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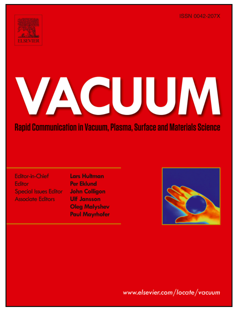

Design aspects of a large scale turbomolecular pump with active magnetic bearings

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Design Aspects of A Large Scale Turbomolecular Pump with Active Magnetic Bearings

***Abstract*—A large scale 5-axis magnetically levitated turbomolecular pump is designed and fabricated in this paper. The rotor is supported by two radial active magnetic bearings (AMBs) and an axial AMB, and driven by a high-speed brushless DC Motor with a ring permanent magnet. The considerations discussed are described by design of an actual magnetic levitation turbomolecular pump with rated high-speed vacuum pumping speed of 4100L/s and ultra-high vacuum of the order of 1.8×10^{-7}Pa. The vacuum, stress, modal, and electromagnetic aspects are put equal weight in the design of a large scale turbomolecular pump supported by AMBs. The thermal assembly technology of the ring PM, sleeve, and shaft for the turbo rotor is proposed. Finally, the suggested design methodology for designing a large scale turbomolecular pump with AMBs is presented.**

***Index Terms*—Turbomolecular pump, brushless DC motor, active magnetic bearing, high-speed applications.**

I. Introduction

Turbomolecular vacuum pump are very key apparatus in maintaining and obtaining high vacuum, and widely used in applications where high vacuum conditions are required [1],[2], such as thin film deposition, semiconductor manufacturing, high energy physics, mass spectrometry, general UHV research, and fusion technology, etc. Compared with traditional ball bearings and fluid film bearings, no contact, no wear, no oil, low maintenance cost, micro-vibration, long-lifetime, and controllability of dynamic characteristics and high-speed rotor unbalance disturbance are the remarkable features of active magnetic bearings (AMBs), so the AMBs are very suitable to support a turbomolecular pump (TMP) rotor.

A magnetic levitation turbomolecular pump is supported by AMBs in five degree-of-freedom (DOF) directions, and is driven by a high-speed electrical machine. The proposed design considerations took into account many papers on various design aspects of TMPs. Many of the publications concern the modeling and control of the magnetic levitation turbomolecular pump. The geometric imperfections in the pump and bearings, gyroscopic effects, the turbo rotor's bending modes, together with the unavoidable residual unbalancing can cause vibrations that will affect the performance of the vacuum system connected to the pump, and in the long-term run even damage the pump itself. An experimental activity concerning the active vibration control of a turbomolecular vacuum pump is proposed [1]-[9]. The effects due to the presence of close or open rotor slots in high-speed induction machines are analyzed and verified by experiments [10]. A fault-tolerant magnetic bearing system which can deal with actuator/amplifier and/or sensors faults is designed and implemented for a turbomolecular vacuum pump [11] and [12]. In order to increase the robustness and decrease the influence of the disturbance for a magnetically suspended turbomolecular pump, an adaptive variable structure controller is presented [13]. The effects of eddy current on magnetic bearing and high-speed permanent motor are investigated by finite-element method [14]. The performances of high-speed induction motors for turbomolecular pump applications are investigated [15]. The dynamic characteristics of rotor-bearing system in a vertical turbomolecular pump is investigated [16]. A sliding mode control with time-varying hyperplane for AMB system is proposed and successfully carried out experiments using a turbomolecular pump [17]. A strategy of variable bias current control is developed to minimize the power consumption of active magnetic bearings (AMB) used in Turbomolecular pumps [18]. A power failure compensation control method is proposed to improve the reliability of the magnetic bearing turbomolecular pump [19]. The key parts of a large scale single gimbal magnetically suspended control moment gyro are designed and tested [20]. A multiple objective optimization of high-speed rotor supported by magnetic bearing in a brushless DC Motor (BLDCM) is proposed [21]. In [23], the design, construction, and testing of an AMB system for high-speed BLDCM application are described. In [22], engineering aspects of turbomolecular pump design are proposed. A design method of combination improving blade profile and stiffer material for rotor is proposed to further decrease the deflection of the turbine blades [24]. Unfortunately, few publications deal with the design of large scale magnetically suspended turbomolecular pump with a Holweck stage

A large scale magnetically suspended turbomolecular pump (MSTMP) with Holweck stage is widely developed for industrial application. A MSTMP consists of high-speed rotor, radial magnetic bearing, axial magnetic bearing, air gap sensors, high-speed motor, backup ball bearing, etc. Most literatures mentioned above focus on the modeling, control strategy or the vibration suppression of the TMP with AMBs. But few literatures focus on the design and fabrication aspects of the MSTMP. The vacuum performance affects the pumping speed and extremely vacuum. The strength or stress limit is inherently connected with the elastic properties of the materials used in the high-speed rotor. The first bending mode frequency of the molecular rotor should exist far from the operating frequency for stable rotation. The vacuum, rotation speed of turbo rotor, and/or stability are influenced by the electromagnetic design aspects of the high-speed motor and the AMBs. The thermal