三叶转子罗茨真空泵内气体过程的热力学计算

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摘　　要:本文以三叶转子罗茨泵为研究对象,从其基本结构和工作原理出发,对泵内被抽气体的输运过程进行热力学分析。对被抽气体在泵内经历的过程作时序分析,将其分解为吸气、输运、反冲、排气四个阶段,详细讨论各个阶段的特点和机理。应用热力学基本原理,建模计算气体返流量,对吸气、输运、排气进行定量分析,得到被抽气体的压强、容积、总质量、总内能等热力学参数随时间变化的计算公式;探究排气功率与进出口压力之间的关系。

关 键 词:三叶罗茨真空泵;热力过程;解析计算;时序分析

Thermodynamic calculation for pumping process in the trilobal Roots vacuum pump

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Abstract:In this paper, the trilobal Roots pump is taken as the research object, starting from its basic structure and working principle, its internal gas transport process was analyzed thermodynamically. Taking the gas as the research object, the time sequence analysis was carried out, and the process of the gas in the pump was decomposed into intake, transport, recoil, discharge, and discussing the characteristics and mechanism of each stage in detail. The knowledge of thermodynamics and the amount of backflow were taken into account. Calculating gas backflow through model. The quantitative analysis of each phase was carried out, and the time−variation formulas of thermodynamic parameters were deduced, such as pressure, volume, mass, and internal energy. The formula was used to explore the relationship between exhaust power and import and export pressure.

Key words:Three−lobe Roots vacuum pump; Thermodynamic process; Analytical calculation; Time sequence analysis

与普通二叶转子罗茨真空泵相比,采用三叶转子的罗茨真空泵具有排气过程平稳、承受气体压力差大等特点,因此更适合于在高压力区域工作的直排大气多级(干式)罗茨泵、湿式罗茨泵或气冷罗茨泵。近年来,随着三叶转子型线设计与加工技术的不断提升,三叶转子罗茨泵已得到越来越多的实际应用。

对于三叶转子罗茨真空泵的研究,前人更多地关注于三叶转子型线的构成与设计算法[1−3],三叶罗茨泵内部气体流动场的模拟计算[4],以及该类型泵的排气噪音[5−8]等工作性能的变化。随着三叶罗茨泵制造与应用的日益增长,对其性能的优化也提出了更高的要求。其中,泵内被抽气体的

热力过程,直接影响着泵的排气温度、排气功耗和抽气效率,在很大程度上决定着泵的性能。

因此,本文以三叶转子罗茨泵为研究对象,对其内部抽气过程作时序分析,将其分解为吸气、输运、反冲、排气四个阶段;提出不同时段的返流量计算式,依据热力学基本原理,对被抽气体进行热力学分析和建模计算。此项工作可以从热力学层面为三叶转子罗茨泵结构设计与性能分析提供理论支撑。

1　过程分解与时序分析

三叶转子罗茨真空泵的每只三叶转子的相邻两叶,可以与泵壁形成一个吸气工作腔。两只