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C1Po3A-08: Dynamic Analysis and Optimization of Aerostatic Bearing-Rotor Systems in Cryogenic Turbo Expanders

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High speed turbo expanders for hydrogen and helium serve as critical components in large-scale cryogenic systems. Their efficient and stable operation directly determines overall system performance. Due to the low density and high enthalpy drop of hydrogen and helium, turbo expanders must operate at extremely high rotational speeds, to achieve high thermodynamic efficiency. Aerostatic bearings are commonly employed to support the rotor; however, the inherent properties of gases make the system prone to vibration and instability, limiting further performance improvements. This study employs an improved polynomial transfer matrix method to develop a discrete mass model for the bearing-rotor system. By incorporating the damping characteristics of bearings, the method enables rapid and accurate calculation of the natural frequencies, critical speeds, and mode shapes. Comparisons with results from commercial software show acceptable deviations, validating the proposed approach. Furthermore, the effects of various parameters—including length, diameter, thrust disk position, and bearing stiffness and damping—on the dynamic characteristics of the system are investigated. These insights contribute to enhancing critical speeds and mitigating vibrations, providing valuable guidance for the optimization of high-speed cryogenic turbo expanders.

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