Indirect Reverse Engineering and Disk Tool Profiling for Air Compressor Screws Pair

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Abstract. The screw compressors are being widely used because of their compact size while stable operation, high pressure, and high flow speed compared to other types of positive displacement machines. The conventional approaches to designing the screws pair of this machine and its embraced cutting tools were based on complicated envelope equations that could not be solved without a computer, especially in the case of singularities and undercutting. This paper presents the method of mixing CAD approaches and reverse engineering for designing the air compressor screws pair and the integrated solutions for the disc tool profiling that avoid the undercutting and singular point with the best angle formed by the screw and its disc tool axis. The air compressor rotor 3D model pair and their disc tools designed using the proposed methods are highly accurate (the RMS error is 0.0145 mm). The proposed method for creating air compressor screw pairs may also be the foundation for studying new air compressor screw profiles.

Keywords: Meshing condition · Compressor screw pair · Disc tool profiling

1 Introduction

Recently, the screw compressors are being widely used because of their compact size while stable operation, high pressure, and high flow speed compared to other types of positive displacement machines. The conventional approaches to designing the screws pair of this machine and its embraced cutting tools were based on envelope equations [1–4]. By trend of applying information technology, numeric solutions [5–7] were usually applied recently. The equation system in the above methods is very difficult to be solved exactly, so it requires a dedicated algorithm. These approaches need the given surface to be represented by the mathematical equations system without singularities and undercutting phenomena. In some most modern works, the CAD approaches are employed: The authors of the work [8] have used the "Projection" command in the CATIA package to project the rotating cutter's axis to the machined surface to get the characteristic curve. In work [9], machining simulation by the Boolean operation is employed to determine generated surface by the given cutting tool. Two main approaches used to design the air compressor screw pair are as below:

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– Traditional design method used for the generation of screw compressor rotor profiles is determining curves on the main screw profile and then generating a corresponding curve on the screw profile based on the envelope theory fundamental research.
– Reverse engineering method is creating 3D models rotors from a real compressor using 3D scan equipment or CMM (coordinate measuring machine).

This paper presents the method mixed both approaches above in detail for designing the air compressor screws pair and the integrated solutions for the disc tool profiling that avoid the undercutting and singular point with the best angle formed by the screw axis and its disc tool axis.

2 Indirect Reverse Designing and Disk Toll Profiling

2.1 Reverse Engineering Data

After using reverse engineering, the air compressor Airman PDS50 rotor pair were not accurate, as shown in Fig. 1. So it needs to correct the profile on the cross-section of the main rotor (as shown in Sect. 2.2) and then create the gate rotor profile from the corrected profile of the main rotor (as shown in Sect. 2.3).

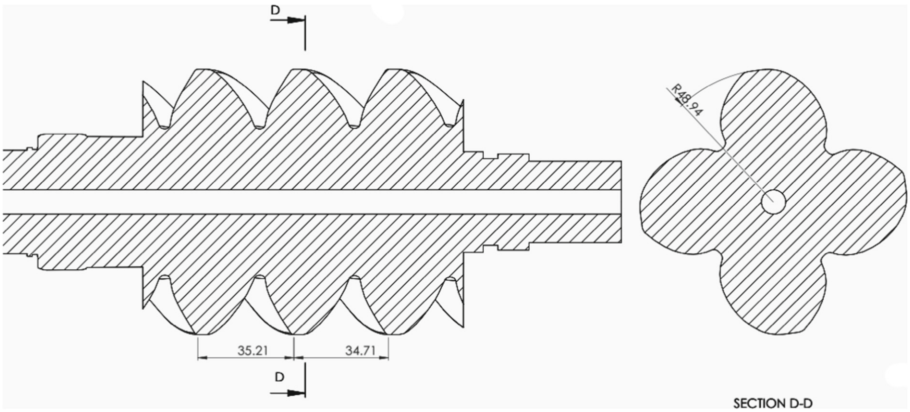


Fig. 1. The main rotor model created by reverse engineering

2.2 Correcting the Main Rotor Profile

From the reverse engineering data, the cross-section profile of the main rotor was analyzed into the segments, as shown in Fig. 2. Where BC is an epicycloid with a pitch circle of radius 30 mm and the epicycle of radius 35 mm, CD, DE, EF, FG, and GH are tangent each to the next one. AB and HI are ellipse arcs.

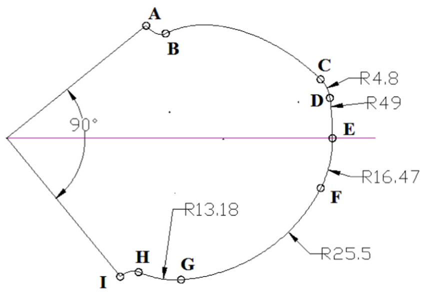


Fig. 2. The main rotor profile after correcting [10]

2.3 Creating the Gate Screw Profile

The algorithm for creating gate rotor profiles is shown in Fig. 3a. Where $Solid_1$ is created from the main rotor correct profile, $Solid_2$ is first created from a circle, and then it will become gate rotor profile after performing the algorithm (see Fig. 3b,c). Form the two profiles created above, using the "SWEEP" command in AutoCAD, create 3D solid models of two screws with the constant leads specified from reverse engineering data.

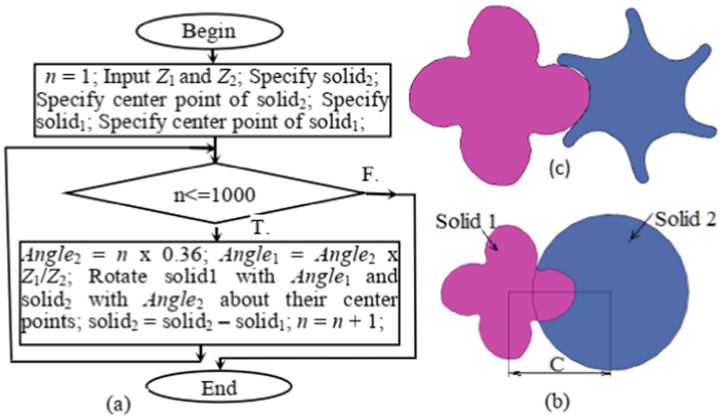


Fig. 3. (a) The algorithm creating profiles; (b) starting solids; (c) the final profile

2.4 Methods for the Disc Tool Creating and Deviation Evaluation

Two advanced methods of creating disc tool are as below

a) The first method uses a subroutine that includes a loop using subtract command in AutoCAD. The subroutine executes the process in which the "cuter" is the rotor, and the "workpiece" is the disc tool [10, 11].
b) The second method is explained as follows

The characteristic curve can be created based on envelope theory [12] by projecting the cutter rotate axis onto the machined surface, as shown in Fig. 4. The reference plane, where the disc toll axis is placed, is parallel to the machined rotor axis. *Σ* is the angle between the disc toll axis and machined rotor axis, and parameter h is the position parameter of the disc toll axis. If the characteristic curve contains singularity or is not continuous, the value of Σ and h must be changed. A simulative machining process can evaluate the geometric error of the machined rotor surface and its disc tool surface. The machining process is performed similarly to creating the disc tool profile mentioned in Sect. 2.4(a). In order to avoid undercutting phenomena and then create a disc tool surface, it is better to use the second method mentioned in Sect. 2.4(b) to specify the appropriate cutter position. By such process, the distance between the cutter axis and the machined gate rotor axis was found as 90 mm, the two axes angle was found as 36,7°.

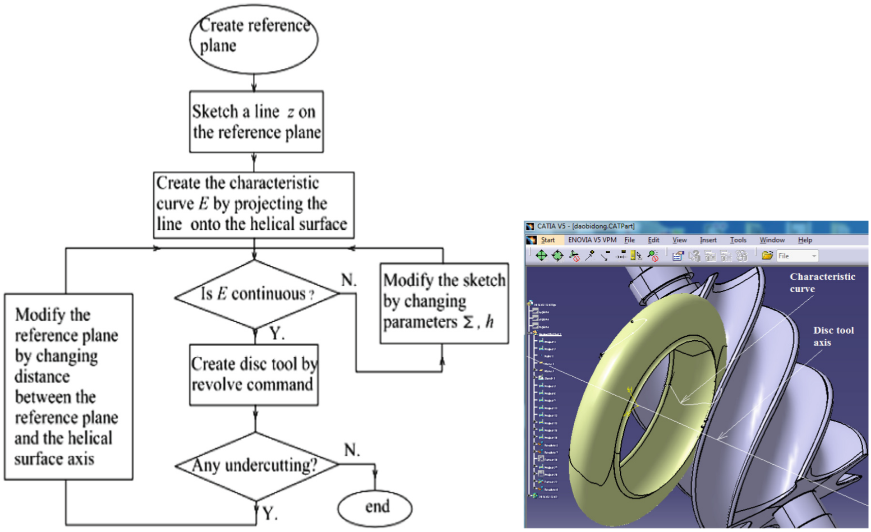
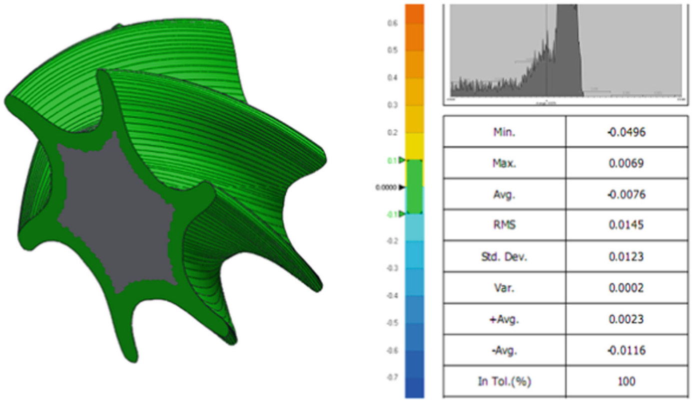


Fig. 4. The characteristic curve and disk tool creating process [12]

A 3D comparison between the gate rotor surface created by the method mentioned in Sects. 2.3 and the gate rotor surface after simulation machining by the disc tool with an angle of 36.7° is shown in Fig. 5. That Figure has demonstrated that the proposed method for the disc tool profiling has achieved a high accuracy of 0.0145 mm.



Min.	-0.0496
Max.	0.0069
Avg.	-0.0076
RMS	0.0145
Std. Dev.	0.0123
Var.	0.0002
+Avg.	0.0023
-Avg.	-0.0116
In Tol.(%)	100

Fig. 5. The 3D accuracy of the helical surface machined by the disc tool with an angle of 36.7°

3 Conclusion

This paper presents the method of mixing CAD approaches and reverse engineering for designing the air compressor screws pair and the integrated solutions for the disc tool profiling that avoid the undercutting and singular point with the best angle formed by the screw and its disc tool axis. The air compressor rotor 3D model pair and their disc tools designed using the proposed methods are highly accurate (the RMS error is 0.0145 mm). To avoid undercutting phenomena and then create a disc tool surface, it is better to use the second method mentioned in Sect. 2.4(b) to specify the appropriate cutter position. By such process, the distance between the cutter axis and the machined gate rotor axis was found as 90 mm, the best angle was found as 36,7°. The proposed method for profiling the rotors may also be the foundation for studying new air compressor screw profiles.

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