Disturbance Observer-Based Antiwindup Control for Nanopositioning Systems Subjected to Actuator Saturations

P. Liu[1], P. Yan[2]

[1]Key Laboratory of High-efficiency and Clean Mechanical Manufacturing, Ministry of Education, School of Mechanical Engineering, Shandong University, Jinan 250061, China

[2]School of Mechanical & Automotive Engineering, Qilu University of Technology (Shandong Academy of Sciences), Jinan, 250353, China

Corresponding.pengyan2007@gmail.com

Abstract

Nanopositioning systems driven by piezoelectric actuators have emerged as a key enabling component in modern industrial applications, such as atomic force microscopy, ultra-precision manufacturing and biomedical manipulations, thanks to the advantages of high resolution and fast response. However, the effects of hysteresis nonlinearities, model uncertainties, motion coupling and external disturbances pose significant challenges to control of nanopositioning systems. The situation is further complicated by nonlinear saturations due to the limited stroke of piezoelectric actuators.

To address such issues, a disturbance observer based anti-windup control method is proposed for piezo driven nanopositioning systems. By regarding the effects of hysteresis nonlinearities, model uncertainties, motion coupling and external disturbances as a lumped disturbance added to the linear dynamic behavior of nanopositioning systems, a disturbance observer is established to estimate and compensate the lumped disturbance, such that improved control performance is obtained for the unsaturated nanopositioning system. On top of the specific control structure of disturbance observer, a robust anti-windup compensator is further designed to handle the unexpected actuator saturations. According to the input/output based equivalent representation, the saturation compensation design is transformed to a control problem with the dead zone nonlinearity fulfilling the sector condition. By combining the anti-windup robustness against model uncertainties, we formulate the design of anti-winup compensators as an H∞ optimization problem. Real time implementations of the proposed control method is applied on a customized piezo driven nanopositioner, where excellent motion performance and saturation compensation capability is achieved in the experimental results.

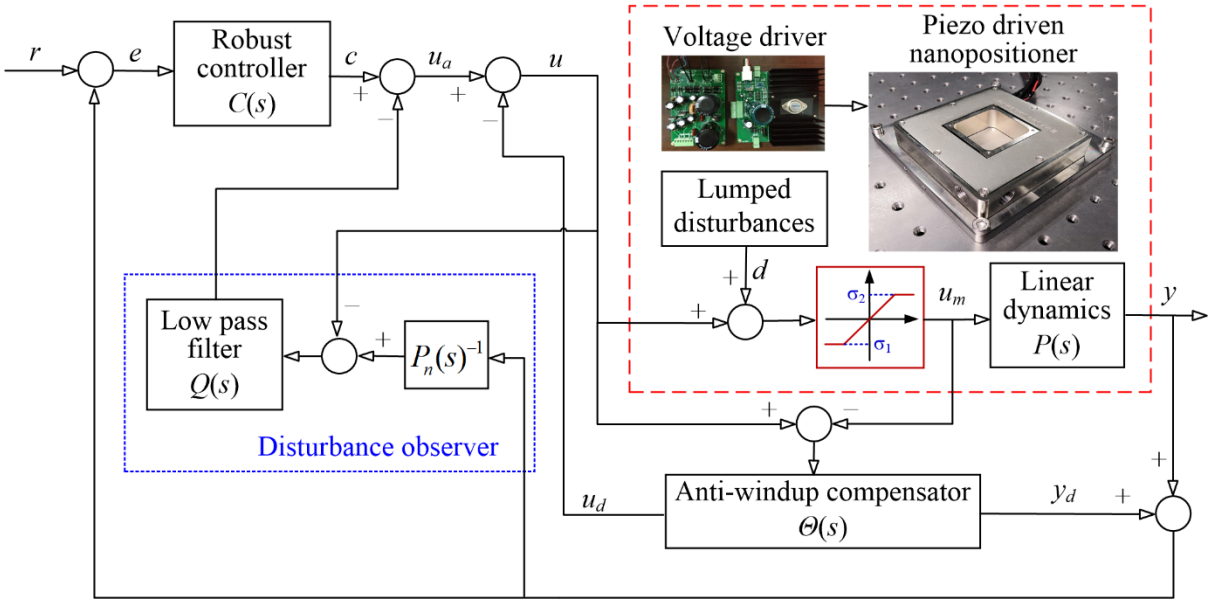

Figure 1: Disturbance observer based anti-windup control structure for nanopositioning systems.