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A ROBUST INTEGRAL TYPE BACKSTEPPING CONTROLLER DESIGN FOR CONTROL OF UNCERTAIN NONLINEAR SYSTEMS SUBJECT TO DISTURBANCE

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Abstract. *This paper considers the design of a robust controller for a class of nonlinear systems subject to both model uncertainties and unknown external disturbances. Using the concept of both backstepping design and sliding mode control theory, an integral type control algorithm is presented. The proposed controller not only stabilizes nonlinear systems in the presence of mismatched uncertainties, eliminates/reconstructs exogenous disturbances, but also provides smooth control effort. As a result, the developed method is adequate for practical implementation. A criterion of control gains setting for achieving closed-loop stability and disturbance rejection is addressed. Control system design for an unstable nonlinear system is used to illustrate the applicability of the proposed approach and experimental study is also provided to demonstrate the disturbance rejection/reconstruction capability.*

Keywords: Integral controller, Disturbance rejection, Sliding mode control, Chattering

1. **Introduction.** In the uncertain nonlinear control system design, model uncertainties and external disturbances are usually taken as the main issues when designing robust controllers. Model uncertainties affect stability of the closed-loop systems and exogenous disturbances degrade control precision, e.g., steady state accuracy. To analyze the stability of perturbed systems, many approaches have been illustrated in [1]. Backstepping design is a systematic recursive design procedure based on the choice of Lyapunov functions. This approach is suitable for the design of a large class of feedback linearizable systems in strict feedback form. The main concept of the backstepping design is to treat the system variable as an independent input for subsystems and each step results in a new virtual controller for the next step. The virtual control law for each step is adopted with satisfaction of selected Lyapunov functions such that the stability of each subsystem can be guaranteed. Owing to its systematic design concept, design of synthetic backstepping controller has been explored to wide class of nonlinear systems and servo mechanisms [2-12]. In [2,3], an integral function was integrated into the backstepping control design, which makes the motion system insensitive to model uncertainties, external disturbance and improves the closed-loop performance. Two robust adaptive backstepping controllers were developed in [4] for dealing with systems subject to unknown backlash-like hysteresis nonlinearities. A sign function is applied for achieving better tracking performance. Combinations of sliding mode control (SMC) and adaption laws have also been studied in [5-7]. In [5], the robust adaptive backstepping sliding controllers were developed for handling motion control with