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Dynamic characteristics analysis and intelligent control of slotted air supply bearing system

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Abstract

Slot-type externally pressurized air bearing (SEPAB) systems have two major advantages including the air supply externally and slot restrictor design, and also provide multi-directional supporting forces and higher stiffness to increase the greater rotational stability. Nowadays, this type of bearing system is used for a high precision, rotational speed, and high stiffness instrumentation. However, SEPAB systems exhibit non-periodic or chaotic motion as the result of a nonlinear pressure distribution within the gas film, gas supplied imbalances, an inappropriate design, and so forth. So, in order to understand and control when the bearing system occurs non-periodic motions and under what kind of operating conditions, the dynamic response of the SEPAB system has been analyzed using different numerical methods, namely a perturbation method and a hybrid numerical scheme combining the finite difference method and the differential transformation method. The key performances and solutions under different physical models obtained by these two methods will be compared and verified. Meanwhile, the intelligent control design of air bearing system combined with a robust control scheme is proposed to restrain the unstable vibration and pneumatic hammer effect by the design of optimum non-uniform slot areas of bearing surface. Also, this controller based on an adaptive sliding mode controller and a dynamic control theory has also been developed to compute and confirm the gas flow rate, sizes and types of slots in real-time to inhibit chaotic motion in SEPAB system and to suppress the amplitude of the bearing system vibrations.

Results

The air float effect will occur at different the rotor mass and the bearing number, and the rotor mass will cause the strength of the air float effect, which will affect the stability of the overall system. At the same time, the bearing number is also the main factor affecting the stability of the system. Therefore, the impact of the rotor quality and the bearing numbers on the gas bearing system is mainly analyzed, and the rotor mass and the bearing number are used as bifurcation parameters and proved by the regions with Lyapunov exponents greater than zero in Figures 1 and 2). The Lyapunov index is used to construct the stable and unstable regions of the axis system. The red region (non-blue regions) in the figure belong to the unstable region, that is, chaotic behavior, and the blue block belongs to the stable region, and when the bearing number is high, the system may appear chaotic motion under different rotor masses. In order to effectively suppress the occurrence of chaotic motion, we designed an improved smooth control module and physical circuit to successfully suppress the bearing system (as shown in Figure 3), and make unstable non-periodic into The stable periodic motion state shows that the results are successful and effectively achieve the expected results.

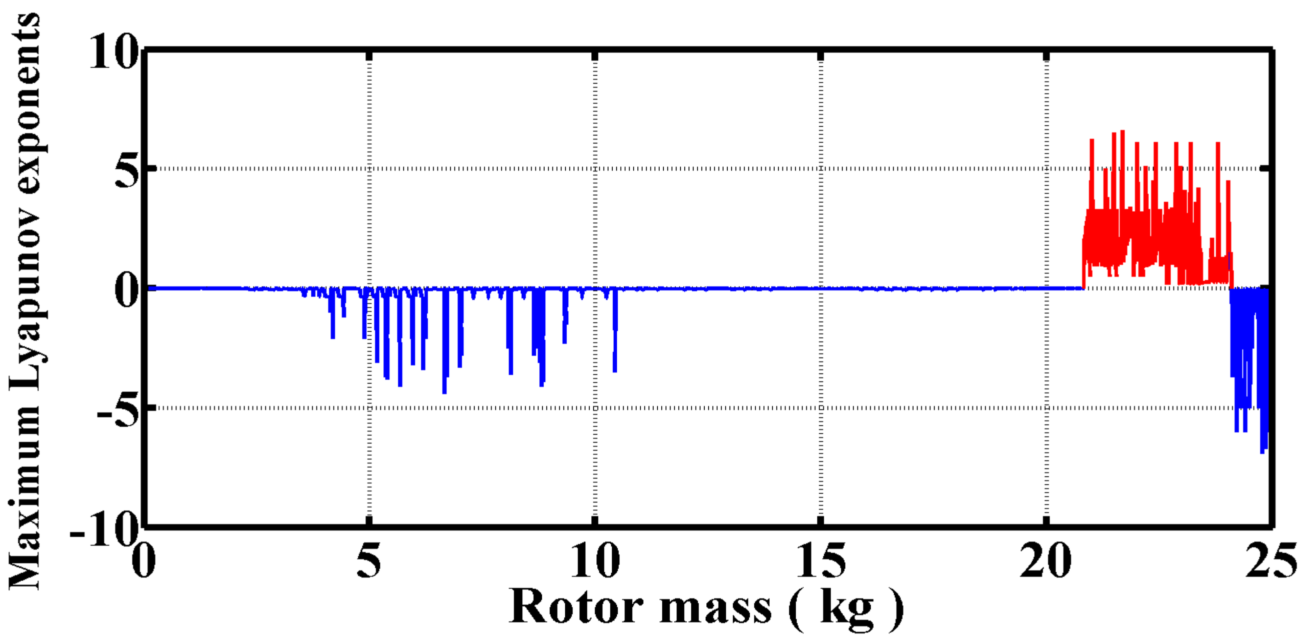

Figure 1

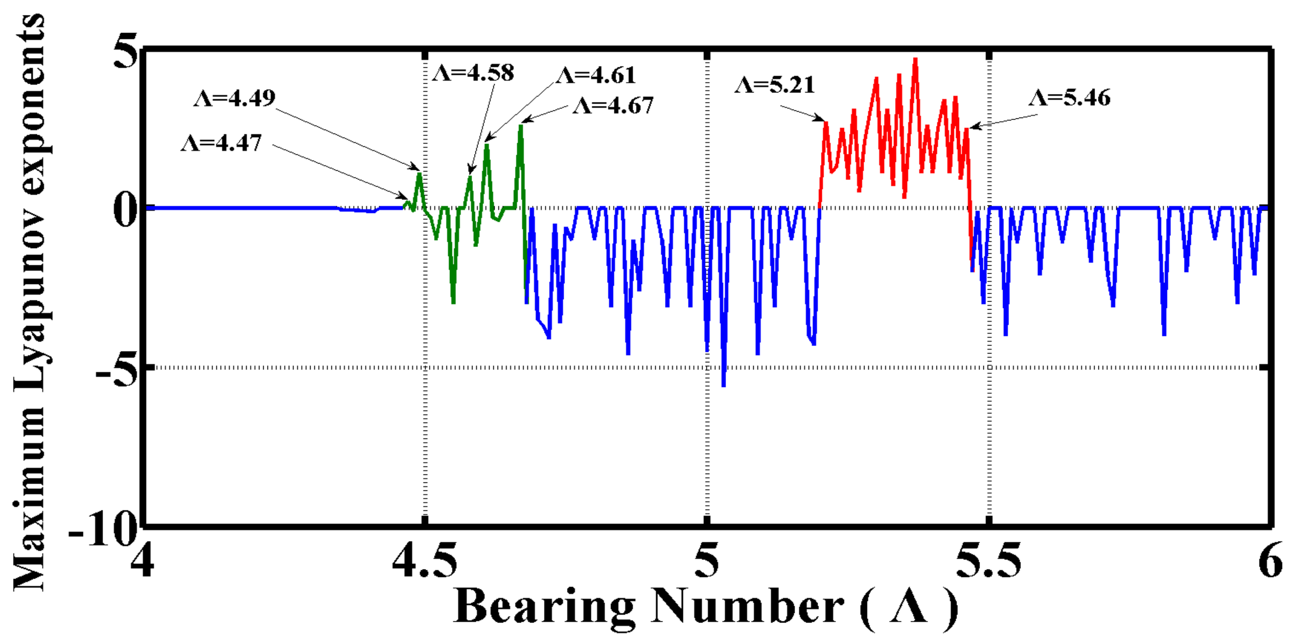

Figure 2

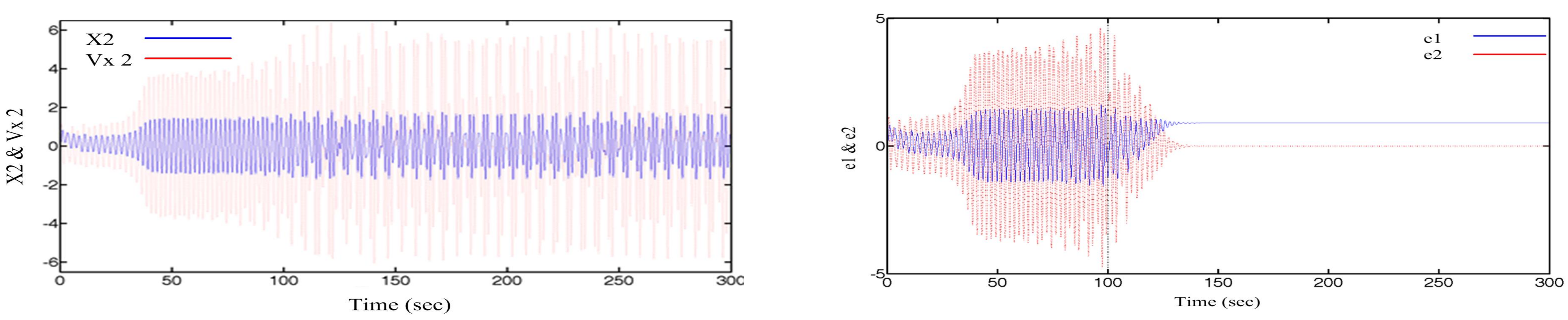

Figure 3