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CONSIDERATIONS REGARDING A NEW MANUFACTURING TECHNOLOGY OF CYLINDRICAL WORMS USING NC LATHES

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Abstract: *This paper presents aspects of a new manufacturing technology cylindrical Archimedean worms on NC lathes using standard frontal – cylindrical milling tools. The frontal-cylindrical milling tools is tilted from the perpendicular to the axis of symmetry of the worm by an angle roughly equal with the pressure angle of the worm flank. At the same time the symmetry axis of frontal-cylindrical milling tools is contained in a plane parallel to the axis of symmetry of the worm. The plane is positioned for the symmetry axis at a distance that we call eccentricity. Depending on the location of the milling tool, shall be determined the shape of the profile resulted in axial plane to be able to be compared to the nominal profile of an Archimedean worm. The profile shape is determined using coordinate transformations. The program that generates the necessary points is AutoLISP and representations are made in AutoCAD.*

Key words: *technology, cylindrical worm, frontal-cylindrical milling tool, eccentricity, NC lathe.*

1. INTRODUCTION

According to STAS 6845-82 standard, the cylindrical worms are classified as: ZA – worm with a straight-line tooth profile in axial section, ZN – worm with a straight-line tooth profile in normal tooth section, ZE – worm with a straight-line tooth profile in a plane tangent to the main cylinder, ZK – profile formed by a cone ground using a wheel and/or shank tool.

The type-worm ZA is a ruled worm, generator of the flank being a straight-line positioned in axial plane of the worm [3]. The steps in wich is executed worms are:

- Roughing,
- Semifinishing,
- Finishing.

Finishing is done by turning if the material is made from steel and improvement is by grinding when the worm is hardening steel. In [1] was presented a new technology for manufacturing of cylindrical worms on NC lathes with frontal-cylindrical milling tool whose axis of symmetry lies in the axial plane of the worm, the tool being inclined toward perpendicular to the axis of symmetry of the worm by an angle α different from the angle of the pressure screw machined worm.

In this paper processing of the cylindrical worm is made using a frontal-cylindrical milling tool inclined with an angle towards the perpendicular to the axis of symmetry of the worm different than the flank pressure angle, but the axis of symmetry of the tool is not located in the axial plane of the worm, but in a plane parallel to the axial one located a distance called eccentricity.

Processing the worm with frontal – cylindrical milling tools eccentric positioned, deviation obtained from nominal profile of Arhimedian worm is much smaller than when the tool is located in the axial plane of the worm.

2. DETERMINATION OF CONTACT BETWEEN THE FRONTAL-CYLINDRICAL MILLING TOOL AND THE HELICAL SURFACE

For determination of contact between the surface of milling tools and screw surface, begin by determining the equation of a milling tool surface and of the normal unit vector at a point on this surface.

2.1 The parametric equations of the cylinder and normal unit vector at a point on the surface

Frontal-cylindrical milling tool shall associate the $X_1O_1Y_1Z_1$ coordinate system as shown in (Fig.1.).

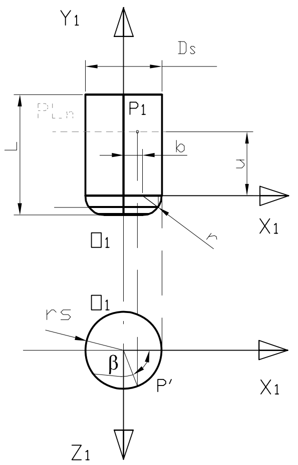

Fig.1. Milling tools and coordinate system

The projection of point P_1 in plane $O_1X_1Z_1$ note with P'. In the plane $O_1X_1Z_1$, note with β the angle between O_1P' and axis O_1X_1. u and β parameters of cylindrical surface will be. We can write parametric equations of cylindrical surface as follows:

$$\begin{cases} x_1 = r_S * \cos\beta \\ y_1 = u \\ z_1 = r_S * \sin\beta \end{cases} \quad (1)$$

for $u \in [0, L-r]$, and $\beta \in [0, 2\pi]$.

For the normal versor to the cylindrical surface parametric equations can be written as:

$$\begin{cases} n_{x_1} = \cos\beta \\ n_{y_1} = 0 \\ n_{z_1} = \sin\beta \end{cases} \quad (2)$$

2.2 Determination of wrap up surface

We consider that the axis of symmetry of the tool (Fig.2.) coinciding with the axis O_1Y_1 of the system tools note with S_1.

To be able to do a comparative study of worm's profile in axial section, consider adjusting the tool before doing the translation movement along the axis O_2X_2 is as follows:

- system S_1 rotates around the axis O_1Z_1 with an angle γ,
- translates along the axis O_1Z_1 for a distance "e" that we call eccentricity.

In case that system S_2 associated half-finished rotates with the angle φ counterclockwise (trigonometric) the worm result will be right, and if the system rotates clockwise the worm result will be left. With $S_{1(0)}$, $S_{1(1)}$, $S_{1(2)}$ was noted the successive positions of the system S_1 without and with eccentricity „e".

Having the parametric equations of the milling surface and normal written in the system of the milling tool $O_1X_1Y_1Z_1$ it will express in the system of helical surface $O_2X_2Y_2Z_2$ using the coordinate transformation and the transformation of vectors.

We know the relativ position of system S_1

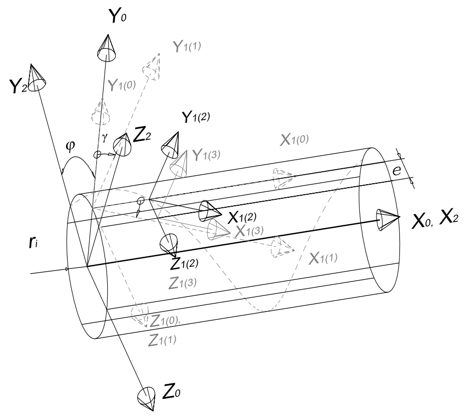

Fig.2. Tool S_1 system position to the worm S_2 system

for the system S_2 thus the coordinate transformation can be written in symbolical matrix form:

$$r_2 = M_{2,1} * r_1 = M_{2,0} M_{0,1(2)} M_{1(2),1(3)} * r_1 \quad (3)$$

The rotation matrix is:

$$M_{2,0} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\varphi & -\sin\varphi & 0 \\ 0 & \sin\varphi & \cos\varphi & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (4)$$

and translation matrices are (5) and (6). Replacing (1), (4), (5), (6) in (3) and making calculations are obtained the equations of the

$$M_{0,1(2)} = \begin{bmatrix} \cos\gamma & \sin\gamma & 0 & \varphi * h \\ -\sin\gamma & \cos\gamma & 0 & r_i \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (5)$$

$$M_{1(2),1(3)} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & e \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (6)$$

cylindrical surfaces written in system S_2 of worm and in parametric form are:

$$\begin{cases} x_2 = r_S \cos\gamma\cos\beta + u\sin\gamma + \varphi h \\ y_2 = \cos\varphi(r_i + u\cos\gamma - r_S\cos\beta\sin\gamma) - \sin\varphi(r_S\sin\beta + e) \\ z_2 = \sin\varphi(r_i + u\cos\gamma - r_S\cos\beta\sin\gamma) + \cos\varphi(r_S\sin\beta + e) \end{cases} \quad (7)$$

If we write the ecuations of family of surfaces as vectorial form we have:

$$r_2 = r_2(\varphi, u, \beta) \quad (8)$$

where:

- φ is the parameter of the surfaces family,
- u, β are parameters of generator surface.

Bearing in mind that the surfaces of each other SYN.envelope have a common tangent plane at the point of contact, we can write the relation:

$$\frac{\partial r_2}{\partial\varphi}\left(\frac{\partial r_2}{\partial u} x \frac{\partial r_2}{\partial\beta}\right) = 0 \quad (9)$$

so the condition to be imposed is that the dot product of the vectors $\frac{\partial r_2}{\partial\varphi}$, n_2 to be null. Making simple calculations in accordance with [2] we obtain:

$$-n_{y2}z_2 + n_{z2}y_2 + hn_{x2} = 0 \quad (10)$$

In this relation we express one of the parameters in the function of the other two. Substituting this into the relation (10) we will get the equation wrapped surface depending on two parameters.

The transformations of the vectors are independent from the point of application of the vectors. Thus the transformation of vectors can be written in symbolical matrix form:

$$n_2 = R_{2,1} * n_1 = R_{2,0}R_{0,1(2)}R_{1(2),1(3)} * n_1 \quad (11)$$

The rotation matrix is:

$$R_{2,0} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\varphi & -\sin\varphi \\ 0 & \sin\varphi & \cos\varphi \end{bmatrix} \quad (12)$$

and translation matrices are:

$$R_{0,1(2)} = \begin{bmatrix} \cos\gamma & \sin\gamma & 0 \\ -\sin\gamma & \cos\gamma & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (13)$$

$$R_{1(2),1(3)} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (14)$$

Replacing the relations we obtain:

$$\begin{bmatrix} n_{x2} \\ n_{y2} \\ n_{z2} \end{bmatrix} = \begin{bmatrix} \cos\gamma & \sin\gamma & 0 \\ -\cos\varphi\sin\gamma & \cos\varphi\cos\gamma & -\sin\varphi \\ -\sin\varphi\sin\gamma & \sin\varphi\cos\gamma & \cos\varphi \end{bmatrix} \begin{bmatrix} \cos\beta \\ 0 \\ \sin\beta \end{bmatrix} \quad (15)$$

For the cylindrical zone of milling tools the equations of normal are:

$$\begin{cases} n_{x2} = \cos\gamma\cos\beta \\ n_{y2} = -\cos\varphi\cos\beta\sin\gamma - \sin\varphi\sin\beta \\ n_{z2} = -\sin\varphi\cos\beta\sin\gamma + \cos\varphi\sin\beta \end{cases} \quad (16)$$

Imposing condition (10) obtain β function of others parameters:

$$\beta = \text{arctg} - \frac{e\sin\gamma + h\cos\gamma}{r_i + u\cos\gamma} \quad (17)$$

3. AXIAL PROFILE

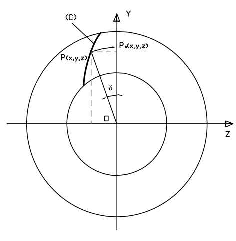

Fig.3. Determining the Axial Profile [1]

To bring in axial plane points of contact between tool surface and the helicoidal surface we consider (Fig.3.). Consider the point P of coordinates (x, y, z) belongs to the curve (C). As seen in [1], point P will move after a cylindrical propeller whose parameter δ is equal with

$\delta = \text{arctg}\frac{z}{y}$. The coordinate of the point in axial plane are:

$$\begin{cases} x_a = x_1 - h\delta \\ y_a = \sqrt{y_1^2 + z_1^2} \\ z_a = 0 \end{cases} \quad (17)$$

4. DEVIATION FROM THE NOMINAL ARCHIMEDIC PROFILE

To determine the points representing the profile obtained in axial plane with frontal-cylindrical milling tool has been conceived a program in AutoLISP. The frontal-cylindrical milling tool using to profile processing is with diameter of 10 mm, the worm workpiece is with axial module 10 mm, diametric coefficient 7.6, helical parameter 7.6, keeping the same conditions of processing. The deviations obtained are (Table.1.):

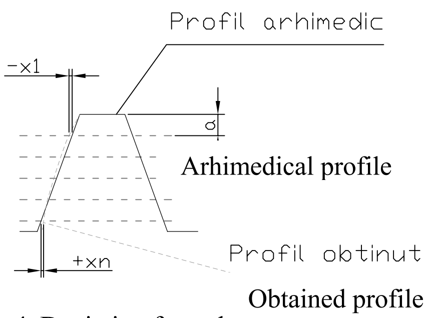

Fig.4. Deviation from the Arhimedical profile

Table 1. Deviations of the Axial Profile

a mm	α=20.35°, e=0	α=19.8°, e=1.8
0	0.000	0.000
5	0.011	0.0011
10	0.013	0.0011
15	0.000	0.0010
19	-0.027	0.0031

5. CONCLUSIONS

Working with frontal-cylindrical milling tools can be done in the best conditions on NC lathes which possess 5 axes. The processing can be done with and without eccentricity. The study demonstrates that with eccentricity leads to getting some deviations from the nominal profile much lower compared to processing without eccentricity to the axis of symmetry of the worm.

6. REFERENCES

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Consideraţii asupra unei noi tehnologii de prelucrare a melcilor pe strunguri CNC

Rezumat: *În lucrare se prezintă aspecte ale unei noi tehnologii de prelucrare a melcilor cilindrici Arhimedici pe strunguri CNC utilizând freze cilindro-frontale.Freza cilindro-frontală este înclinată faţă de perpendiculara pe axa de simetrie a melcului cu un unghi aproximativ egal cu unghiul de presiune a flancului melcului. Tot odată axa de simetrie a frezei cilindro-frontale este conţinută într-un plan paralel cu axa de simetrie a melcului. Planul este poziţionat faţă de axa de simetrie la o distanţă pe care o numim excentricitate. În funcţie de poziţia frezei se determină forma profilului rezultat în plan axial pentru a putea fi comparat cu profilul nominal al unui melc arhimedic. Forma profilului se determină folosind transformările de coordonate. Programul care generează punctele necesare este conceput în AutoLISP, iar reprezentările sunt făcute în AutoCAD.*

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