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Motion synchronization of dual-cylinder pneumatic servo systems with integration of adaptive robust control and cross-coupling approach

Key words: Synchronization, Pneumatic servo system, Cross-coupling, Adaptive robust control

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Motivation

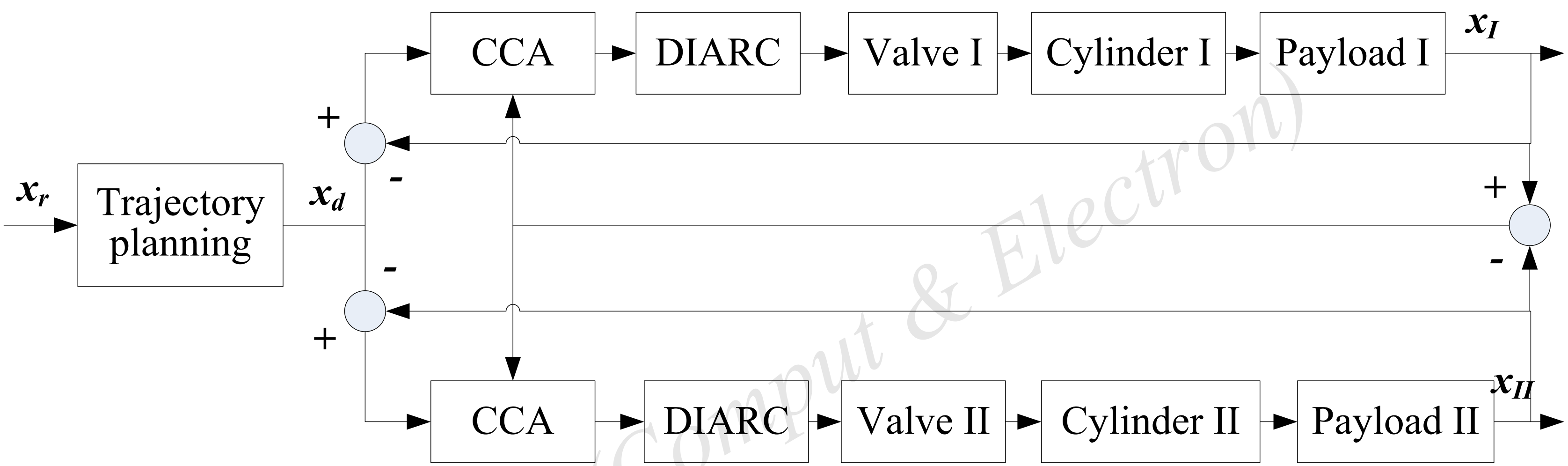
- Disadvantages of existing methods:
  - ✓ A bounded synchronization error cannot be explicitly achieved
  - ✓ The achievable motion synchronization performance is not satisfactory

- A new synchronization control strategy is proposed to achieve precision synchronized motion control of two pneumatic cylinders that are not mechanically connected.

Features of our control strategy

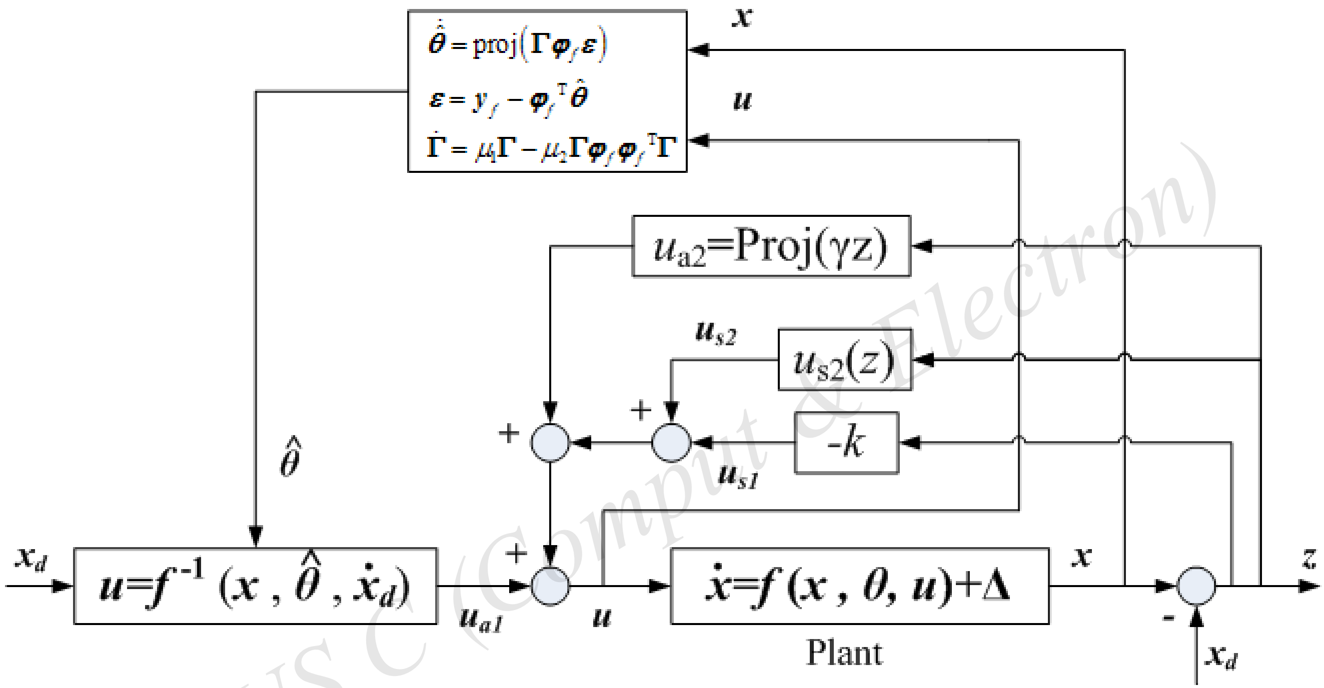
- The proposed synchronization control strategy incorporates the cross-coupling concept into the integrated direct/indirect adaptive robust controller (DIARC) architecture
- An online recursive least squares estimation algorithm is used to obtain accurate estimates of model parameters to reduce the extent of parametric uncertainties
- A robust control law is used to attenuate the effects of parameter estimation errors, unmodeled dynamics, and disturbances
- Asymptotic convergence to zero of both trajectory tracking and synchronization errors can be guaranteed

Controller design (I)



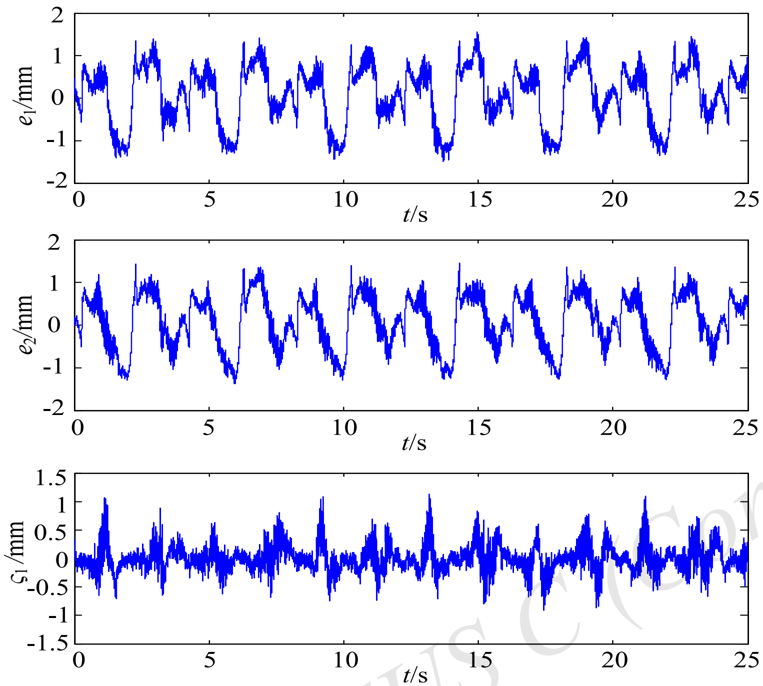
The proposed adaptive robust synchronization control can be divided into two parts: (1) robust control law; (2) parameter estimation algorithm. Due to the use of projection mapping, these two parts can be designed separately.

Controller design (II)

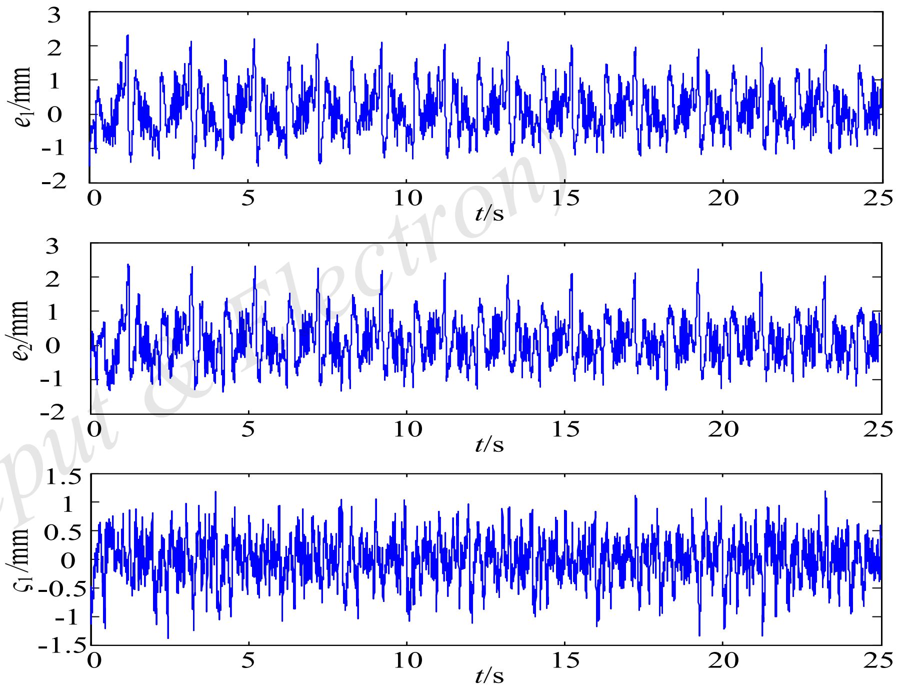


- Since the system model uncertainties are unmatched, recursive backstepping technology is adopted to design the robust control law
- Online recursive least squares estimation is developed to reduce parametric uncertainties

Experimental results (I)



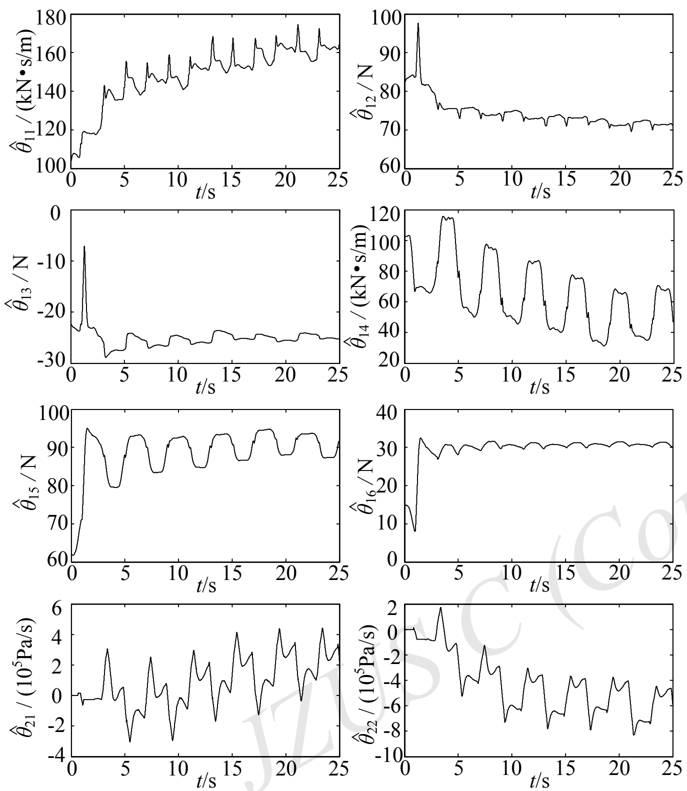
Tracking errors and synchronization error for a 0.25 Hz sinusoidal trajectory



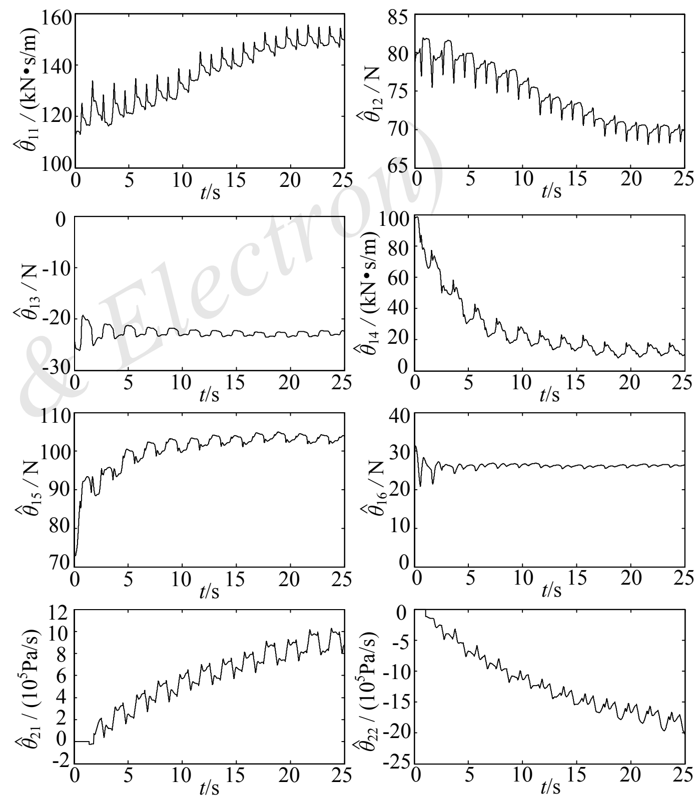
Tracking errors and synchronization error for a 0.5 Hz sinusoidal trajectory

The average synchronization errors in terms of L_2 norm are 0.48 mm and 0.49 mm; the maximum absolute synchronization errors are 1.05 mm and 1.45 mm.

Experimental results (II)



Parameter estimation for a 0.25 Hz sinusoidal trajectory



Parameter estimation for a 0.5 Hz sinusoidal trajectory

As can be seen, the estimates of parameters all converge quickly and stay close to some constant values.

Conclusions

- An adaptive robust synchronization control strategy which incorporates the cross-coupling concept into the DIARC architecture is proposed for the dual-cylinder pneumatic servo systems
- Theoretically, asymptotic convergence to zero is achieved for both position synchronization and trajectory tracking errors
- Extensive experimental results illustrate the effectiveness of the proposed controller and its performance robustness to sudden disturbances