi_1 - A_{12}\sin i\varphi_1. \end{vmatrix}$$

The wrapping condition is obtained from equation

$$\frac{\xi'_u}{\xi'_\varphi} = \frac{\eta'_u}{\eta'_\varphi}.$$

The proof was made by Gohman method, based on the following equations:

$$\Sigma : \begin{vmatrix} X = -a; \\ Y = u, \end{vmatrix}$$

with u variable parameter;

$$a = \frac{R_r}{\sqrt{2}}; \quad u_{min} = -\frac{R_r}{\sqrt{2}}; \quad u_{max} = \frac{R_r}{\sqrt{2}}.$$

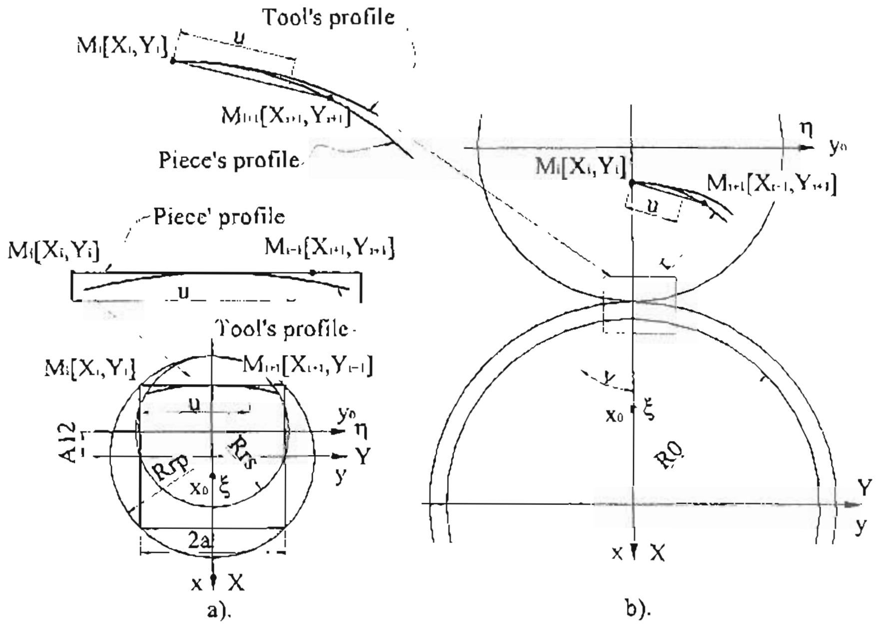

Figure 5. Gear-shaped tool's profiling

The coordinates of the points that belongs of the tool's profile will be:

$$\Sigma : \begin{vmatrix} \xi = -a\cos(1-i)\varphi_1 - u\sin(1-i)\varphi_1 + \\ \quad + A_{12}\cos i\varphi_1; \\ \eta = -a\sin(1-i)\varphi_1 + u\cos(1-i)\varphi_1 - \\ \quad - A_{12}\sin i\varphi_1; \end{vmatrix}$$

The wrapping condition is obtained from equation

$$\vec{N}_\Sigma \cdot \vec{R}_\varphi = 0;$$

where

$$\vec{N}_\Sigma = \begin{Vmatrix} 1 \\ 0 \end{Vmatrix}$$

and

$$\vec{R}_\varphi = \begin{Vmatrix} u(1-i) + A_{12} i \sin\varphi_1 \\ a(1-i) + A_{12} i \cos\varphi_1 \end{Vmatrix}$$

After development results

$$\varphi = \arcsin\left(\frac{u(1-i)}{A_{12}}\right).$$

The coordinates obtained from these two methods are showing in table 3.

Table 3.

Gohman method		Generation method		Error
ξ [mm]	η [mm]	ξ [mm]	η [mm]	d_{min} [mm]
-13.77	0	-13.77	0	3.4356E-06
-13.711	3.1054	-13.711	3.1054	3.4727E-06
-13.536	6.17865	-13.536	6.17865	3.5801E-06
-13.241	9.26515	-13.241	9.26515	3.7574E-06
-12.819	12.3744	-12.819	12.3744	4.0041E-06
-12.248	15.5603	-12.248	15.5603	4.3292E-06
-11.906	17.1549	-11.906	17.1549	4.5235E-06
-11.52	18.7697	-11.52	18.7697	4.747E-06
-11.351	19.4228	-11.351	19.4228	4.8455E-06
-11.34	19.4638	-11.34	19.4638	4.852E-06

III.2. Gear-shaped cutter tool's for circle's arc profiling

In figure 5. b, are present the reference systems associated with piece and gear-shaped cutter tool:

XY is the reference system joint to C_1 piece's centroid;

ξη is the reference system joint to C_2 tool's centroid;

xy is the fixed system.

We consider a circle-wise profile with this dimensions: Rr=60 mm; R0=55 mm; i=1,33; r=10 mm; $v_{min}=0°$; $v_{max}=20°$.

The circle's arc of the profile is divided into 200 arcs with equal length, and the extremes point of each arc will be $M_i(X_i,Y_i)$ and $M_{i+1}(X_{i+1},Y_{i+1})$. Regarding the small length of each arc, those may be approximated with a straight segment. The calculus is making similarly with the antecedent case (see equations 1-3 and figures 1-2).

The proof was made by Gohman method, based on the following equations:

$$\Sigma: \begin{cases} X = -R_0 - r \cdot \cos v; \\ Y = r \cdot \sin v, \end{cases}$$

with v, variable parameter;

$v_{max} = 20°$; $v_{min} = 0°$. The coordinates of the points that belongs of the tool's profile will be:

$$\Sigma: \begin{cases} \xi = -r\cos(v - \varphi_1(1+i)) - \\ \quad - R_0 \cos\varphi_1(1+i) + A_{12}\cos i\varphi_1; \\ \eta = r\sin(v - \varphi_1(1+i)) - \\ \quad - R_0 \sin\varphi_1(1+i) + A_{12}\sin i\varphi_1. \end{cases}$$

The wrapping condition is obtained from equation

$$\vec{N}_\Sigma \cdot \vec{R}_\varphi = 0$$

where

$$\bar{N}_\Sigma = \begin{Vmatrix} r\cos v \\ -r\sin v \end{Vmatrix}$$

and

$$\bar{R}_\varphi = \begin{Vmatrix} r\sin v - ir\sin(v - 2\varphi_1) + \\ + iA_{12}\sin\varphi_1 \\ R_0 + r\cos v + ir\cos(u - 2\varphi_1) - \\ - R_0 i - iA_{12}\cos\varphi_1 \end{Vmatrix}.$$

After development results

$$\varphi_1 = \arcsin\left(\frac{R_0(1+i)\sin v}{iA_{12}}\right) + v.$$

The coordinates obtained from these 2 methods are showing in table 4.

Table 4.

Gohman method		Generation trajectories		Error
ξ [mm]	η [mm]	ξ [mm]	η [mm]	d_{min} [mm]
40.11278196	0	40.11278203	0.000338886	0.000339
40.11303728	0.075641915	40.11303964	0.075980947	0.000339
40.19529819	1.357761487	40.19533916	1.358096981	0.000338
40.21629152	1.520112215	40.21633728	1.520446427	0.000337
40.23963625	1.682096261	40.23968675	1.682429	0.000337
40.45705078	2.759996808	40.45713113	2.760314522	0.000328
40.45859009	2.766082051	40.4586706	2.766399653	0.000328
40.50959612	2.960291765	40.50968158	2.960605617	0.000325
40.54490082	3.087176759	40.54498942	3.087487978	0.000324
40.546618	3.093207359	40.54670674	3.093518449	0.000323

III. The rotary- cutter tool's profiling

In figure 6, are present the reference systems associated with piece and rotary-cutter tool.

The reference systems:

XY is the reference system joint to C_1 piece's centroid;

ξη is the reference system joint to C_2 tool's centroid;

xy is the fixed system.

We consider an Archimedes's screw with the dimensions: Rr=60 mm; Re=70 mm; Ri=50 mm; α=20°.

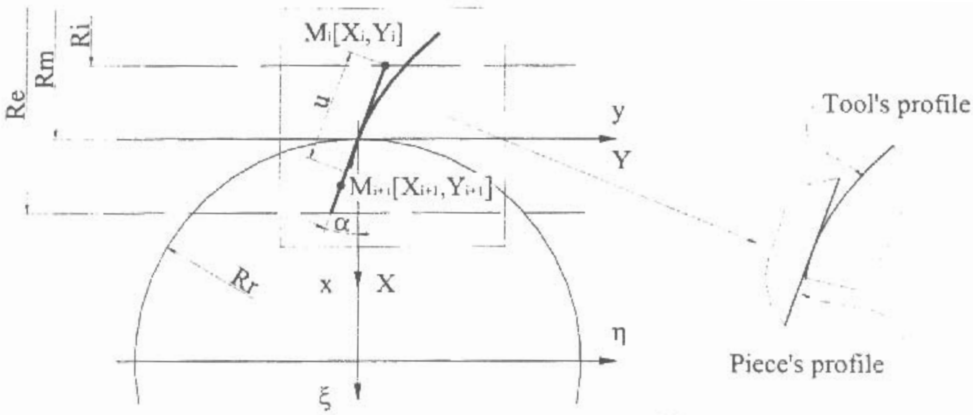

Figure 6. Rotary-cutter tool's profiling

The profile is divided into 500 segments with equal length, and the equation of each segment will be:

$$\Sigma : \begin{vmatrix} X = X_i + u\cos\alpha; \\ Y = Y_i - u\sin\alpha, \end{vmatrix}$$

with u variable parameters (see equation 1-3);

The coordinate conversion between XY and ξη coordinate systems will be:

$$\xi = \omega_3(\varphi)\cdot[X + a];$$

$$X = \omega_3^T(\varphi)\xi - a;$$

with $a = \begin{Vmatrix} -R_r \\ -R_r\cdot\varphi \end{Vmatrix}$.

In this way, we obtain the coordinates of the points which belongs of the tool's profile:

$$\Sigma : \begin{vmatrix} \xi = X_i\cdot\cos\varphi + Y_i\cdot\sin\varphi - u\cos(\varphi+\alpha) - \\ \quad - R_r\cos\varphi - R_r\varphi\sin\varphi; \\ \eta = -X_i\cdot\sin\varphi + Y_i\cdot\cos\varphi - u\sin(\varphi+\alpha) + \\ \quad + R_r\sin\varphi - R_r\varphi\cos\varphi. \end{vmatrix}$$

The wrapping condition is obtained from equation

$$\frac{\xi'_u}{\xi'_\varphi} = \frac{\eta'_u}{\eta'_\varphi}.$$

The proof was made by Gohman method, based on the following equations:

$$\Sigma : \begin{vmatrix} X = -u\cos\alpha; \\ Y = u\sin\alpha, \end{vmatrix}.$$

with u, variable parameter.

$$u_{max} = \left(\frac{R_e + R_i}{2} - R_i\right)\cdot\frac{1}{\cos\alpha};$$

$$u_{min} = \left(\frac{R_e + R_i}{2} - R_e\right)\cdot\frac{1}{\cos\alpha}.$$

The coordinates of the points that belongs of the tool's profile will be:

$$\Sigma : \begin{vmatrix} \xi = -u\cos(\varphi+\alpha) - R_r(\cos\varphi - \varphi\sin\varphi); \\ \eta = u\sin(\varphi+\alpha) + R_r(\sin\varphi - \varphi\cos\varphi). \end{vmatrix}$$

The wrapping condition is obtained from equation

$$\vec{N}_\Sigma \cdot \bar{R}_\varphi = 0,$$

where

$$\vec{N}_\Sigma = \begin{Vmatrix} -\cos\alpha \\ \sin\alpha \end{Vmatrix}$$

and

$$\vec{R}_\varphi = \begin{Vmatrix} \cos\alpha \\ R_r\varphi - u\sin\alpha \end{Vmatrix}.$$

After development, it results

$$\varphi = \frac{u}{R_r\sin\alpha}.$$

The coordinates obtained from these two methods are showing in table 5.

Table 5.

Gohman method		Generation trajectories		Error
ξ [mm]	η [mm]	ξ [mm]	η [mm]	d_{min} [mm]
-57.04399726	-0.91956185	-57.04400579	-0.91956107	8.5647E-06
-56.40089876	-0.84119781	-56.40090375	-0.84119636	5.2036E-06
-56.52776064	-0.8350938	-56.52776336	-0.8350924	3.0532E-06
-57.25582271	-0.74902547	-57.25582382	-0.74902449	1.4865E-06
-60.40980099	0.154031867	-60.409801	0.154031778	9.0399E-08
-62.73589433	1.203197152	-62.73589479	1.20319679	5.7972E-07
-65.46532345	2.791584521	-65.4653249	2.791584307	1.4618E-06
-68.50580048	5.010715892	-68.50580335	5.010716403	2.9127E-06
-71.7507905	7.938233356	-71.75079506	7.9382353	4.9598E-06
-74.41452818	10.83241488	-74.41453418	10.83241855	7.028E-06

Conclusions

The comparison between the shape and the dimensions of the tool's profiles -rack-gear tool, gear-shaped cutter tool and rotary cutter tool- for analyzed blank' profiles –straight segment and circle's arc- relieves the similitude of the coordinates values (see tables 1-5), the very small errors, on 10^{-5} mm values order, in condition of the relatively small number of points considered on those profiles, fact that attest the quality of the proposed method and of the application way of these.

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Metoda traiectoriilor de generare.
Verificarea metodei.

Rezumat

Profilarea sculelor mărginite de suprafeţe periferice primare de revoluţie poate fi făcută prin diferite metode: GOHMAN [1], [2], NIKOLAEV [2], prin metoda „distanţei minime" [4], prin metoda „familiei de cercuri substitutive" [5], [6], prin „metoda modelării solide" [7]. Având în vedere că **metoda traiectoriilor de generare** constituie o noua interpretare a unei condiţii de înfăşurare cunoscută din geometria analitică, în lucrarea de faţă, se propune o verificare a acesteia realizând o comparaţie între rezultatele obţinute prin această metodă şi rezultatele obţinute printr-o metodă clasică- metoha Gohman.

La méthode de trajectoires de génération.
La vérification de la méthode.

Résumé

Le profilage des outils avec rotative peripherical souprafeces peut être réalise avec différentes méthodes (GOHMAN [1], [2], NIKOLAEV [2], la méthode de „minimum distance" [4], la méthode de modelage). En c'est ouvrage on vérifie des résultats obtenus avec **la méthode des trajectoires de génération** avec une méthode classique- la méthode Gohman.