Study on the influence of different combinations of Roots pump sets on flow characteristics

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Abstract: The multi-stage series Roots pump set has broad application prospects in fields such as nuclear fusion vacuum systems, semiconductor manufacturing, aerospace environment simulation, and large-scale scientific devices due to its advantages of high pumping speed, high compression ratio, no oil pollution, and suitability for high flow gas transportation. By operating in series with multi-stage pump bodies, the working pressure range of the pump group can be significantly expanded, the ability to extract light gases can be improved, and the demand for efficient pumping under complex working conditions can be met. However, the internal flow process of multi-stage Roots pump sets is complex, and phenomena such as gas transport, pressure distribution, and reflux leakage between stages are coupled with each other. The matching relationship between different stages has a significant impact on the pumping speed, compression ratio, and operational stability of the pump set. Especially under conditions of high speed, large pressure difference, and light gas, significant issues such as increased flow loss, uneven inter stage flow field, and local temperature rise are prone to occur within the pump unit, which in turn affects the overall pumping performance and long-term operational reliability. This study is based on computational fluid dynamics methods to establish a transient flow model for multi-stage Roots pump sets. Numerical simulations were conducted on the inter stage flow field, pressure distribution, and gas transport process of the pump sets, and the flow characteristics and pressure distribution laws of different combinations of pump sets under different operating conditions were analyzed. The research results indicate that as the compression ratio increases from 10 to 1000, the inter stage pressure difference significantly increases, and the clearance reflux velocity and reflux rate significantly increase; The heat generation effect of gas compression is enhanced, and the inter stage temperature at a compression ratio of 1000 is significantly higher than that at a compression ratio of 10; And the highest

temperature occurs in the stage before the exhaust stage, not in the final exhaust stage, indicating that this stage has undergone the strongest gas compression and thermal accumulation; The gap between Roots rotors decreases, resulting in a decrease in leakage, but the reflux velocity increases, leading to an increase in inter stage pressure. This study provides a theoretical basis for the structural design, inter stage parameter matching, and performance optimization of pump sets applied to light gas extraction.

Keywords: Roots pump set, CFD, Flow field distribution, Numerical simulation, Pumping performance

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