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A novel tilt form grinding method for the rotor of dry vacuum pump

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ABSTRACT

The twin-screw dry vacuum pump is widely used in low and medium-low vacuum applications. Its core element consists of a pair of rotors rotating in opposite direction on parallel axes. Usually one side of the rotor profile is a concave cycloid curve to prevent the inter-lobe leakage. Screw rotors are typically finished by the form grinding method. However, such concave rotor profile is almost impossible to grind on a conventional thread grinder due to severe undercutting and secondary enveloping problems. In this paper we propose a novel tilt form grinding (TFG) method to overcome the problem of concave profile grinding. The conventional thread grinder is modified by tilting the grinding wheel about an axis normal to the rotor and swivel axes. By using this proposed machine arrangement, the concave rotor profile can be ground without undercutting and secondary enveloping. Numerical examples are presented to validate the proposed TFG method.

1. Introduction

The performance of a twin-screw vacuum pump largely depends on the inter-rotor-clearances formed by the rotor profile. These clearances should be as small as possible to prevent leakage, yet not too small to avoid rotor lock-up due to thermal expansion. To facilitate the sealing effect, an extended epicycloid curve is often applied to the tooth profile of the vacuum pump rotor, as shown in Fig. 1(b). This extended epicycloid curve is basically an undercutting curve and its profile is a concave shape when the tooth height is as high as shown in Fig. 1(c). This makes it difficult to complete the grinding by the conventional form grinding method. As a result the rotor manufacturer is forced to employ the more expensive and time-consuming pencil-type milling process.

The tooth profile of the rotor of a twin-screw vacuum pump is generally derived from the theory of gearing [1,2]. However, the rotor profile of a vacuum pump is designed mainly to prevent leakage, and not to transmit torque. The tooth profile of the mating rotor might not be in surface-to-surface conjugation as required by the gear profile. Several line-to-surface conjugate tooth profiles, including arc meshing with extended cycloid curve are utilized by many rotor profile designers [3–8] to form a better sealing line between rotors. The extended cycloid curve is a concave shape when the pressure angle is small and the tooth height is large. Fong et al. [9] introduced the maximum sphere method to calculate inter-rotor-clearances. The clearance topography is represented by the Iso-Clearance Contour Diagram (ICCD).

The accuracy of the rotor's profile is critical since the performance of a vacuum pump depends on sealing the inter-rotor-leakage. Form grinding after heat treatment is a popular method for tooth profiling. Litvin and Fuentes [10] proposed a methodology to calculate the transverse section of the form grinding wheel by employing the concept that the normal of the contact point on the rotor must pass through the rotation axis of the grinding wheel. Xing [11] and Stosic et al. [12] adopted the same concept used to develop the mathematical model of the form grinding wheel of the twin-screw compressor rotors. Spitas [13] introduced a method for the discretization

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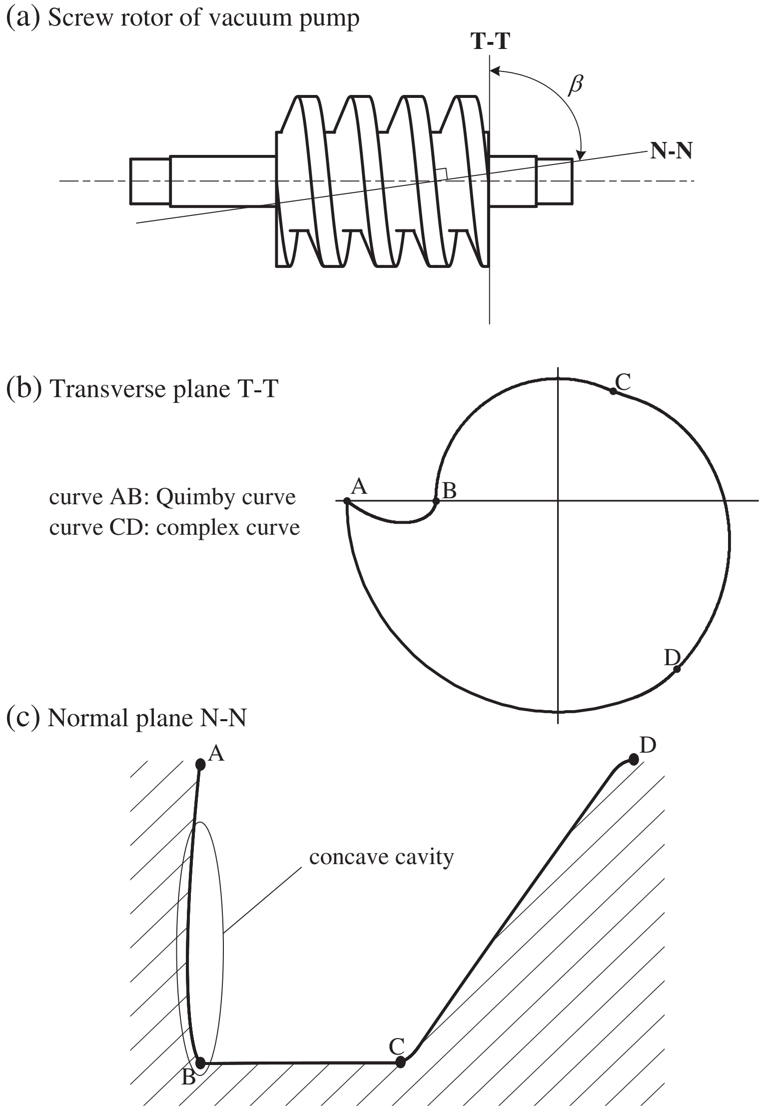

Fig. 1. Transverse and normal tooth profile of the screw rotor.

of the gear tooth flank in involute segments to determine the conjugate gear tooth profile rather than the theory of gearing. In 2001, Liang et al. [14] presented a numerically simulated calculation to obtain the grinding wheel profile and the manufactured gear tooth profile by applying a converse calculation process. You et al. [15] used bi-arc segments to approximately fit the theoretical grinding wheel profile. Stosic [16] presented a method to predict the wear of the grinding wheel profile from cutting uniform stock.

However, when undercutting and secondary enveloping appears, the correct profile of the form grinding wheel cannot be calculated by the traditional mathematical model using the equation of meshing or by discretization using the numerical method. In 2005, Zanzi and Pedrero [17] added a tilt angle into the machine setup as an extra freedom to crown the pinion with a grinding wheel. In 2009, Chiang and Fong [18] proposed a tilt form grinding method and a methodology to determine the minimum tilt angle for avoiding undercutting and secondary enveloping. The tilt of the grinding wheel [18] is rotated about the normal axis of the normal section of the rotor tooth profile. This tilt is skewed to any known linear movement of the thread grinder, and therefore a special mechanism is required to validate this tilt movement.

This study proposes a novel tilt form grinding (TFG) method to overcome the undercut problem of concave profile grinding. The grinding wheel is tilted about an axis normal to the rotor and swivel axes, and the tilt rotation axis is normal to the existing grinding wheel infeed as shown in Fig. 3. This tilt arrangement makes it easy to design the TFG thread grinder, simply by modifying the infeed table of the existing thread grinder. As a result the tool's profile can be successfully calculated without secondary enveloping and undercut. Three numerical examples are presented here to show the validation of our proposed TFG method.