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Optimization of sensor and actuator location in mechanical system: AMB-rotor case

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ABSTRACT

Active magnetic bearing (AMB) rotors have been on steady rise in particular with various high-speed applications, such as compressors, turbines, or flywheels. Often multi rotor systems or AMB-rotors connected to the external load through the coupling are used. The system stability and performance depend on disturbances such as unbalance, position sensor runout, unbalance magnetic pull (UMP), and external disturbance forces, i.e. gravity, process forces, and on plant own characteristics. The designers can alter the plant (and rotor) layout by changing location and position of sensor and actuator planes. The relative position of rotor rigid and bending modes to the location of plant inputs (actuators) outputs (position sensors) as well as location of disturbance inputs (location of wheels as a main source of unbalance and input of process forces) affect the observability and controllability of the modes. This in turn will affect the final closed-loop performance measured in terms of output sensitivity functions, measured rotor vibrations and measured AMB currents during rotor acceleration.

We analyse finite element models of the single and multi-rotor AMB systems with different locations of actuators and sensor. We are interested in quantitative evaluation of relative controllability and observability of this set of objects and use controllability and observability grammian matrixes, which are directly related to the frequency-domain characteristics such as zeros and residues, and to time-domain characteristics such as the influence of energy injection onto mode excitation as well the contribution of each mode of oscillation into the energy of the output [3]. Various grammian matrix characteristics are used to rank the location of sensors and actuators. Optimal placement of actuators and sensors has key role for control synthesis.

We also discuss the differences in the positions of sensors from the perspective of robust control, how the uncertainty in the location of sensor can influence the stability or performance of closed-loop system [2, 4]. The effect is illustrated by the example of lumped spring-mass train system [1] and AMB-rotor plant.

Keywords: AMB rotor, actuators, controllability, sensors, observability.

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