USING AUTO-CAD ENVIRONMENT TO PROFILE THE REVOLUTION TOOLS GENERATING HELICAL ROTORS WITH INVOLUTE UNDERCUTTING PROFILED LOBS

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ABSTRACT: *In the paper is presented a method, developed in AUTOCAD graphic design environment, in order to profiling the tools bounded by revolution surfaces, for machining the screw compressor rotors, with a small number of lobes (4-6 lobes). Surfaces of this kind are used as working elements of helical rotors, screw compressors components. The graphical method proposed is based on a complementary method of studying the enveloping processes between a helical surface, cylindrical and constant pitch and a surface of revolution - the primary peripheral surface of a disk tool or end mill tool*
KEYWORDS: *AUTOCAD, helical, rotors, compressors, surface*

1 INTRODUCTION

The tools bordered by primary peripheral surfaces of revolution, which generate a cylindrical helical surface of constant pitch, are profiled on the basis of the fundamental theorem of enveloping surfaces, with condition of a linear contact between them - theorem I Olivier (Litvin, 1984), (Oancea, 2004), (Radzevich, 2008).

The Olivier Theorem is a general method, defined in an analytical form, easy to apply for a parametric expression of helical surface. On the other hand, Nikolaev Theorem (Litvin, 1984), was created and applied in order to profile a helical surface, cylindrical and constant pitch, as a specific method, based on the decomposition of helical movement in rotation movements around two conjugated axes. The problem of enveloping between a cylindrical helical surface of constant pitch and a revolution surface - the case of generation with disk tool - can also be handled on the basis of the complementary theorem such as "Minimum Distance Method" (Oancea, 2004). This theorem is treated in analytical way (Popa, 2016) by reinterpreting the general enveloping theorem in orthogonal planes to the axis of the future revolution surface, using the distance between the sectioning curves of helical surface and the axis of the revolution surface - the axis of the disk tool or the axis of the cylindro-frontal tool.

The issue can be also treated on the basis of the "Generating Trajectories" theorem, both in the analytical and graphic form, in the CATIA graphics design environment. A similar solution is presented in (Berbinschi, 2014), (Teodor, 2016) as a graphical solution in CATIA design environment, based on the complementary theorem of "Substitution Circles Family".

An application, developed in Auto-CAD graphical design environment, for profiling the tools bordered by revolution surfaces (disk tool, end mill tool), is presented in the following. It's about a type of tool to generate helical rotors, shaped with helical surfaces with involute undercutting cross-sectional profile. These kindsof rotors, screw compressor components, are made up with a small number of lobes, 4 or 6.

2 The front view of rotor profile

Involute toothed with z = 4 are generated by a normal rack, as reveal in Figure 1a. In this figure area also represented the centrodes below: C1- jointed with the front view of rotor teeth, C2-jointed with rack generator.

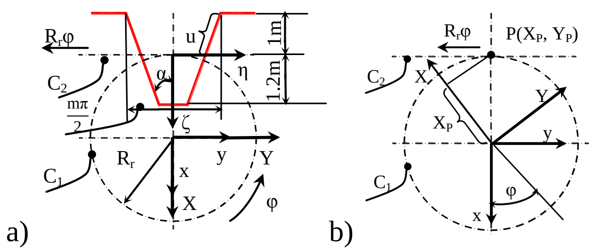


Figure 1.a) The generation of rotor front view profile; b) Gearing pole coordinates, in XY system

The reference systems are as follows: xy - global system; XY- mobile system attached to the front view of rotor profile; ζη - mobile system, attached to the generating rack-gear.

Mark "u" scalar variable across the flank of the generator rack profile, whose equations in the ζη system are as follows:

$$\zeta = u\cos\alpha;$$
$$\eta = \frac{m\pi}{4} + u\sin\alpha. \qquad (1)$$

Where: m - is the rack-gear module, α - the pressure angle and

$$u_{min} = -1.2\frac{m}{\cos\alpha};\ u_{max} = \frac{m}{\cos\alpha}. \quad (2)$$

The relative movement of the space ζη, attached to the rack, with the XY system, associated with the centrode C1 (the gear), is given by transformation:

$$X = \omega_3(\varphi)[\zeta + a], \quad (3)$$

with X and ζ the matrix of current points in the XY and ζη spaces, respectively, and

$$a = \begin{pmatrix} -R_r \\ -R_r\varphi \end{pmatrix}, \quad (4)$$

where φ variable angular parameter.

Over developing and taking the Eq. 1, 3, 4, the rack flanks family in the XY system results in the form below and according to:

$$X = -(u\cos\alpha + R_r)\cos\varphi + \left[(u\sin\alpha - R_r\varphi) + \frac{m\pi}{4}\right]\sin\varphi;$$
$$Y = (u\cos\alpha + R_r)\sin\varphi + \left[(u\sin\alpha - R_r\varphi) + \frac{m\pi}{4}\right]\cos\varphi. \quad (5)$$

Defining the gearing pole in the XY space, according to Figure 1b, in the form below:

$$P\left| \begin{aligned} X_P &= -R_r\cos\varphi; \\ Y_P &= R_r\cos\varphi, \end{aligned} \right. \quad (6)$$

makes possible to find the distance from the current family point (Eq.5) to this pole, as follows:

$$d = \sqrt{[X_{(u,\varphi)} - X_P]^2 + [Y_{(u,\varphi)} - Y_P]^2}, \quad (7)$$

for a moment of the rolling motion (taking an arbitrary value of the parameter φ).

The following form is achieved, over the developing:

$$u = R_r\varphi\sin\alpha - \frac{m\pi}{4}\sin\alpha \Rightarrow \varphi = \frac{1}{R_r\sin\alpha}\left[u + \frac{m\pi}{4}\sin\alpha\right]. \quad (8)$$

Eq. 8 represents the enveloping condition, appropriate to "Minimum Distance Method" (Oancea, 2004), and next to the Eq. 5, will determine the envelope of flank family of the rack – gear in the XY system, as in Figure 2a.

Point V displays a singular point on the composite flank of the rack tool (Figure 3b). The size of u parameter, corresponding to V point on the rack, is marked with u_v.

The crossing curve, defined by point V, in XY system, is described by the equations as follows:

$$X_v = -u_v\cos(\alpha + \varphi) - R_r\varphi\sin\varphi + \frac{m\pi}{4}\sin\varphi + R_r\cos\varphi;$$
$$Y_v = u_v\sin(\alpha + \varphi) - R_r\varphi\cos\varphi + \frac{m\pi}{4}\cos\varphi + R_r\sin\varphi. \quad (9)$$

Thus, the composite profile of the involutes teeth flank of the rack-gear and also of the crossing curve, consists of two arcs, (Figure 4a) - an involute arc and a cycloidal arc (undercutting curve). Intersection of these arcs, (Eq. 5, 8, 9), leads to:

$$-u\cos(\alpha + \varphi) - R_r\varphi\sin\varphi + \frac{m\pi}{4}\sin\varphi + R_r\cos\varphi =$$
$$-u_v\sin(\alpha + \varphi) - R_r\varphi\sin\varphi + \frac{m\pi}{4}\sin\varphi + R_r\cos\varphi; \quad (10)$$

for $u_v = \frac{1.2m}{\cos\alpha}$, there is the dependence:

$$\varphi = \frac{1}{R_r\sin\alpha}\left[-1.2\frac{m}{\cos\alpha} + \frac{m\pi}{4}\sin\alpha\right], \quad (11)$$

m is the rack-gear module.

The coordinates of the singular point on the front profile will be determinate from Eq.9, for u_v and from Eq.11 for φ, namely: involute arc
and cicloidal arc

The two frontal flanks will determine the equations of the compound helical flank, in helical motion manage by Eq. 12, (Figure 4b).

$$X = \omega_3^T(\phi)X + p\phi\vec{K}. \quad (12)$$

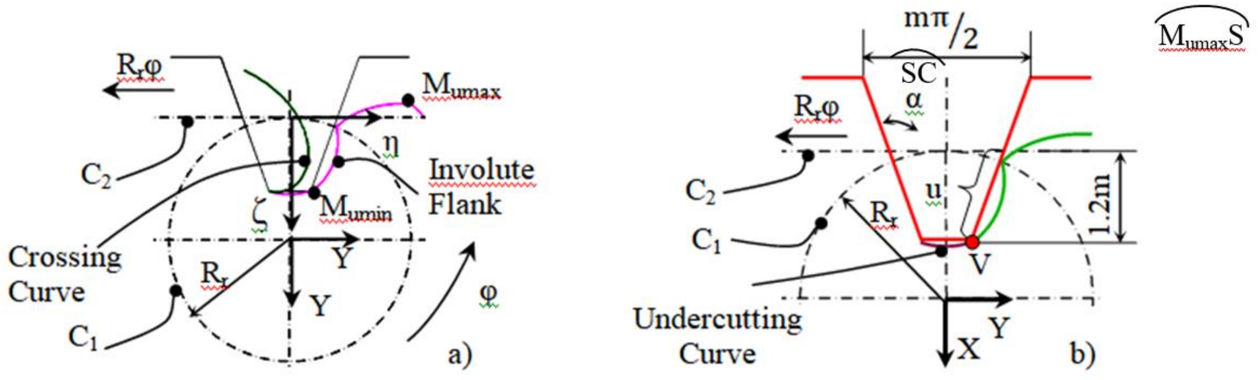


Figure 3. a) Involute flank in XY space; b) Singular point on the rack flank; the undercutting curve

The equations of involute flank and cycloidal flank are as follows:

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} \cos\phi & -\sin\phi & 0 \\ \sin\phi & \cos\phi & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} -u\cos(\alpha+\varphi) - R_r\varphi\sin\varphi + \frac{m\pi}{4}\sin\varphi + R_r\cos\varphi \\ u\sin(\alpha+\varphi) - R_r\varphi\cos\varphi + \frac{m\pi}{4}\cos\varphi + R_r\sin\varphi \\ 0 \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ p\phi \end{pmatrix} \tag{13}$$

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} \cos\phi & -\sin\phi & 0 \\ \sin\phi & \cos\phi & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} -u_v\cos(\alpha+\varphi) - R_r\varphi\sin\varphi + \frac{m\pi}{4}\sin\varphi + R_r\cos\varphi \\ u_v\sin(\alpha+\varphi) - R_r\varphi\cos\varphi + \frac{m\pi}{4}\cos\varphi + R_r\sin\varphi \\ 0 \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ p\phi \end{pmatrix}$$

(14)

The surfaces defined by Ec. 13 and 14 express the compound helical surface of the rotor.

3 PROFILING ALGORITHM

The relative position of the end mill tool, meaning $\vec{A}$ axis, corresponding to the rotor groove surface reference system, is represented in Figure 5a.

$$\vec{A} = \vec{i}\,. \tag{15}$$

Relative to perpendiculars planes to $\vec{A}$, described by equations as follows:

$$X = -H\,\vec{i}\,, \tag{16}$$

the intersections of surfaces (13), respectively, (14) will determine plane curves of shape as bellow:

$$C_H \left| \begin{aligned} X_H &= -H; \\ H_H &= Y(\phi); \\ Z_H &= Z(\phi). \end{aligned} \right. \tag{17}$$

The condition of "minimum" for the distance of points belong to C_H curve, for arbitrary H, is as follows:

$$d = \left| \sqrt{(Y_H)^2 + (Z_H)^2} \right|_{minim} \tag{18}$$

Distance "d" will determine the radius of the end mill tool, of axis $\vec{A}$.

The axial section of the end milltool is given by Eq.19 and illustrated in Figure 5b.

$$S_A \left| \begin{aligned} X &= -H \\ R &= d_{min}. \end{aligned} \right. \tag{19}$$

Pseudocode algorithm

Processing "Minimum Distance Methode"

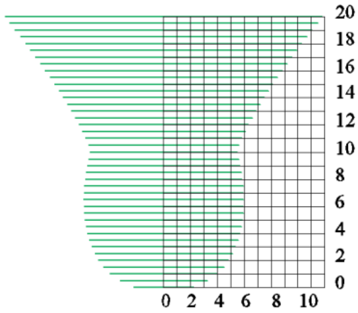
GIVEN: tool initial position; n- number of steep; i- contor

DO: for i<n :

LOOP definition: Slice (XY); Section (XY); Circle; Measure R; UCS (0,0, 0.5); list (R,Z)

END LOOP; END DO; Return list (R,Z)

a)



b)

Figure 5. a) Relative position of cylindro-frontal tool axis to the XYZ system; b) Axial section of the tool

4 CONCLUSIONS

The "Minimum Distance Method" is a complementary procedure for studying the enveloping surfaces that can be applied for profiles associated to couples of centrodes in rolling motion;it goes to a rigorously achievement of the axial profile of the tool, increasing number of points considered.

In the presented example, the solving problem was made, at first hand, using specific command AUTOCAD, contained in a suitable pseudocode; parameterization of the tool dimensions and helical surface can be written a specific code in LISP, allowing automatisation.

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