GRAPHICAL METHOD IN AUTOCAD FOR PROFILING TOOLS FOR GENERATION OF HELICAL SURFACES

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ABSTRACT

The profiling of tools bounded by revolution surfaces for generating helical surfaces may be solved calling the basic theorems of surface enveloping or calling complementary methods. In this paper a method developed in the AutoCAD design environment is proposed. The method is based on the specific theorem of the "substituting circles family" for profiling end mill which generates a helical surface with constant pitch.

KEYWORDS: helical surfaces, enveloping theory

1. INTRODUCTION

1.1. Problem definition

The generation of cylindrical helical surfaces with constant pitch with tools bounded by revolution surfaces is the usual method for machining worms for pumps, helical flutes of the tools or compressor rotors.

The profiling of tools reciprocally enveloping with cylindrical helical surfaces with constant pitch is made calling the Gohman basic theorem [1] or Nikolaev specific theorem for generation of helical surfaces with tools bounded by revolution surfaces [2], [3].

Complementary theorems were also elaborated for profiling this tool types, as the "substitutive circles family", based on a specific definition of the enveloping condition [4].

The graphical method, developed in the AutoCAD design environment, uses the capabilities of this software in order to transpose the graphical form of the substituting circles family, leading to an intuitive and rigorous form of this specific theorem for the study of the reciprocally enveloping surfaces [4].

In this paper it is proposed the solving of the end mill tool's profiling for generating a ruled helical surface, in a graphical expression, by the method of "substituting circles family".

2. THE METHOD OF SUBSTITUTING CIRCLES FAMILY

The end mill tool for generating a cylindrical helical surface of constant pitch is bounded by a revolution surface with the rotation axis perpendicular to the axis of the helical surface to be generated.
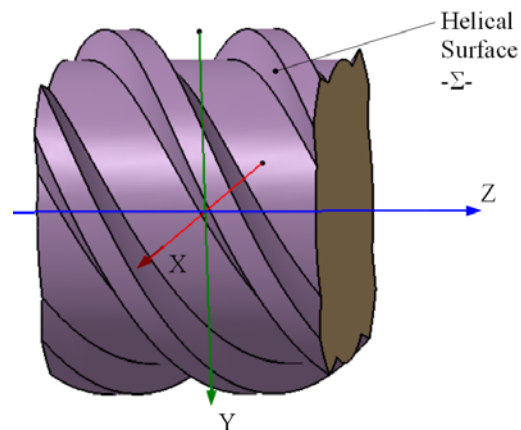

Fig. 1. *Reference systems and helical surface*

The contact between the helical surface Σ and the peripheral primary surface of the end mill in planes perpendicular to the axis of the tool should be regarded as contact between the crossing section of

the helical surface and the circle representing the crossing section of the revolution surface.

The XYZ reference system is joined with the helical surface, with the Z axis as axis of helix and the X axis as axis of end mill tool.

Let

$$\Sigma : \begin{vmatrix} X = X(u,v); \\ Y = Y(u,v); \\ Z = Z(u,v), \end{vmatrix} \qquad (1)$$

the parametrical equations of the helical surface, with u and v variable parameters.

In plane

$$X = H, \qquad (2)$$

the arbitrary variable H determines on the Σ surface a curve obtained eliminating the v parameter:

$$\Sigma_H : \begin{vmatrix} X = H; \\ Y = Y(u); \\ Z = Z(u). \end{vmatrix} \qquad (3)$$

The substitutive circles family Σ_H is determined in the plane $X = H$. The substitutive circles family is defined as the family of circles with centres on the Z axis and tangents to the Σ_H curve.

Assuming that the centres of the circles belong to a straight line parallel with the Z axis, the circles family has equations:

$$(C_i): \begin{vmatrix} Y = -r_i \sin\beta_i; \\ Z = \lambda_i + r_i \cos\beta_i; \end{vmatrix} \qquad (4)$$

$$i = 1, 2, ... n.$$

with r_i, λ_i, and β_i variables parameters of the circles family.

From the tangency condition between the curves C_i and Σ_H, (3), results:

$$\begin{aligned} Y(u) &= -r_i \sin\beta_i; \\ Z(u) &= \lambda_i + r_i \cos\beta_i; \\ \dot{Y}_u &= -r_i \cos\beta_i; \\ \dot{Z}_u &= -r_i \sin\beta_i. \end{aligned} \qquad (5)$$

From (5), after replacements, it is obtained the enveloping condition:

$$Y(u) \cdot \dot{Y}_u + Z(u) \cdot \dot{Z}_u = 0, \qquad (6)$$

assuming that

$$\tan\beta_i = \frac{\dot{Z}_u}{\dot{Y}_u}, \qquad (7)$$

$$r_i = (Z(u) - \lambda_i)\cos\beta_i - Y(u)\sin\beta_i.$$

According to the theorem of the substituting circles family, the characteristic curve between a helical surface and a revolution surface is the locus of points belonging to the helical surface where, in crossing planes of the revolution surface, the circles of the family have as centres the intersection points between the axis of revolution surface and these planes. This definition corresponds to the condition:

$$\lambda_i = 0. \qquad (8)$$

The assembly of equations (3), (6) and (7) determines the coordinates of the points onto the characteristic curve. The H and r_{iH} values represent the axial section of the end mill tool, see figure 2.
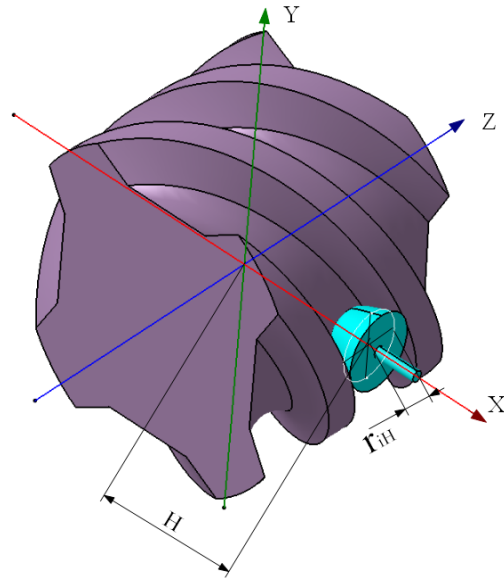

Fig. 2. *Reference system, axial section of the end mill tool*

3. GRAPHICAL METHOD

Considering as known the crossing section of the helical surface and the helical parameter p_e, the tool's profile can be determined using the following algorithm:

► The graphical reference system is set in such way that the X axis be the tool's axis.

► It is drawn the plane section of the Σ surface with a plane perpendicular to the X axis, plane $x = H$, see figure 3.
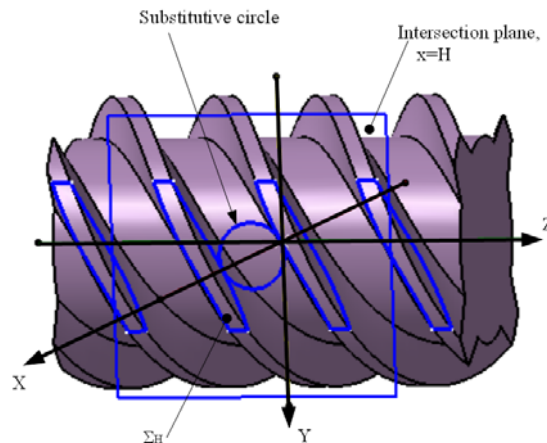

Fig. 3. *The 3D model of the helical surface. Plane section x = H.*

The H value varies between limits:

$$R_e \geq X \geq R_i. \tag{9}$$

The R_e and R_i values are input data.

► The Σ_H section is determined using *SLICE* and *SECTION* commands.

► The circle with centre in O_H point and tangent to the plane curve Σ_H is determined using the *CIRCLE* command.

► The last step is repeated for H in the given domain (9).

► The r_i radius is measured.

► The assembly of H and r_i values determines the axial section of the peripheral surface of the end mill tool, the S surface, see figure 4.
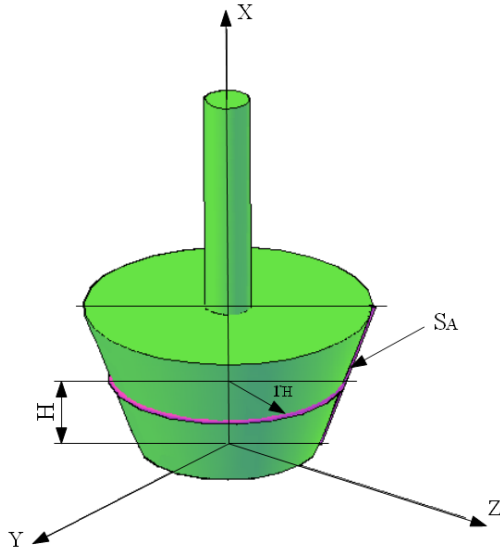

Fig. 4. *The solid model of the end mill tool*

The generatrix of the S surface represents the axial section of the end mill, the S_A curve.

4. APPLICATION

It is proposed the method application for profiling the end mill which generates an Archimedes's worm, see figure 5.

The axial section of the worm is given by the straight lines $\varDelta_1$ and $\varDelta_2$.

The flanks are generated by the helical movements, with $\vec{V}$ axis and p helical parameter,

$$p = \frac{p_{ax}}{2\pi}. \tag{10}$$

The generation of the solid model is possible using the *SWEEP* command, from the crossing section of the worm extruded on a helix.

The helical flanks range between the inner cylinder radius R_i and outer cylinder radius R_e, see figure 6.

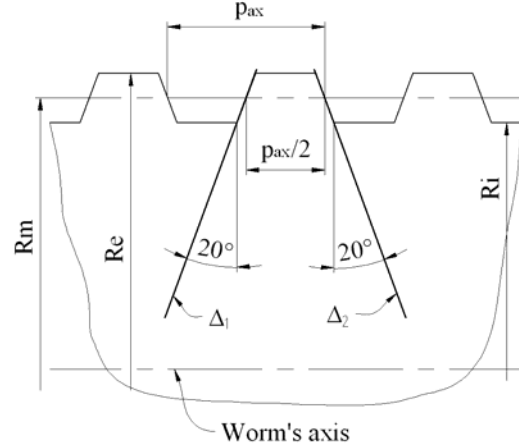$R_i = 50$ mm; $R_e = 60$ mm; $p_{ax} = 31.4$ mm and $\alpha = 20°$.

Fig. 5. *Axial section of the Archimedes's worm*

The reference system, where are defined the rotor axis and the end mill, is established according to the previously presented conditions.

The crossing planes will be generated with equation

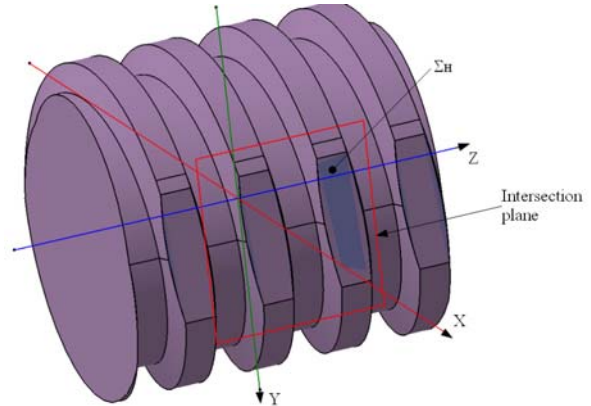$$X = H, \ R_i \leq H \leq R_e. \tag{11}$$

Fig. 6. *Solid model*

In these sections, the plane sections of the helical surface will be determined. These sections are the curves Σ_H.

The circles with centres in point O and which are tangents to the Σ_H curve will be drawn. The O point represents the projection of end tool's axis onto the YZ plane. The measured radii corresponding to the different planes of sectioning are the radii of end mill tools at different heights. In this way, the theorem of substituting circles family is applied in graphical form to determine the revolution surface which represents the primary peripheral surface of the end mill tool.
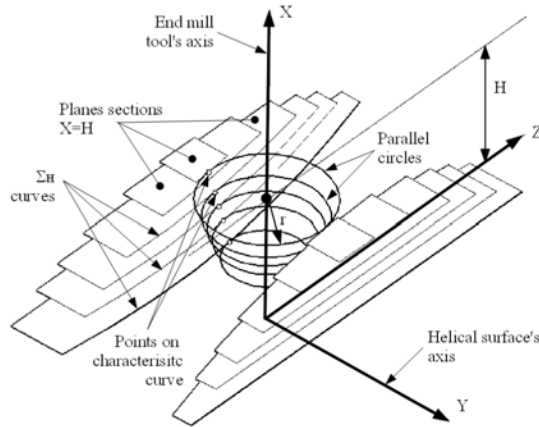
Fig. 7. *The curves family*

The coordinates

$$X = H,$$
$$Y = r_{iH},$$

(12)

determine the axial section of the end mill tool.

In table 1 and fig. 8 are given the coordinates of points from the axial section of the end mill.

Tab. 1. *Coordinates of points from axial section*

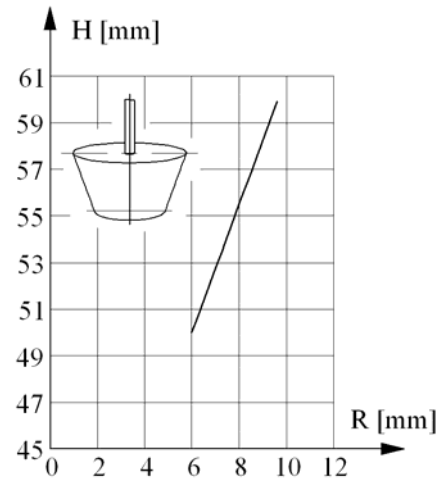| R [mm]	H [mm]
9.6019	59.9
9.4564	59.5
9.2745	59.0
9.0925	58.5
8.9106	58.0
8.7287	57.5
8.5468	57.0
8.3650	56.5
8.1831	56.0
8.0012	55.5
7.8194	55.0
7.6375	54.5
7.4557	54.0
7.2738	53.5
7.0921	53.0
6.9103	52.5
6.7285	52.0
6.5467	51.5
6.3650	51.0
6.1832	50.5
6.0015	50.0

Fig. 8. *The tool's axial section*

5. CONCLUSIONS

The "substitutive circles family" method can be used to profile generating tools for helical surfaces, using graphical design environments. The AutoCAD environment is convenient for solving this problem type.

The graphical method is simple, rapid and rigorous and it has the advantage to be intuitive, avoiding the profiling errors for tools bounded by revolution surfaces reciprocally enveloping with helical surfaces.

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