COMPUTER AIDED DESIGN OF A HELICAL AUGER SURFACE FROM SOIL DRILING MACHINE

V. Ros, M. I. Gheres, V. R. Muntean, G. Balc

Abstract. *A method of computer aided design for helical conveyor surface was developed. The method may be used for designing of different type of helical surface from auger conveyors, elevators or soil drilling machines. There was developed a mathematical model of the helical surfaces and a computer program for generating and plotting the profiles of the surface. A numerical application is presented for the design of the soil drilling machine auger.*

Key words: *computer aided design, auger, soil drilling machine, helical surface.*

INTRODUCTION

Developing new mathematical models of helical surfaces intended to use them in a computer assisted generation is necessary because this type of surfaces are widely encountered in agriculture transportation, food industry, construction materials. Thus, we can mention helical conveyors for powder and grain agriculture products, for fodder silo conveyors in stock's farm, for fodder factories, for deep hole drills.

The expansion of these machinery elements in production was favorized by its advantages: simple construction, good mechanical seal, the possibility to discharge in different points, although the helical conveyor is characterized by low mechanical efficiency, high components erosion due the dust and mechanical friction between the conveyered material and conveyor elements (gutter and worm), the length transport limitation and working capacities.

The large spectrum of applicability of these conveyors imposes a computer aided design to obtain a wide family of conveyors. In consequence, we developed a mathematical model to generate the helical surface, which includes all parametric variables.

The code we developed to represent the helical surfaces is flexible and allow the design of different conveyors by changing the input data. The initial data, imposed by constructive and functional characteristics of working elements of the helical conveyor are mainly represented by the outer and inner screw diameter, the worm length, number of rotation, step variation law, the geometry of longitudinal sections.

This method that we developed in this paper can be easily extended to design worm conveyors active surfaces, helical screw or helical drill of the worm gears.

2. THE MATHEMATICAL MODEL OF THE HELICAL SURFACES

Here we present a method to generate helical surfaces, a study concerning the influence of the functional and design parameters, and also a computer aided generation methodology of a deep hole grill.

The helical conveyor (the auger) is a conveyor with continue section which realize the powder and grain materials movement in closed gutter movement generated by a helix. The working principle of the conveyor is the same as in the screw gearing, here the transported material replaces the nut from the screw gearing system.

2.1 The equations of the helical surface

In order to generate a helical surface let us consider a curve having a kinematics composed by a rotational movement around a fix axis Δ (identical with Oz), characterized by ω - angular velocity, and a simultaneous, translation movement (parallel to Δ axis) determinated by the kinematics screw (Δ,ω, p).

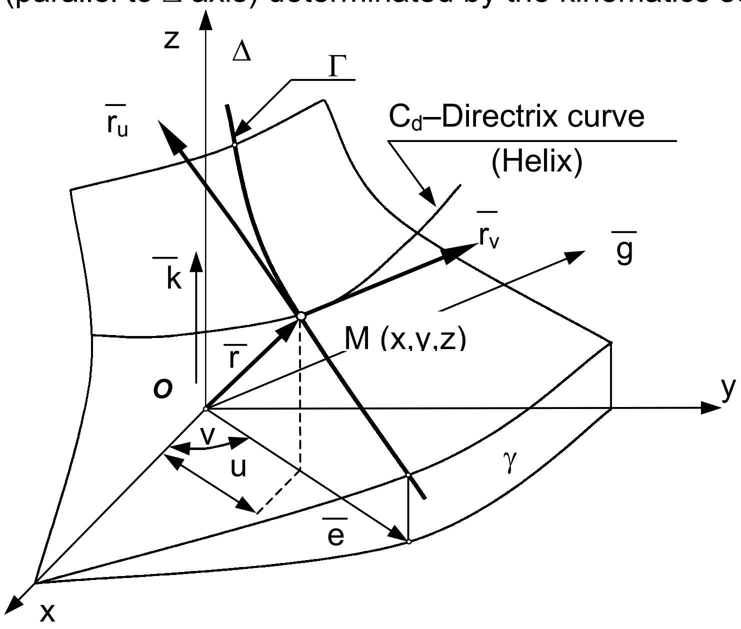


Figure 1. Geometrical parameters of helical surface

The characteristic parameter (p - step) of this movement may be determinate by the following equation:

$$p = \frac{\dot{z}}{\omega}, \tag{1}$$

where:

ω - represents the modulus of the angular speed, and

$\dot{z}$ - represents the translatational speed (parallel with the Δ axis of the helical movement)

A coordinating system $(\overline{e}, \overline{g}, \overline{k})$ was chosen in order to develop the mathematical model. This coordinating system makes a rotational movement reported to the Cartesian coordinating system (xOyz).

The vectors $\overline{e}$ and $\overline{g}$, which characterize the rotational movement in the xOz plane are described by the parametric equations:

$$\begin{aligned} &\overline{e}, \overline{g} \in (xOy), \\ &\overline{e} = \overline{e}(v), \quad , \\ &\overline{g} = \overline{g}(v), \end{aligned} \tag{2}$$

so that the two vectors, $\overline{e}$ and $\overline{g}$, must be perpendicular one to the other $\overline{e} \perp \overline{g}$.

On the other side, the angle between the vector $\overline{g}$ and the Ox axis is given by the expression:

$$m(\widehat{\overline{g}, Ox}) = v + \frac{\pi}{2}. \tag{3}$$

The vector $\overline{e}$ will describe in the horizontal reference plane, a circle arc γ with the center in the coordinating system origin, and the radius equal to 1.

To generate a helical surface we consider a curve Γ contained in the (*e, k*) plane which makes an helical movement reported to the coordinating system xOyz

The vector equation as we described above is:

$$\overline{r} = u \cdot \overline{e}(v) + \overline{k} \cdot [G(u) + p(v)], \tag{4}$$

Based on the equation (4), we can write the surface parametric equations as follows:

$$(S) \quad \begin{cases} x = u \cdot \cos(v) \cdot f(v) \\ y = u \cdot \sin(v) \cdot f(v) \\ z = \Gamma(u) + p(v) \end{cases} . \tag{5}$$

In the equation (5) all the geometric independent surface parameters occurs, as follows:

p(v) - the step of the helical surface;

f(v) – this function represents the variation law of surface border;

u – linear parameter, $u \in [R_i, R_e]$. R_i, R_e representing the inner and the outer screw radius;

v - angular parameter and $v \in [\alpha, \beta]$. α and β are the initial and the final rotation angles of the curve Γ. α - is an independent parameter and β is a function of the total screw high, $\beta = f(H)$;

$\Gamma(u)$ - the profile function of the generation curve;

(x,y,z) - the coordinates of a M point arbitrary chosen on the surface.

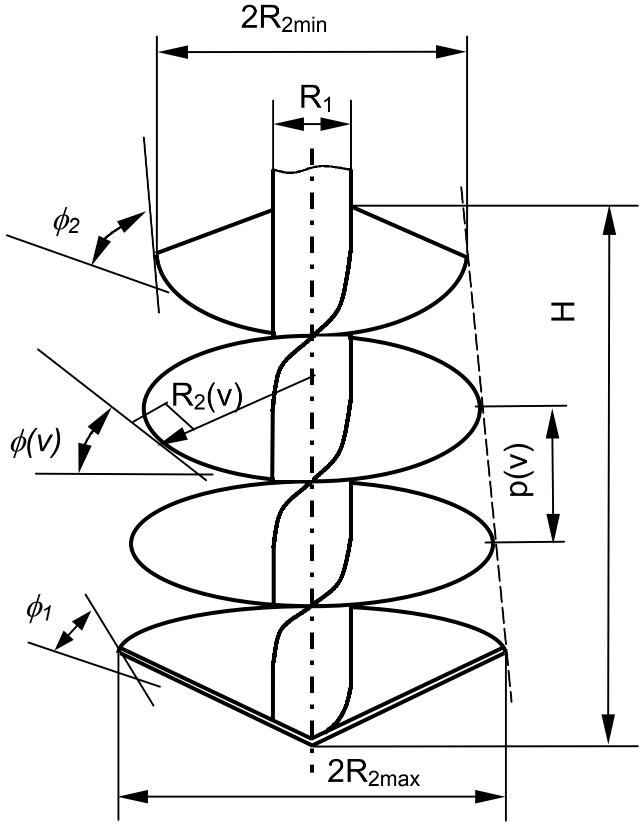


Figure 2. Main parameters from a helical auger of soil drilling machine.

The parametric equations (5) particularized for different functional conditions of the conveyor can be used to generate the helical surface.

For example, for a helical conveyor for small grain size and specific weight, to increase the conveyor flow with geometric restriction applied on the inner gutter diameter, we recommend to increase the slope helix angle and of the helical step, which ensures us an acceleration of transported material.

Most of helical conveyors with a constant step p are used to transport medium grain size materials (20 – 80 mm).

To develop the mathematical model of the active surface from the deep hole drills (see figure 2) we will particularize the parametric equations (5). Also, the financial aspect and the manufacturing aspects must be taken into account. Thus we decline: the Γ curve is represented by a straight line, the generated surface is a ruled surface, easy to manufacture. The line slope will take values in the range of ϕ_1 to ϕ_2 , corresponding to the beginning and to the conveyor surface end. The equations is:

$$\Gamma(u) = c_1 \cdot u + c_2 . \tag{6}$$

where the coefficient c_1 is given by:

$$c_1 = tg(\phi(v)), \tag{7}$$

where, $\phi(v)$ is the current value of the helix slope, ($\phi(v) \in [\ \phi_1\ ,\ \phi_2\ ]$) and is given by the relation:

$$\phi(v) = \phi_1 + v \cdot \frac{\phi_2 - \phi_1}{\beta - \alpha}. \tag{8}$$

According to the specific literature, the ϕ_1 angle takes values in the range 10^0 - 15^0 in order to reduce the soil cutting resistance forces and for ϕ_2 angle values in the 25^0 – 45^0 range are recommended in order to ensure the material exhaustion.

For a good functionality, a variable step is recommended, so that the soil can extend its volume during the transportation process without creating undesired resistance forces. To simplify the problem, we imposed a linear step variation given by the following function:

$$p(v) = p_0 + R_{2\max} \cdot tg(\phi(v)). \tag{9}$$

were p_0 represents the initial step.

To create the helical surface of the screw, we impose a maximum value for the pin diameter ($2R_{2max}$) and a minim diameter ($2R_{2min}$) at the end to avoid the friction with the hole wall. Thus, the variation law of the exterior radius is given by the next linear expression:

$$f(v) = R_2(v) = R_{2\max} + v \cdot \frac{R_{2\min} - R_{2\max}}{\beta}. \tag{10}$$

2.2 The code developed to generate the helical surfaces

We used Matlab 5.2 platform to create the code that generates the parametric surfaces. To visualize the graphs we used surf and mesh visualization functions.

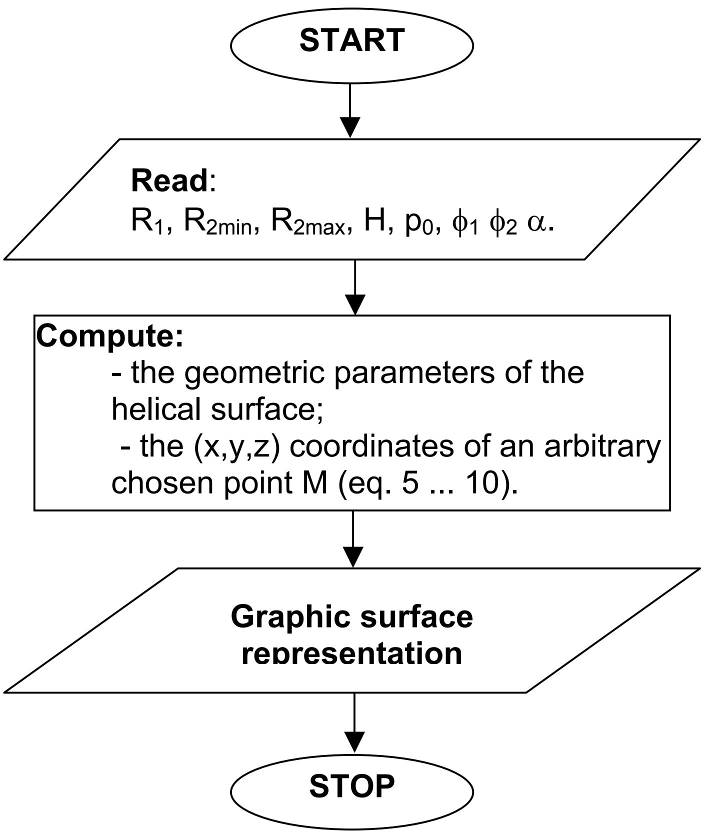


Figure 3. Flowchart diagram of elaborate program.

In figure 3 we present the flowchart diagram of the application. First the input data are introduced by the user, then, based on the equations we described above, the parametric surface is being generated.

When the input data are introduced, the user must acknowledge:

The geometric elements (lengths, diameters) are given in mm and the angular elements in radians;

The ruled surfaces are much easier to manufacture than unruled surfaces, so the nonlinear sections are not recommended.

To visualize the surface, the code uses a 65 or 127 grid point generation.

The code offers the user to represent the surface at the desired scale and view point. When needed, the user can refine the grid used to generate the surface.

2.3 The numerical application

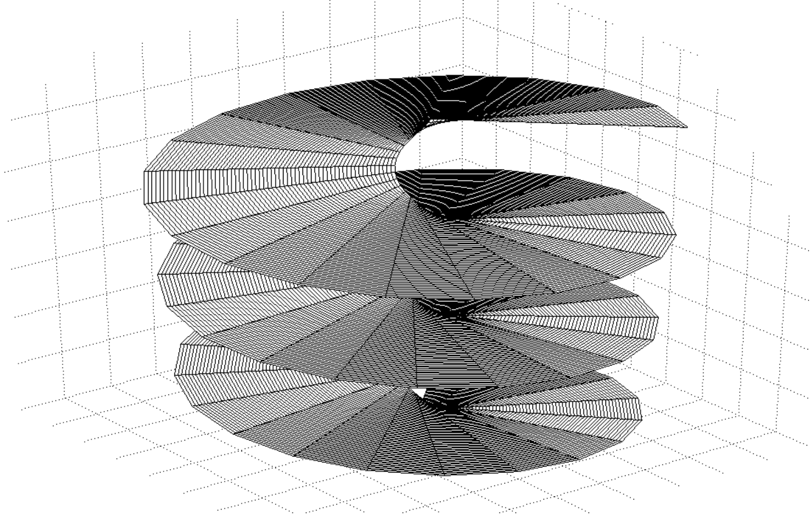
To emphasis, we developed a specific program for the helical surface generation for soil drilling machines and the graphical representation, designed with the above methodology. The input data are given in Table 1.

A specific program for the helical surface generation from soil driling machine augers and graphical representation were developed. The program is based an the above methodology. The input data given in Table 1.

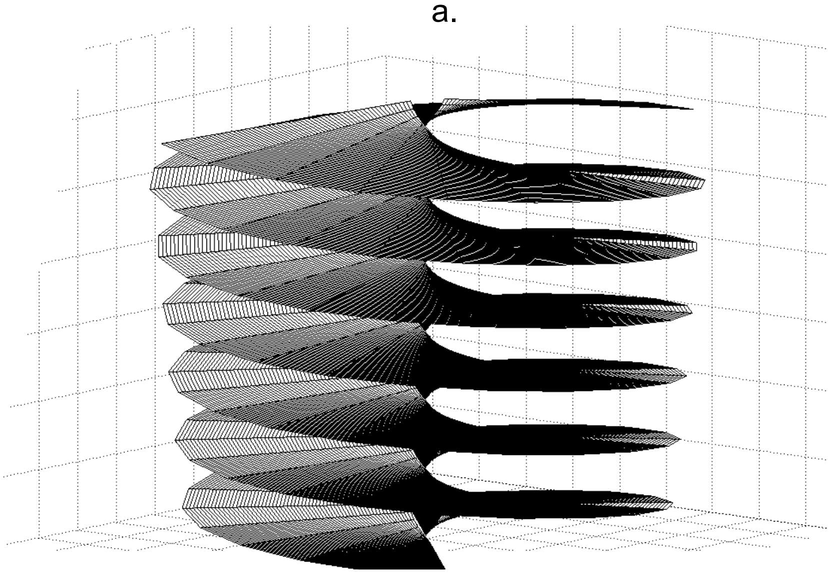
Table 1.

R_1 [mm]	R_{2min} [mm]	R_{2max} [mm]	H [mm]	α [^{0}]	Φ_1 [^{0}]	Φ_2 [^{0}]
150	400	470	600	0	10	45

Based on the above data, there were generated and plotted the graphical representation of the active surface of the two types of soil drilling machine augers.



a.



b.

Figure 4. Graphical representation of two helical auger:
a. - one helix auger; b. – two helix auger
(v. point ,)

3. CONCLUSIONS

The method presented herein can be easily generalized to other surfaces.

The code we created to generate the helical surface ensures a high fidelity representation and in the same time, allows the time and money saving in the manufacturing process.

The mathematical model we developed can be used in an optimisation problem of functional and design parameters of the helical conveyors like: the mechanical efficiency, the flow growth.

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ABOUT THE AUTORS

Victor Ros, Professor of Technical University of Cluj – Napoca, Bd. Muncii, 103-105, Cluj - Napoca 400641, Romania, E-mail: victor.ros@personal.ro.

Marius Ioan Gheres, Lecturer of Technical University of Cluj – Napoca, Bd. Muncii, 103-105, Cluj - Napoca 400641, Romania, E-mail: marius.gheres@personal.ro.

Vlad Radu Muntean, Junior lecturer of Technical University of Cluj – Napoca, Bd. Muncii, 103-105, Cluj - Napoca 400641, Romania, E-mail: vlad@imuntean.ro

Gavril Balc, Asociated professor of Technical University of Cluj – Napoca, Bd. Muncii, 103-105, Cluj - Napoca 400641, Romania, E-mail: balcgabi@yahoo.com