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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

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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

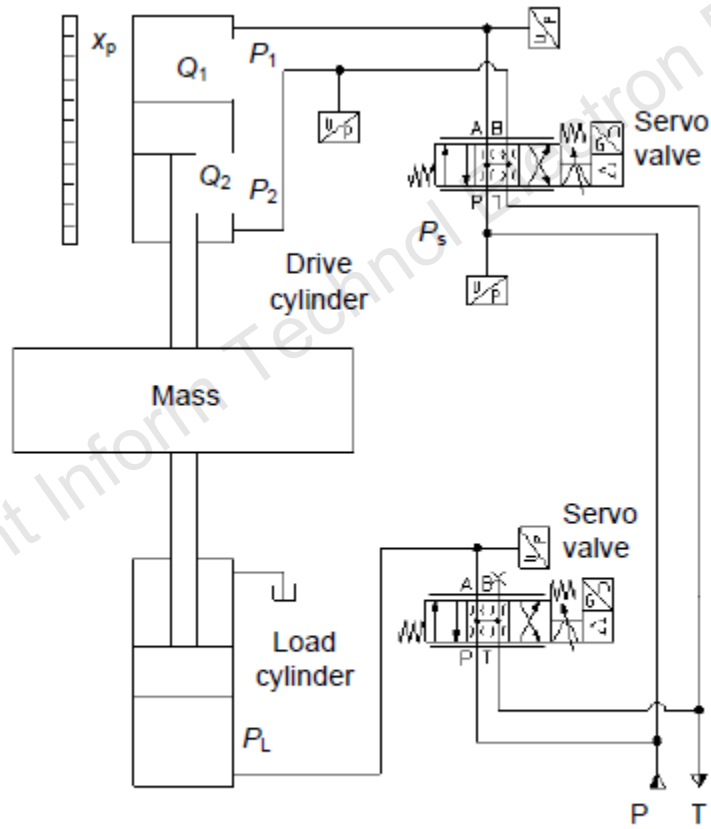


Fig. 1 Schematic of the electro-hydraulic system (P: high pressure oil; T: oil tank)

2. Block diagram of the whole system

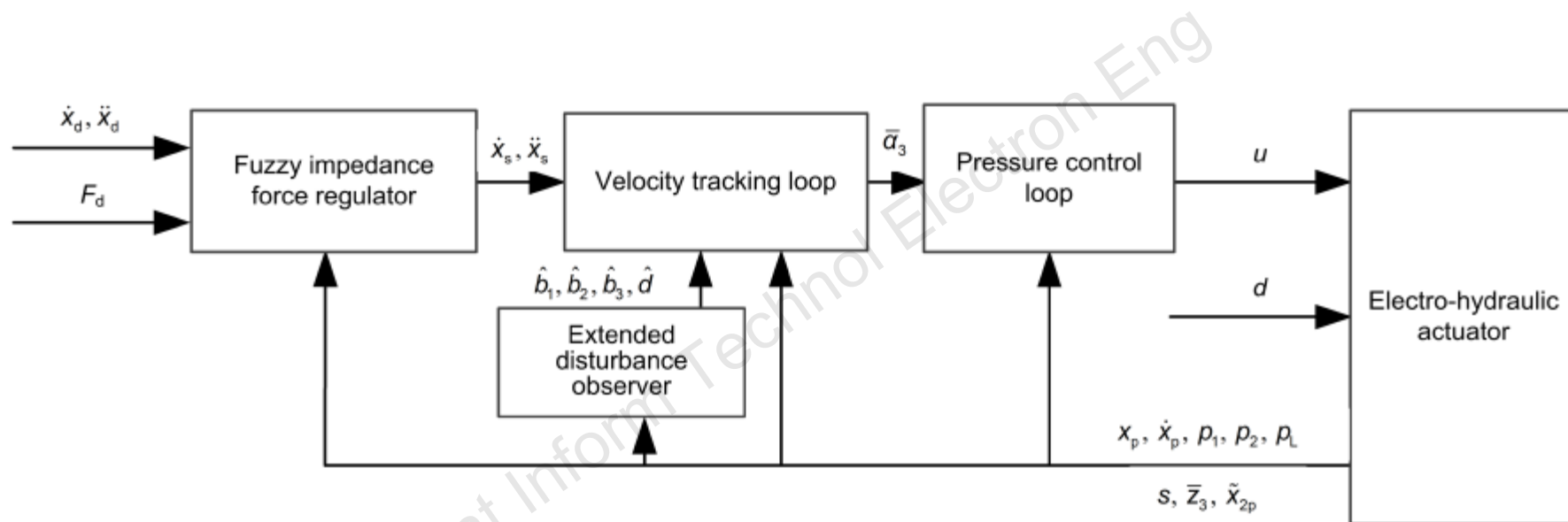


Fig. 6 Block diagram of the whole system

Major results

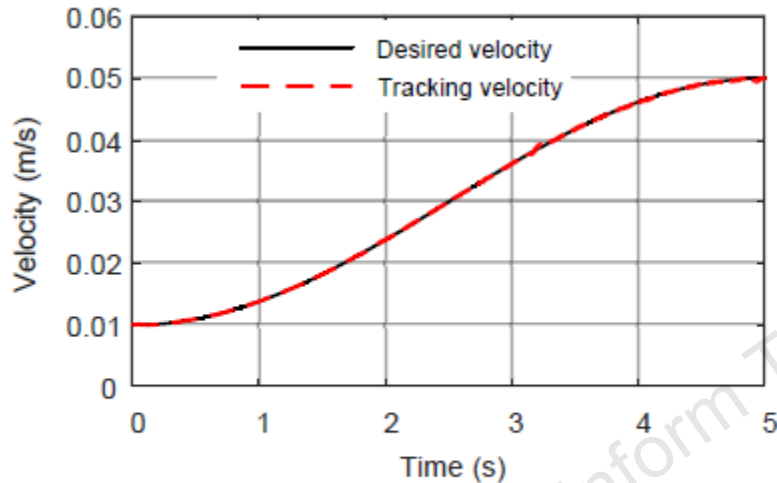


Fig. 7 Velocity tracking of the extended disturbance observer based nonlinear velocity control

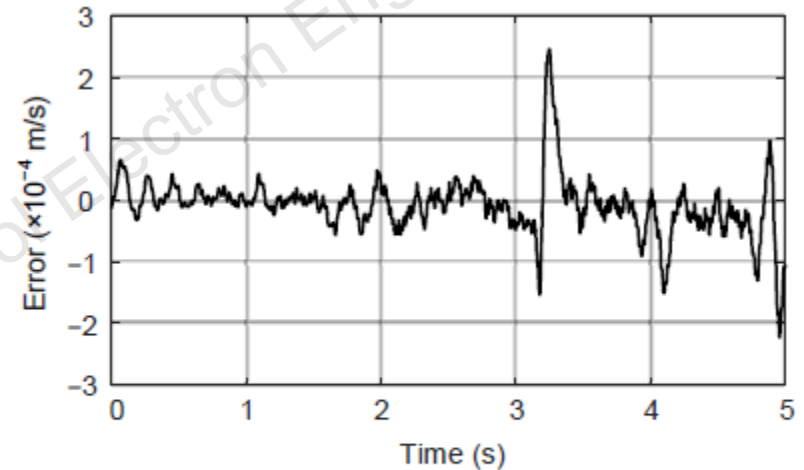


Fig. 8 Tracking errors of the extended disturbance observer based nonlinear velocity control

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

Major results

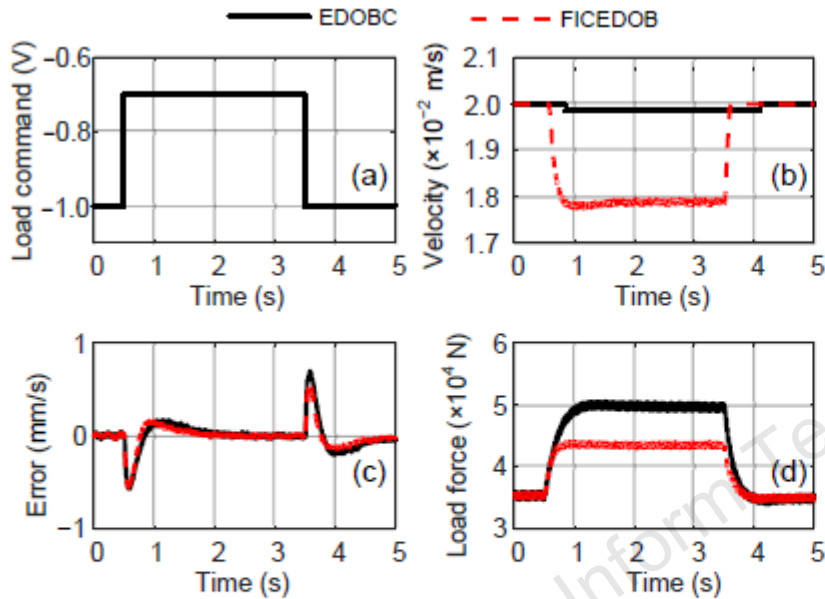


Fig. 11 Tracking results with a 0.02-m/s velocity command and $-1 \rightarrow -0.7 \rightarrow -1$ V load command: (a) load command; (b) adjusted velocity command; (c) velocity tracking error; (d) load force

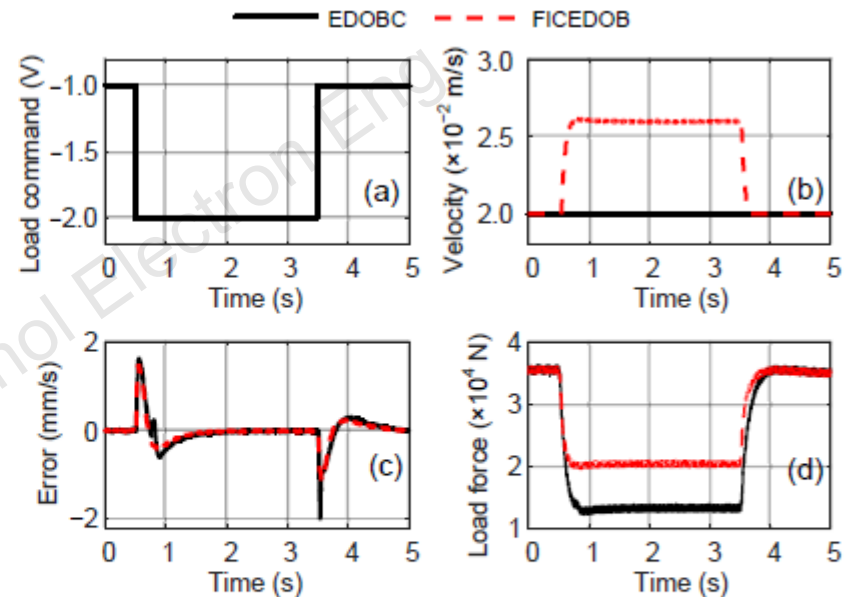


Fig. 12 Tracking results with a 0.02-m/s velocity command and $-1 \rightarrow -2 \rightarrow -1$ V load command: (a) load command; (b) adjusted velocity command; (c) velocity tracking error; (d) load force

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

Major results

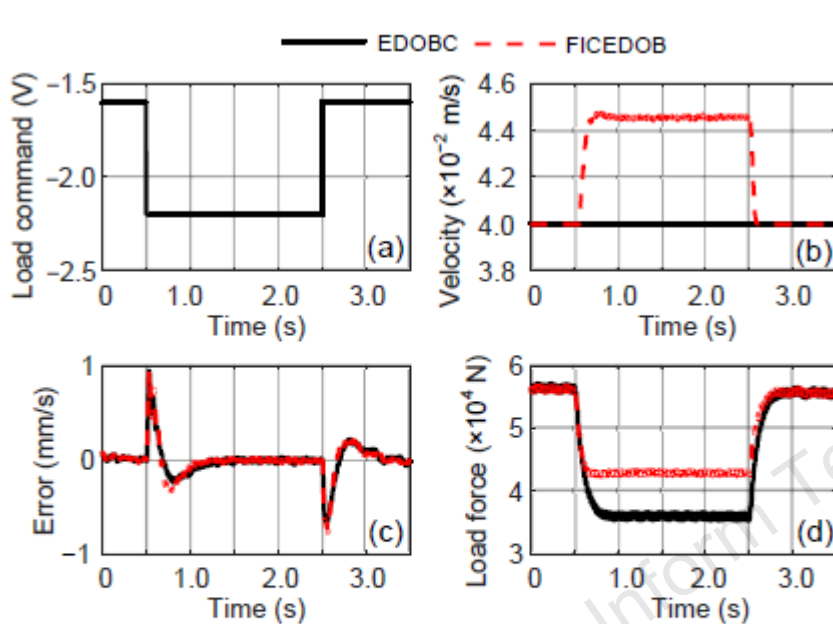


Fig. 13 Tracking results with a 0.04-m/s velocity command and $-1.6 \rightarrow -2.2 \rightarrow -1.6$ V load command: (a) load command; (b) adjusted velocity command; (c) velocity tracking error; (d) load force

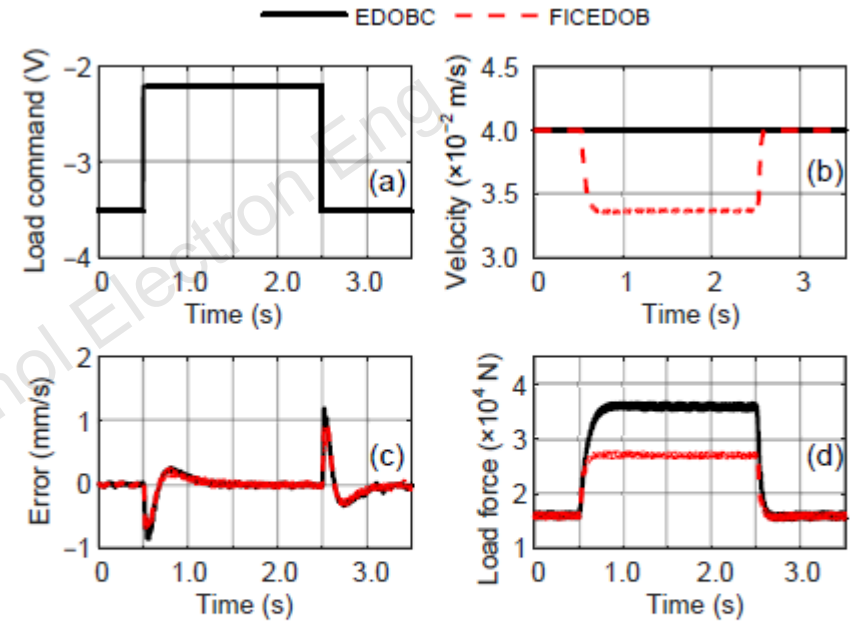


Fig. 14 Tracking results with a 0.04-m/s velocity command and $-3.5 \rightarrow -2.2 \rightarrow -3.5$ V load command: (a) load command; (b) adjusted velocity command; (c) velocity tracking error; (d) load force

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

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