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Effects of Various Profile Parameters on the Performance of a Variable Cross-section Scroll Compressor

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Abstract

In order to quantitatively study the variable cross-section scroll compressor geometric performance, a profile of variable cross-section scroll compressor is proposed, which is composed of circular involute and high-order curve. The profile formula is derived. The scroll profile is generated by the normal isometric method, the tooth head is corrected by double arc and straight line. The generation principle of variable cross-section scroll is introduced in detail, and its geometric model is established. Using the control variable method, the influence of profile parameters (connection point and radius of revolution) on the volume of working chamber, the length of radial leakage line and the volume ratio of content were studied. Comprehensive analysis shows that when the optimal parameter connection point is in 2π-4π, the corresponding volume of each cavity is the largest, and the system has good performance, which provides theoretical guidance for design new variable cross-section scroll compressor.

Keywords

Profile; Scroll Compressor; Variable Cross Section; Geometric Model.

1. Introduction

As the core device of fluid machinery, compressor is the heart of refrigeration system. As the third generation of positive displacement compressor, scroll compressor has the advantages of light weight, low noise and high efficiency. It has been widely used in air conditioning and refrigeration and has broad application prospects and market [1-2].

Profile is the basis of studying scroll compressor, and its parameter optimization directly affects the volume of compression chamber and compression ratio of scroll compressor. As the key point of scroll compressor design and processing, the selection of scroll profile directly affects the mechanical properties, vibration characteristics and service life of the compressor [3]. The profile can be divided into two categories: equal section (the main working scroll tooth has equal wall thickness) and variable section (the main working scroll tooth has non equal wall thickness). The cross-section of scroll teeth of constant cross-section compressor is equal everywhere. To increase the compression ratio, only the length of profile and the number of turns can be increased, which will make the compressor size too large and increase the length of leakage line. Variable cross-section scroll compressor can achieve high pressure ratio at a small number of turns. Researchers at home and abroad have carried out a lot of research work on this.

Ahn et al. [4] studied the lubrication characteristics of journal bearing of scroll compressor, and considered the deformation and dynamic characteristics of crankshaft. The pressure distribution of journal bearing is determined by solving Reynolds equation with finite difference method. The results show that the deflection of crankshaft has a significant effect on the minimum clearance of journal bearing. Pereira et al. [5] studied the influence of different gases, working conditions and geometric

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shapes on the radial and tangential leakage of scroll compressor through numerical analysis. The geometric model and numerical model are established. Liu Guoping et al. [6-7] established a finite element model of scroll compressor based on thermal field coupling, and analyzed the stress of scroll. The results show that the maximum stress and deformation of scroll is at the exhaust hole, and thermal deformation is the main factor affecting the overall deformation of scroll. Peng bin et al. [8-9] studied the performance of new oil-free scroll compressor and carried out experimental verification]Based on the isentropic laminar flow theory, the calculation model of axial clearance leakage of variable cross-section scroll compressor at any spindle angle was established; Yang Fen et al. [11] established the finite element model of scroll plate of automobile scroll compressor based on the coupling of thermal stress field; Zhang Lifang [12] established the prediction model of instantaneous milling force of variable cross-section scroll plate considering the factor of tool runout; Qiu Haifei [13] established the prediction model of instantaneous milling force of variable cross-section scroll plate through the virtual sample The flexible body dynamics simulation of scroll compressor is carried out based on the virtual machine technology and ADAMS simulation platform. Jia Qingchen [14] Based on the thermodynamic and dynamic analysis of the compressor movement process, optimized the structural parameters of the variable base circle involute scroll compressor; Liu Tao et al. [15] studied the generation of the scroll compressor profile using the normal equidistant method, and gave the calculation formula of the compression chamber volume.

At present, the research of variable cross-section scroll compressor mainly focuses on the profile and volume characteristics, but the research on the influence of profile parameters on the performance of variable cross-section scroll compressor is rarely reported. In this paper, the geometric model of scroll compressor with different profile parameters is established, and the influence of profile connection point and radius of gyration on the volume of working cavity, length of radial leakage line and content product ratio of scroll compressor is studied quantitatively by control variable method.

2. Establishment of profiles

2.1 Baseline equation and inner and outer wall equation

The baseline of the combined profile is shown in Figure 1. The baseline is composed of circular involute + high-order curve + circular involute. The circular involute is selected for the inner ring and outermost ring, and the high-order curve in the form of power series is selected for the middle connecting profile.

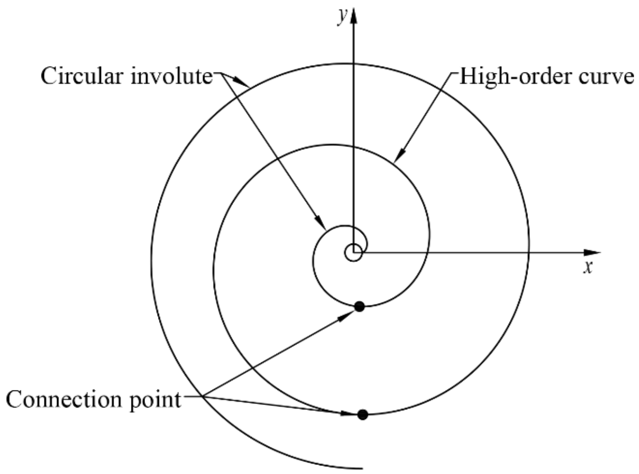

Figure 1. Baseline of combined profile

The first segment of circular involute:

$$\begin{cases} x = R_{g1} \cos\varphi + R_{s1} \sin\varphi \, , \\ y = R_{g1} \sin\varphi - R_{s1} \cos\varphi \, . \end{cases} \varphi \in 0, \varphi_1) \tag{1}$$

Where, R_{g1}=R_{s1}.

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The second high degree curve:

$$\begin{cases} x = R_{g2}\cos\varphi + R_{s2}\sin\varphi\,, \\ y = R_{g2}\sin\varphi - R_{s2}\cos\varphi\,. \end{cases} \varphi \in \varphi_1, \varphi_2) \tag{2}$$

Where, C_0, C_1, C_2, C_3 is a constant, φ_1, φ_2 they are connection points.

$$\begin{cases} R_{g2} = C_1 + 2C_2(\varphi - 0.5\pi) + 3C_3(\varphi - 0.5\pi)^2 \\ R_{s2} = \begin{Bmatrix} C_0 + C_1(\varphi - 0.5\pi) + C_2(\varphi - 0.5\pi)^2 \\ +C_3(\varphi - 0.5\pi)^3 \end{Bmatrix} \end{cases}$$

The third circle involute:

$$\begin{cases} x = R_{g1}\cos\varphi + R_{s1}\sin\varphi\,, \\ y = R_{g1}\sin\varphi - R_{s1}\cos\varphi\,. \end{cases} \varphi \in [\varphi_2, 8\pi] \tag{3}$$

$$\varphi_1 \begin{cases} R_{g1}(\varphi_1) = R_{g2}(\varphi_1) \\ R_{s1}(\varphi_1) = R_{s2}(\varphi_2) \end{cases} \quad \varphi_2 \begin{cases} R_{g2}(\varphi_2) = R_{g1}(\varphi_2 + 2\pi) \\ R_{s2}(\varphi_2) = R_{s1}(\varphi_2 + 2\pi) \end{cases}$$

Table 1. Basic parameters of scroll plate

parameter	numerical value
Radius of base circle a/mm	10
Radius of gyration R_{or}/mm	15.7
Generating angle of involute α /rad	π/4
Vortex height h/mm	10

2.2 Generation of scroll

In Figure 2, the geometric model of the scroll disk is established, and double arcs and straight lines are modified. ab, bc and cd are double arcs and straight lines. The profile composed of af and de segments is the involute of the first segment. The curves composed of eh and fg segments are of higher order. The profile consisting of hi and gj segments is the circular involute of the second segment.

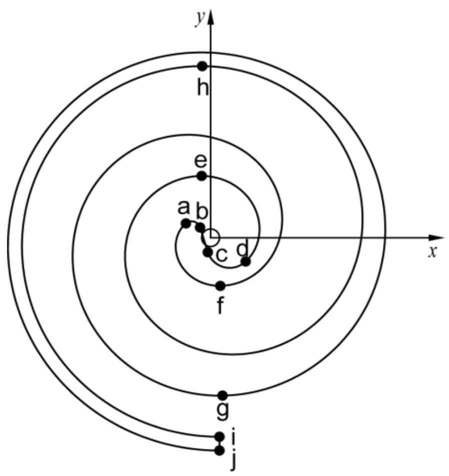

Figure 2. Geometric model of vortex teeth

3. The influence of the connection points on the system

3.1 Influence of connection points on volume cavity

The calculation of the working chamber volume is the key to establish the geometric model of scroll compressor, as well as the key to establish the thermodynamics and dynamics model.

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Calculation formula of working cavity volume [16]:

$$V = h\xi \tag{4}$$

Where h for vortex teeth tooth depth, ξ for work cavity corresponding projection area.

In Figure 3, on the circle involute of infinitesimal triangle ABC, according to the characteristics of the circular involute, micro yuan the lengths of straight and curve edges of the triangle is $a\delta$ respectively and $a\delta \times d\delta$, micro yuan of the triangle area of:

$$d\xi = \frac{1}{2}(a\delta)^2 d\delta \tag{5}$$

$$\xi = \int_0^{\delta} \frac{1}{2}(a\delta)^2 d\delta \tag{6}$$

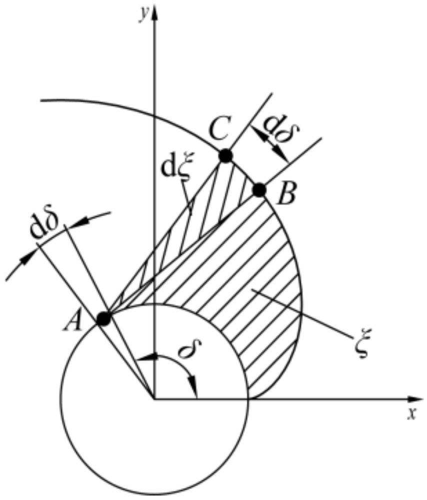

Figure 3. Area Schematic diagram

When other profile parameters remain unchanged, four groups of different profile connection points are selected and a high-order curve of 1 turn is used to replace a 2-turn involute, which not only achieves a high compression ratio with fewer turns, but also reduces the overall size. The connection points are 1.5π-3.5π of the higher-order curve instead of 1.5π-5.5π of the circular involute; The 2π-4π of the higher-order curve replaces the 2π-6π of the circular involute; 2.5π-4.5π of a high-order curve replaces 2.5π-6.5π of a circular involute; The 3π-5π of the higher-order curve replaces the 3π-7π of the circular involute. The coefficients of the corresponding high-order curves C_0, C_1, C_2, and C_3 are shown in Table 2.

Table 2. Curve coefficient of higher order

Connection point	1.5π-3.5π	2π-4π	2.5π-4.5π	3π-5π
C_0	78.539	174.751	329.867	555.669
C_1	-35.000	-68.750	-110.000	-158.75
C_2	9.549	11.936	14.323	16.711
C_3	-0.506	-0.506	-0.506	-0.506

Figure 4 shows the variation trend of the working chamber volume with the spindle rotation Angle. The suction chamber gradually increases with the spindle rotation Angle increasing, that is, the gas volume in the cavity increases with the spindle rotation Angle increasing. It can be seen from the figure that the suction chamber volume reaches the maximum when the spindle rotation Angle is 300°; With the increase of the spindle Angle, the suction chamber is gradually closed, and the volume of the compression chamber is reduced. Finally, a pair of closed cavities are formed to complete the suction process. I, II shape line corresponds to the suction cavity volume is larger, the join PI PI in

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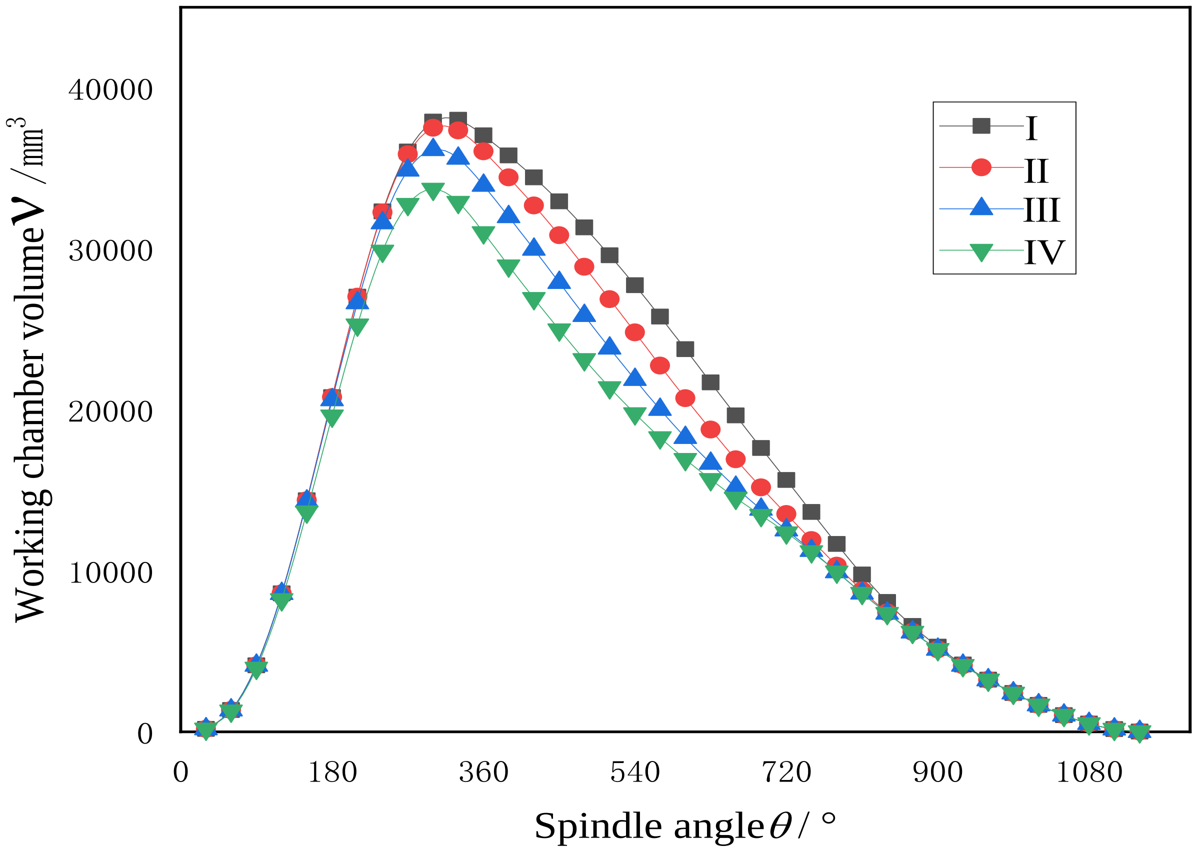
1.5-3.5 when the corresponding circle involute accounted for the biggest, can guarantee the biggest suction cavity volume, but the compression ratio is small. The system corresponding to 2π-4π can guarantee large suction cavity area and large compression ratio. With the increase of the spindle Angle, the working cavity decreases gradually, so as to realize gas compression. The corresponding spindle rotation Angle of the compression chamber is 360°~810°, and the profile of the compression chamber is circular involute + high-order curve. When the connection point 2π-4π, the ratio of the suction terminal volume to the initial exhaust volume is the largest, the compression ratio is the highest, and the working performance is the best. Finally, when the compression chamber is connected with the central exhaust port, the exhaust chamber starts to exhaust, and the corresponding spindle rotation Angle of the exhaust chamber is 810°~1140°. The profile of the exhaust chamber is composed of circular involutes + high-order curves. The profile composition of the exhaust chamber is also different according to the different working time. As can be seen from the figure, the area of exhaust cavity corresponding to different connection points does not change much. Compressed gas can leave the exhaust chamber faster, which is conducive to reducing the exhaust temperature.



I-1.5π-3.5π II-2π-4π III-2.5π-4.5π IV-3π-5π

Figure 4. Variation rule of working cavity volume with spindle rotation Angle

3.2 The effect ofn the radius of rotation on the system

The other parameters constant, change the radius of gyration, select $R_{or} = 0.3\pi R,\ 0.4\pi R,\ 0.5\pi R,$ $0.6\pi R$ research on the influence of cavity volume.

As shown in Figure 5, when other profile parameters remain unchanged, the volume of the working chamber increases with the increase of the turning radius, so that the gas enters the compressor more smoothly and more gas can be absorbed. However, too large turning radius will lead to too large eccentric moment. Therefore, the influence of suction volume and eccentric moment should be taken into account, and the radius of rotation should be selected to take into account both aspects.

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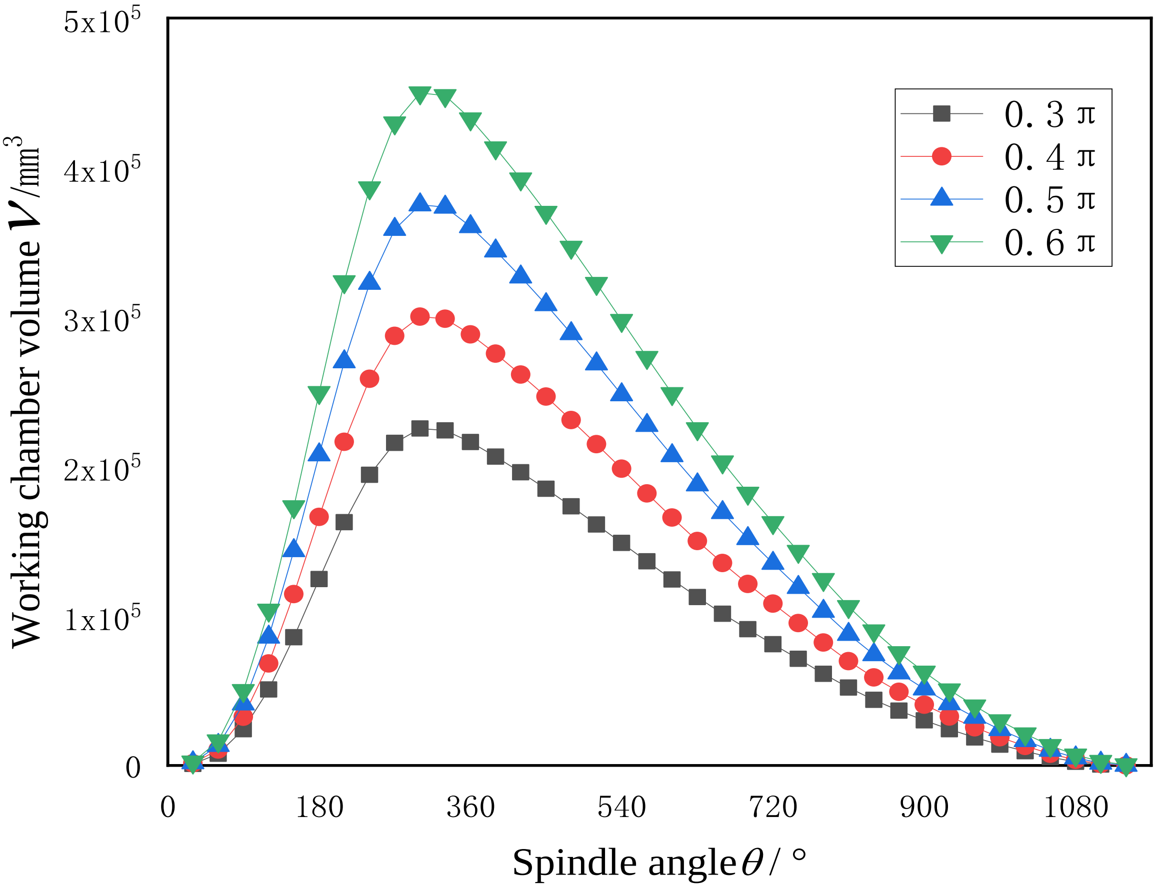

Figure 5. Changes of working cavity volume with spindle rotation Angle

4. Conclusion

1. A new type of variable cross section vortex compression machine line was established, which was composed of circular involute with higher order curve, and a one-turn higher order curve was used to replace the two-turn circular involute, and the corresponding profile formula was given.

2. Through the control variable method, the influence of profile parameters (connection point, turning radius) on the volume of each chambe. When the connection point is 2π-4π, the working cavity volume of each cavity is the largest, and the system has a better performance.

Acknowledgments

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