Ming-jie LI, Jian-hua WEI, Jin-hui FANG, Wen-zhuo SHI, Kai GUO, 2019. Fuzzy impedance control of an electro-hydraulic actuator with an extended disturbance observer. *Frontiers of Information Technology & Electronic Engineering*, 20(9):1221-1233. https://doi.org/10.1631/FITEE.1800155

Fuzzy impedance control of an electro-hydraulic actuator with an extended disturbance observer

Key words: Fuzzy control; Impedance control; Disturbance observer; Parameter uncertainties; Electro-hydraulic actuator

Corresponding author: Jin-hui FANG
E-mail: jhfang@zju.edu.cn
ORCID: http://orcid.org/0000-0003-4371-2609

Motivation

High-accuracy motion control is a great challenge for electro-hydraulic systems, due to the parameter uncertainties and uncertain nonlinearities. Both velocity control and force control are needed in some special applications, e.g., robot manipulators and tunnel boring machines, in which a dynamic balance between the actuator motion and contact force on the environment or workpieces needs to be maintained.

Impedance control proposed by Hogan (1985a, 1985b, 1985c) solves this problem by regulating dynamic relationship between the end effector position and force as a second-order mass-damper-spring system.

Main idea

A fuzzy impedance controller with an extended disturbance observer based nonlinear velocity controller (FICEDOB) is proposed, which combines fuzzy impedance control and extended disturbance observer based nonlinear velocity control (EDOBC). FICEDOB can not only compensate for both external disturbances and parameter uncertainties, but also regulate the dynamic relationship between output force and velocity.

Method

1. Schematic of the electro-hydraulic system

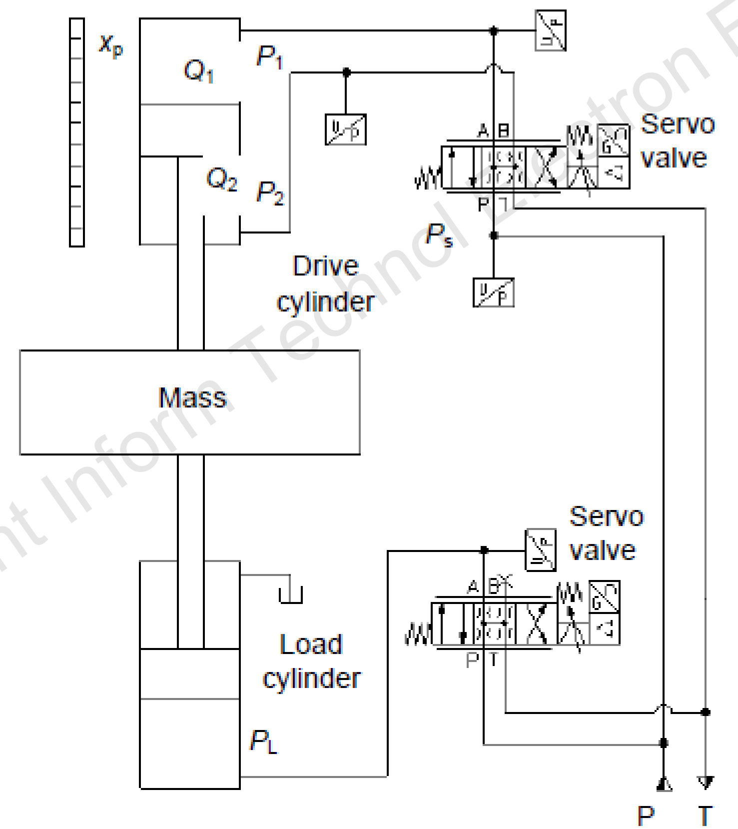

Fig. 1 Schematic of the electro-hydraulic system (P: high pressure oil; T: oil tank)

2. Block diagram of the whole system

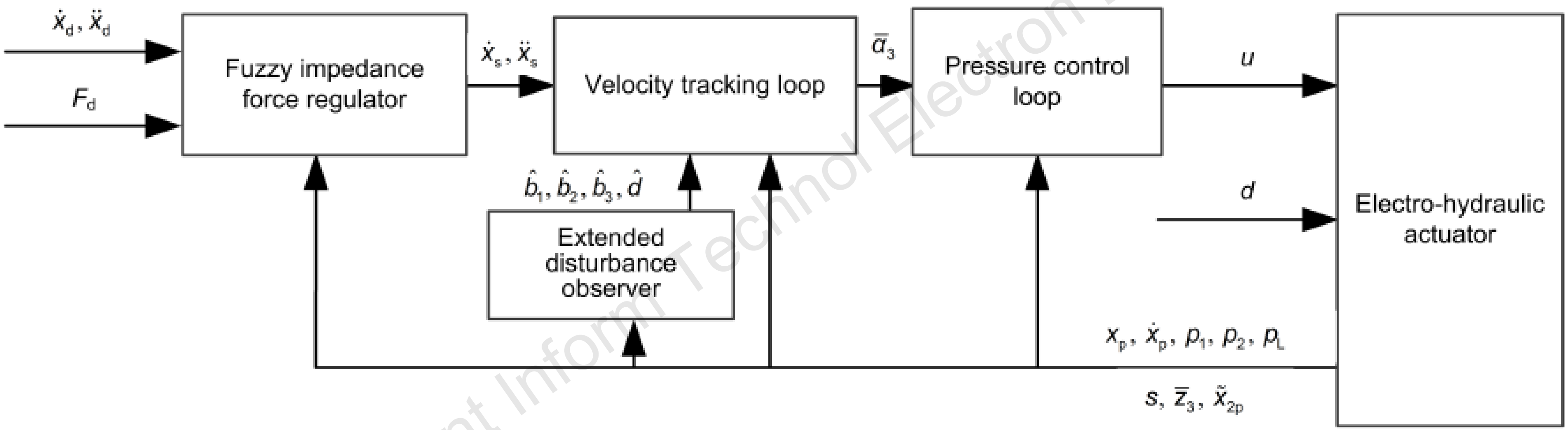

Fig. 6 Block diagram of the whole system

Major results

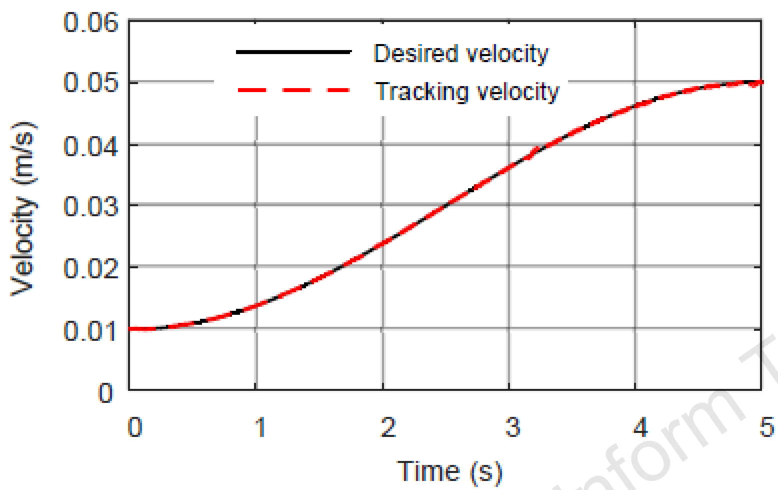

Fig. 7 Velocity tracking of the extended disturbance observer based nonlinear velocity control

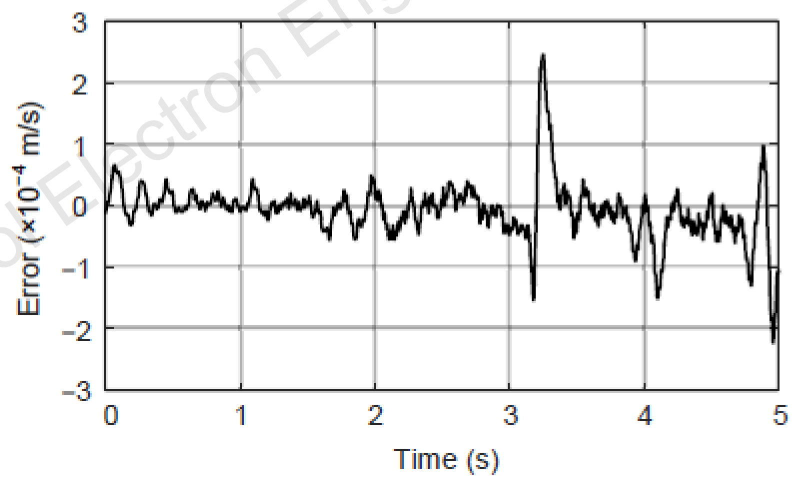

Fig. 8 Tracking errors of the extended disturbance observer based nonlinear velocity control

The performance of the EDOBC without impedance control was verified. The tracking errors were small than 3×10^{-4} m/s.

Major results

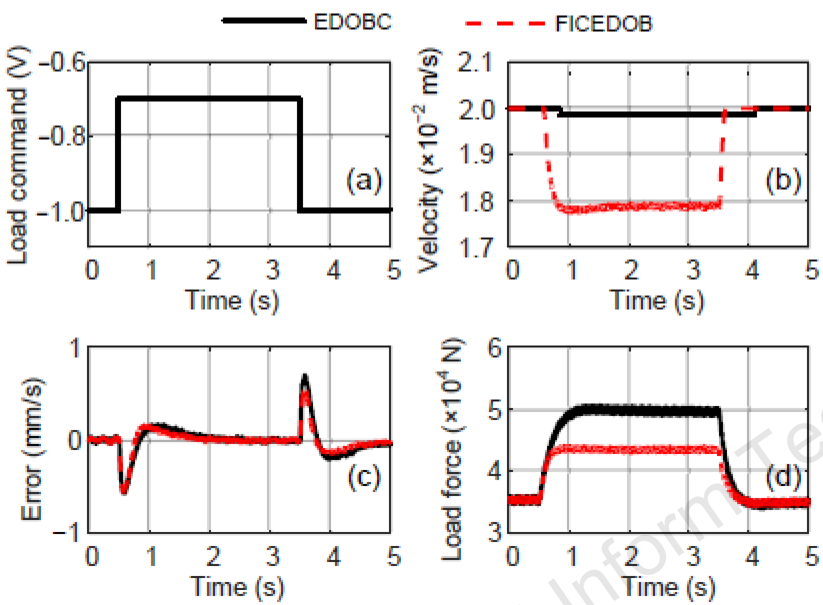

Fig. 11 Tracking results with a 0.02-m/s velocity command and −1→−0.7→−1 V load command: (a) load command; (b) adjusted velocity command; (c) velocity tracking error; (d) load force

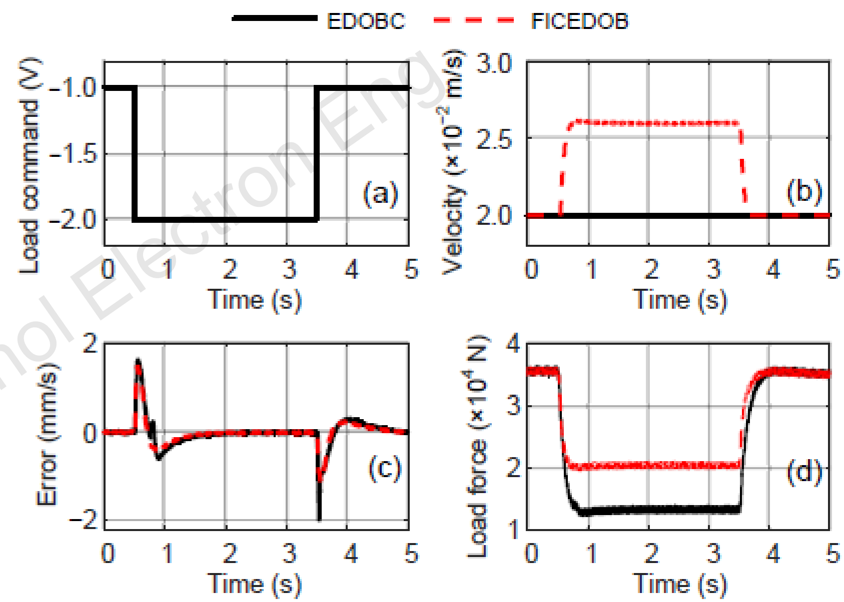

Fig. 12 Tracking results with a 0.02-m/s velocity command and −1→−2→−1 V load command: (a) load command; (b) adjusted velocity command; (c) velocity tracking error; (d) load force

The performance of FICEDOB was verified. The load force to the load cylinder was kept within a close range.

Major results

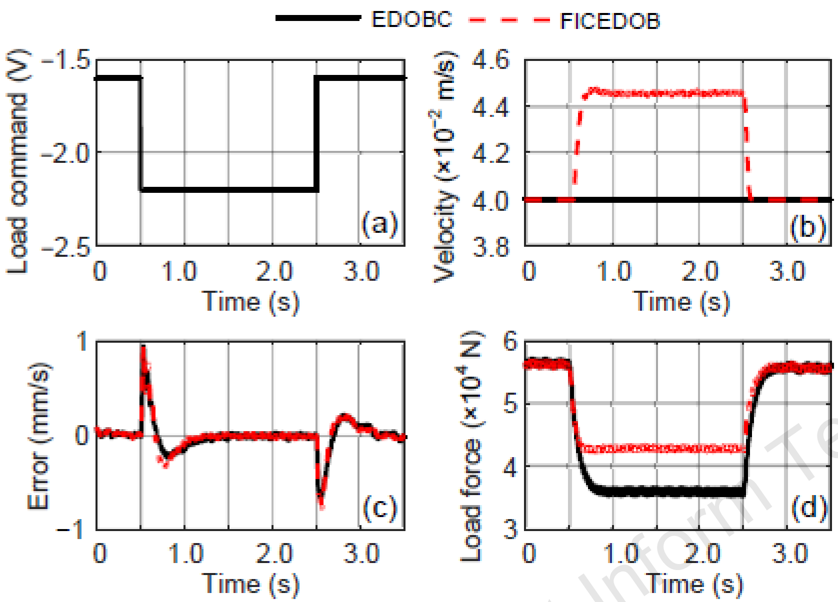

Fig. 13 Tracking results with a 0.04-m/s velocity command and −1.6→−2.2→−1.6 V load command: (a) load command; (b) adjusted velocity command; (c) velocity tracking error; (d) load force

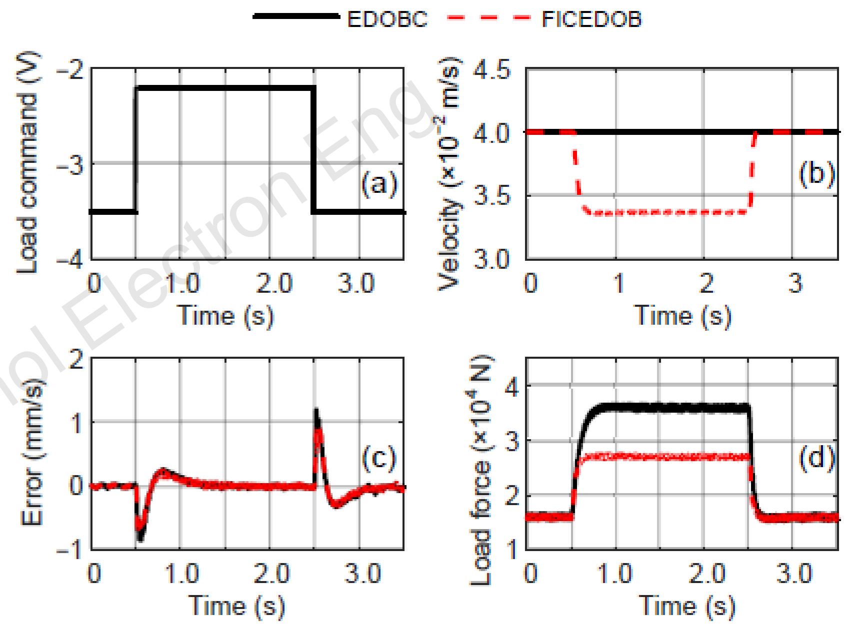

Fig. 14 Tracking results with a 0.04-m/s velocity command and −3.5→−2.2→−3.5 V load command: (a) load command; (b) adjusted velocity command; (c) velocity tracking error; (d) load force

The performance of FICEDOB was verified. The load force to the load cylinder was kept within a close range.

Conclusions

An impedance control strategy has been combined with an extended disturbance observer based nonlinear velocity controller to deal with not only velocity control but also force control of an electro-hydraulic actuator. The proposed controller has combined the advantages of an impedance controller and an extended disturbance observer based nonlinear velocity controller.

Using the proposed FICEDOB, better control performance can be achieved by focusing more on velocity control than on force control.

References

Hogan N, 1985a. Impedance control: an approach to manipulation: part I—theory. *J Dynam Syst Meas Contr*, 107(1):1-7. https://doi.org/10.1115/1.3140702

Hogan N, 1985b. Impedance control: an approach to manipulation: part II—implementation. *J Dynam Syst Meas Contr*, 107(1):8-16. https://doi.org/10.1115/1.3140713

Hogan N, 1985c. Impedance control: an approach to manipulation: part III—applications. *J Dynam Syst Meas Contr*, 107(1):17-24. https://doi.org/10.1115/1.3140701