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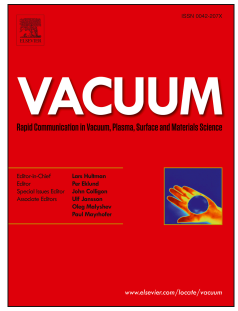

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Geometric Study and Simulation of an Elliptical Rotor Profile for Roots Vacuum Pumps

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Abstract: The rotor profile is one of the key factors for improving the performance of the Roots vacuum pump. A novel elliptical rotor profile consisting of the elliptical arc and its conjugate curve is proposed in this paper. The mathematical model of the elliptical rotor profile is established, and profile equations without incurring undercutting and carryover are derived. The elliptical rotor profile is tested using six Roots rotors, including five new elliptical rotors and one conventional circular arc rotor. Additionally, to assess the performance of the elliptical rotor profile, three-dimensional numerical simulations of the above six Roots rotors are conducted; and then the working process of the Roots vacuum pump is analyzed. The results indicate that all the new designs produce higher flow rate than the traditional circular rotor under the same conditions. As the elliptical axial ratio decreases, the area efficiency of the elliptical rotor increases.

Key words: Roots vacuum pump; elliptical rotor; mathematical model; undercutting and carryover; area efficiency

1 Introduction

Roots vacuum pumps are positive displacement rotary pumps and are widely used in food, chemical, and pharmaceutical industries. The advantages include simple components, compact size, high flow rate, easy assembly, and low-cost maintenance. The performance of the Roots vacuum pump is directly influenced by the rotor profile. Accordingly, most important research focus is on the rotor profile.

Yang et al. [1] proposed a method, called the deviation-function method, which is to use reshape the original pitch pairs so that the desired profiles of generated pairs can be obtained. This method is applicable to any pitch-curve pairs including circular or noncircular and identical or non-identical curves. Yang et al. [2] derived a general specific flow rate formula for lobe pumps in terms of the pitch and deviation functions of a lobe, and designed a few classes of new lobe pumps with circular pitch curves. Tong et al. [3] presented a complete synthesis procedure for lobe pumps with required flow rate function, and gave new lobe profiles based on some typical flow rate functions. Liu et al. [4] presented a method for the design of new rotor profiles for high-sealing lobe pump by designing chamber profile conforming rotors. This method allows a designer to select desirable rotor length and conformity angle. Hsieh and Hwang [5, 6] proposed a new method to design the Roots rotor that was the trochoidal curve with variable trochoid ratio, used the fifth-order polynomial and cubic spline functions to generate smoothly trochoid ratio functions, and thus generated a regular addendum curve for the Roots rotor. Hsieh et al. [7] studied an extended cycloid curve with variable trochoid ratio in rotor design. Variable trochoid ratio designs based on third-, fifth-, and seventh-order polynomials and sinusoids were used to illustrate the effectiveness of the new method. Wang et al. [8] derived the design constraints for the tooth profile of the five-arc Roots vacuum pump. The addendum portion of the five-arc tooth profile comprises five smoothly connected circular arcs, while the dedendum portion consists of conjugate curves of the addendum portion of the mating rotor. Litvin et al. [9] derived equations of trochoid and its equidistant curve, and obtained the curvature of trochoid and conditions of non-undercutting for trochoid. They designed the screw Roots rotors by applying trochoids. Mimmi et al. [10] made a comparison between internal involute gear pumps and internal pumps, and obtained the flow rate and its impulse based on diverse parameters for both pumps.