Disk Tool Profiling for Helical Surfaces Generation

Xác định biên dạng dụng cụ dạng đĩa gia công mặt xoắn vít

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Abstract

This paper proposed solutions for profiling the disc tool in machining a helical cylindrical surface with constant pitch. A section method has been developed in AutoCAD environment together with a Boolean operation. Especially, this work presented a computational problem of determining the any section of a helical surface, while other documents only refer to the section along axis and cross section. The authors used a combinative method of analytics, graphics and programming to solve that problem, applying in designing cutting tool for machining helical cylindrical surfaces. The proposed method has been implemented and verified through subroutines written in Visual C running in AutoCAD. The testing results have confirmed that the proposed methods achieve high accuracy for variant profiles of helical surfaces in short time conputation.

Keywords: Helicoids, Profiling, **D**isc tool

Tóm tắt

Bài báo đề xuất nhiều giải pháp tạo biên dạng cụ dạng đĩa gia công mặt xoắn vít có bước xoắn không đổi. Phương pháp mặt cắt cùng phương pháp sử dụng toán tử Boolean đã được triển khai trong môi trường AutoCAD. Đặc biệt, công trình đã trình bày vấn đề tính toán xác định tiết diện bất kỳ của mặt xoắn vít trong khi các tài liệu khác chỉ trình bày tiết diện dọc trục và tiết diện ngang. Các tác giả đã kết hợp phương pháp giải tích, đồ hoạ và lập trình để giải quyết vấn đề, ứng dụng vào thiết kế dụng cụ gia công mặt xoắn vít. Phương pháp đề xuất đã được thực hiện và kiểm tra thông qua những chương trình con viết bằng Visual C chạy trong AotoCAD. Những kết quả kiểm tra đã khẳng định phương pháp đề xuất đạt độ chính xác cao cho các biên dạng khác nhau của mặt xoắn vít trong thời gian ngắn.

Từ khoá: Xoắn vít, Tạo hình, Dụng cụ dạng đĩa.

1. Introduction

Helical cylindrical surfaces with constant pitch are encountered in practice as helical slots on the active surfaces of different parts such as helical screws, worms, helical teeth gears, helical pumps components etc. or cutting tools such as helical drills, helical teeth reamers, helical counter bores, cylindrical mills with helical teeth. Disk tool profiling for helical surfaces generation involves solving a specific problem: to find the contact conditions and the corresponding characteristic curve, at the contact between a helical cylindrical surface and the tool primary peripheral surface.

Analytical solutions for profiling tools generated by surfaces enveloping are common and have been used for a long time. These solutions are based on the fundamental theorems of the surfaces enveloping such as Olivier's first theorem [1] and Gohman's fundamental theorem [1, 2]. Also, frequently used is Nicolaev's theorem [3, 4], based on the helical movement decomposition. Complementary analytical methods have also been developed more recently. Examples include the "minimum distance" method [5] and the "in-plane generating trajectories" method [6]. A profiling solution based on the Bezier approximating polynomials for the helical surfaces generatrix [2] was also proposed recently. This solution allows the determination of the tool's cutting edge via a finite number of points along the profile to be generated with an acceptable precision from an engineering perspective. These methods allow obtaining solution that is rigorous and suggestive for the designer.

The development of the graphical design environment such as AutoCAD or Inventor allows us to elaborate new methods and dedicated software to solve the issue of generation of helical surfaces, that will be presented in this paper.

2. Methods for disk tool profiling

2.1. Fundamental theory in brief

The generating process kinematics in the case of helical surface generation using a tool delimited by a

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revolution primary peripheral surface – a disc tool – involves a combination of three motions (see Fig. 1):

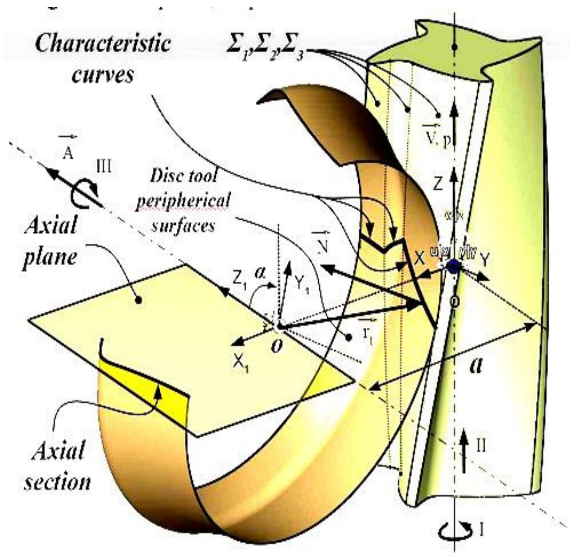


Fig. 1. Disc-tool primary peripheral surface and helical surface to be generated [2]

I – rotation motion of the worked piece on which the helical surface to be generated (cylindrical and having constant pitch) is placed;

II – translation motion along the worked piece rotation axis, correlated to the rotation motion, having as purpose to create a helical motion of $\vec{V}$ axis and p parameter identical to the generated surface ones;

III – cutting motion – tool rotation around its axis, $\vec{A}$.

The following reference systems have to be considered:

- XYZ, meaning a system attached to the helical surface to be generated, having the $\vec{Z}$ axis coincident to $\vec{V}$ axis of the helical surface.

- $X_1Y_1Z_1$ – system attached to the disc-tool axis, $\vec{A}$ Nikolaev theorem applied in order to find the characteristic curve owning to both surfaces, Σ, to be generated and S – tool primary peripheral surface is [2]: (see also Fig. 1)

$$(\vec{A}, \vec{N}_\Sigma, \vec{r}_1) = 0 \qquad (1)$$

where: $\vec{A}$ is the vector of the disc-tool surface S rotation axis;

$\vec{\boldsymbol{N}}_\Sigma$ - Σ surface normal, into the XYZ system;

$\vec{\boldsymbol{r}}_1$ the position vector of the current point from Σ surface, referred to $X_1Y_1Z_1$ origin, O1.

2.2. Proposed Methods

2.2.1. Section method

Use many cutting planes, that is perpendicular to the axis of the disk tool. For each cutting plane, the intersection beetwen the plane and the helical surface (see Fig. 2: EF) must be tangent to the circle, that is intersection beetwen the cutting plane and the disk toll, the contact point can be found. The characteristic curve (B_TC_T) is specified by a set of contact points.

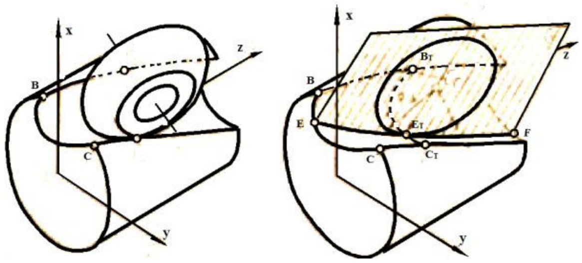


Fig. 2. Two intersections are tangent

a) 3D CAD Methode

Using 3D CAD software such as Inventor, it is easy to draw the intersection between any cutting plane and 3D solid model of the given detail that contains helical surfaces (see Fig. 3).

Export Drawing File to AutoCAD, in AutoCAD, specify contact points by using perpendicular osnap mode (see also Fig. 3).

Affter specifying a number of contact points, it is not diffical to specify the axial section of disk tool, then using Revole command to creeate *primary peripheral surface* of the disk tool.

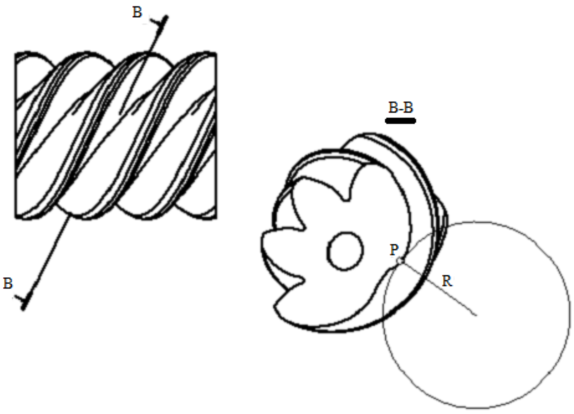


Fig. 3. Specify the contact point P

b) Computation method (see Fig. 4)

<u>Given:</u>

- The profile BC of cross section N-N of helical surface.
- Position of a cutting plane P-P

Specify: The section P-P

The profile BC on section N-N is given by a number of points, as usual, each point of them is given by a pair r, δ (polar coordinates), it can be translated into Cartesian coordinates as:

$$x = r \sin \delta \quad (2)$$

$$y = - r \cos \delta \quad (3)$$

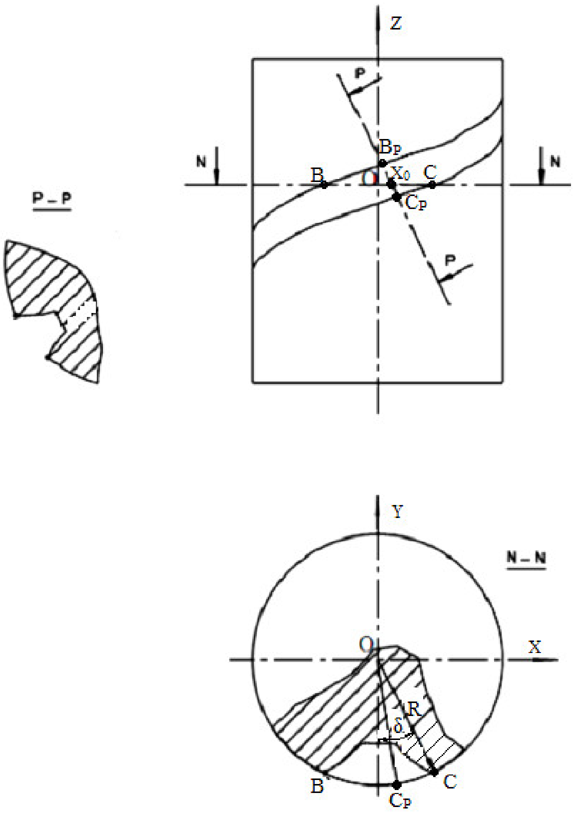


Fig.4 Specify intersection of a helix and cutting plane

The equations of the helical surface are written as:

$$x = r \sin(\delta + d\delta) \quad (4)$$

$$y = - r \cos (\delta + d\delta) \quad (5)$$

$$z = p\, d\delta \quad (6)$$

Where p is the parameter of the helix, dδ is angle that the profile N-N rotates about the axis of the helical surface.

The equation of the cutting plane P-P is written as:

$$z = k\,(x - x_0) \quad (7)$$

Where k, x_0 are parameters of the given cutting plane P-P.

So, the intersection point between cutting plane P-P and the helix from any point on cross section N-N, such as C_N, satisfies the equation:

$$p\, d\delta = k\,(r \sin(\delta + d\delta) - x_0) \quad (8)$$

The equation (8) can not be solve exactly, but it can be solve approximately by using computer with the subroutine in ARX language, running in AutoCAD, its algorithm as follows (see Fig. 5):

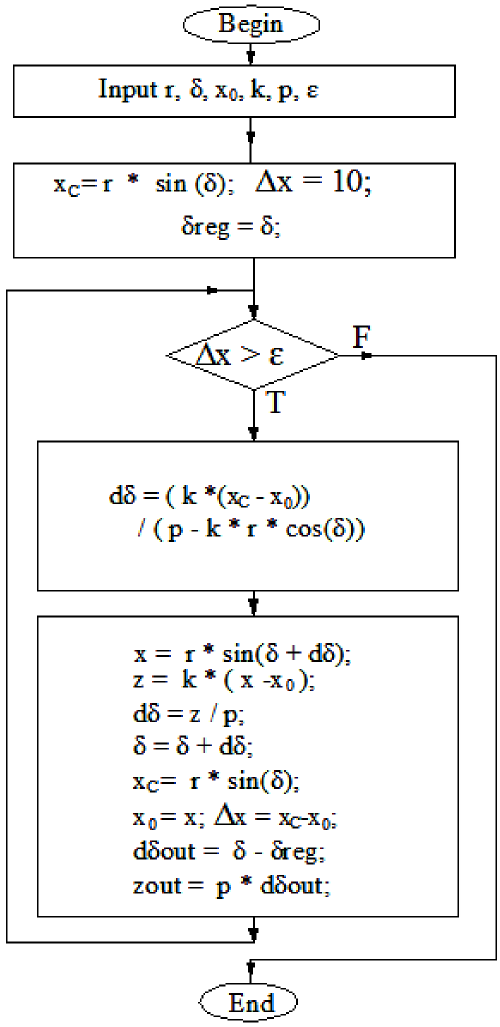


Fig.5 The algorithm for solving the equation (8)

Using the above subroutine, after specifying a number points on cutting plane P-P, join them by a spline and find contact point then create axial section of disk tool by the way shown in the section 2.2.1.a

2.2.2. Boolean operation method

In this method, CAD approach is used to simulate generation machining process. For this purpose, the cutter and work blank are taken as solid models and simulation is performed using Boolean operation to remove unwanted material in an incremental manner, maintaining the kinematic relationship. (see Fig. 6)

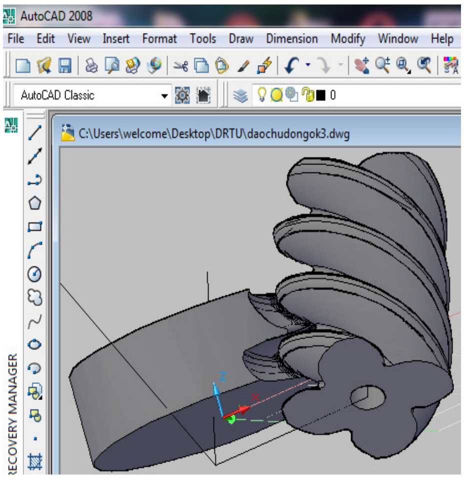


Fig. 6. Creating the disk tool for helical surfaces in AutoCAD

3. Testing results, discussion and conclusion

The disk tool created by using the methods mentioned above and the given helical surface have been cheeked the tangency condition as follows (see Fig. 7, 8):

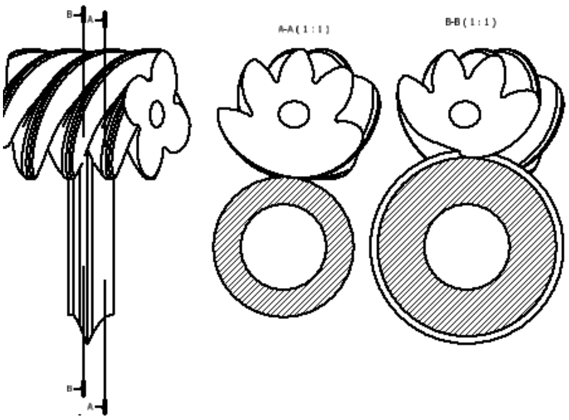


Fig. 7. Testing tangency condition on sections

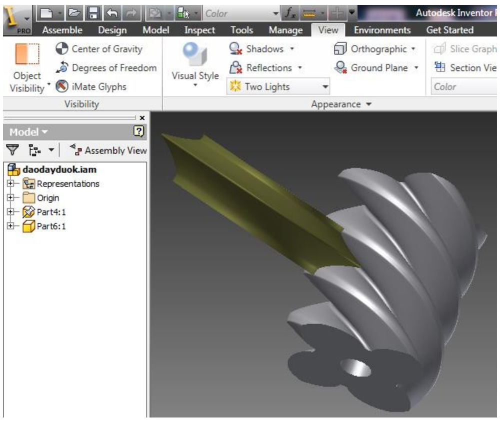


Fig. 8. Testing tangency condition by using “constrain” command in Inventor

The Fig. 7 and Fig. 8 have shown that the disk tool and the given helical surface seem to satisfy absolutely the contact conditions.

The accuracy of the disk tool profile have been also tested by the simulative machining, that has used the Boolean operation in AutoCAD as shown on Fig. 9, 10.

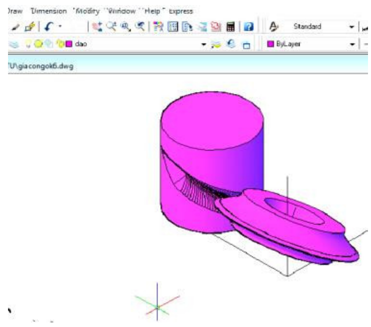
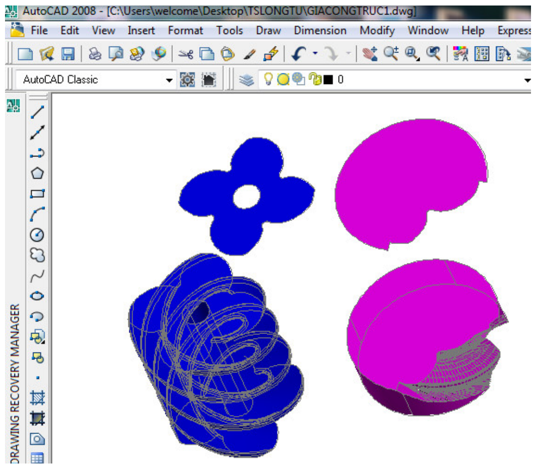
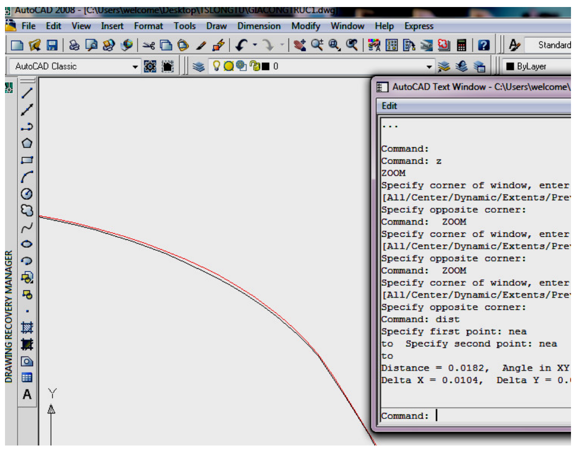


Fig. 9. Simulative machining in AutoCAD



(a) Creating two profiles



(b) Comparison between two profiles

Fig. 10. Testing accuracy of the disk tool by simulative machining

The Fig. 9 and Fig. 10 have shown that the helical surface generated after the simulative machining have been compared with the given helical surface, the maximum difference between their cross sections is 0.0182 mm (see also Fig. 10b, in the AutoCAD text window).

The testing results have confirmed that the proposed method achieve high accuracy for variant profiles of helical surfaces in short consumed time and have demonstrated the functionality and the reliability of the proposed methods that confront the complex problem of disk tool profiling for helical surfaces generation. The proposed method was created on implementation point of view while the most others were conceptual [1,3,4] so the method is suitable to create application software running in the AutoCAD which is more popular and cheaper than CATIA [2,5,6].

In near future, we will complete the method in order to design more complex cutting tool based on upgraded envelope technique.

Acknowledgments

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