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Quantitative feedback controller design and test for an electro-hydraulic position control system in a large-scale reflecting telescope

Key words: Large-scale reflecting telescope; Quantitative feedback theory; Electro-hydraulic position control system; Micron level position control capability; System identification; Robust stability

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Introduction

- A micron-level position control capability with fast convergence rate, high tracking accuracy, and stability is needed to improve imaging quality of telescope.
- System parameters vary across different working conditions, thus rendering the system nonlinear.
- A robust controller design procedure and experimental test has been presented in this work.

The micron-level position control system on this work

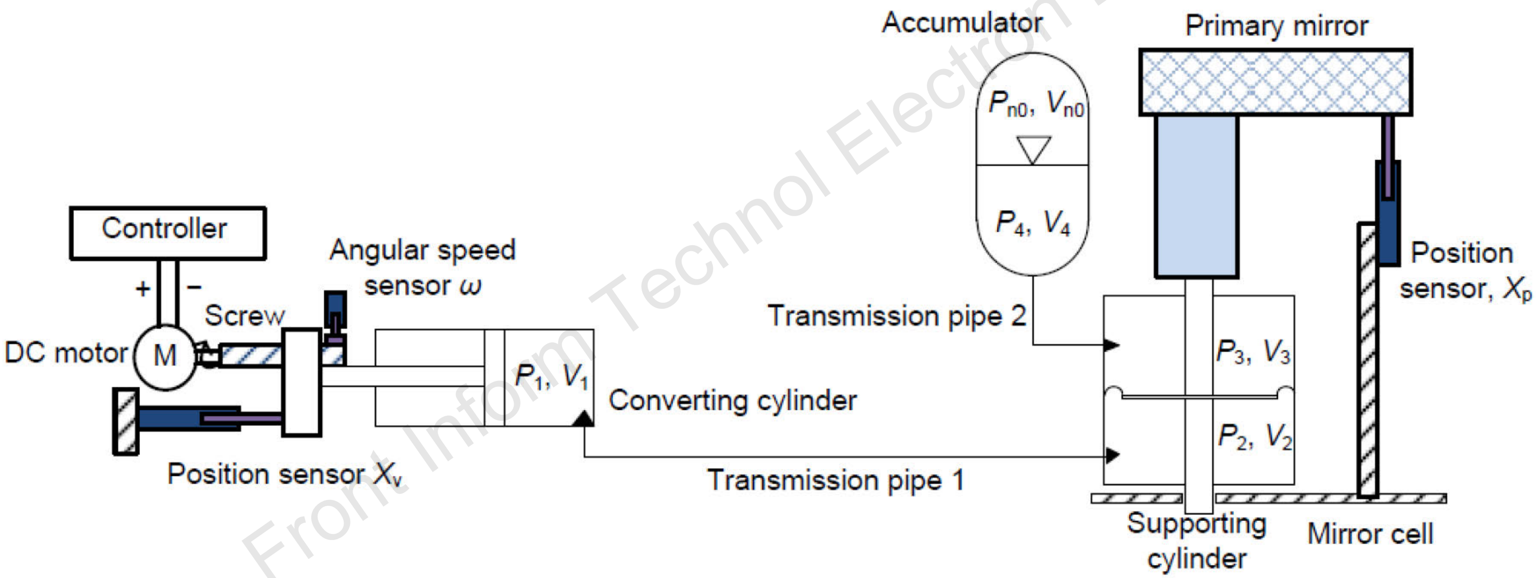

Fig. 1 Schematic of the electro-hydraulic position control system (EHPCS) for a large-scale reflecting telescope

System parameters identification and results

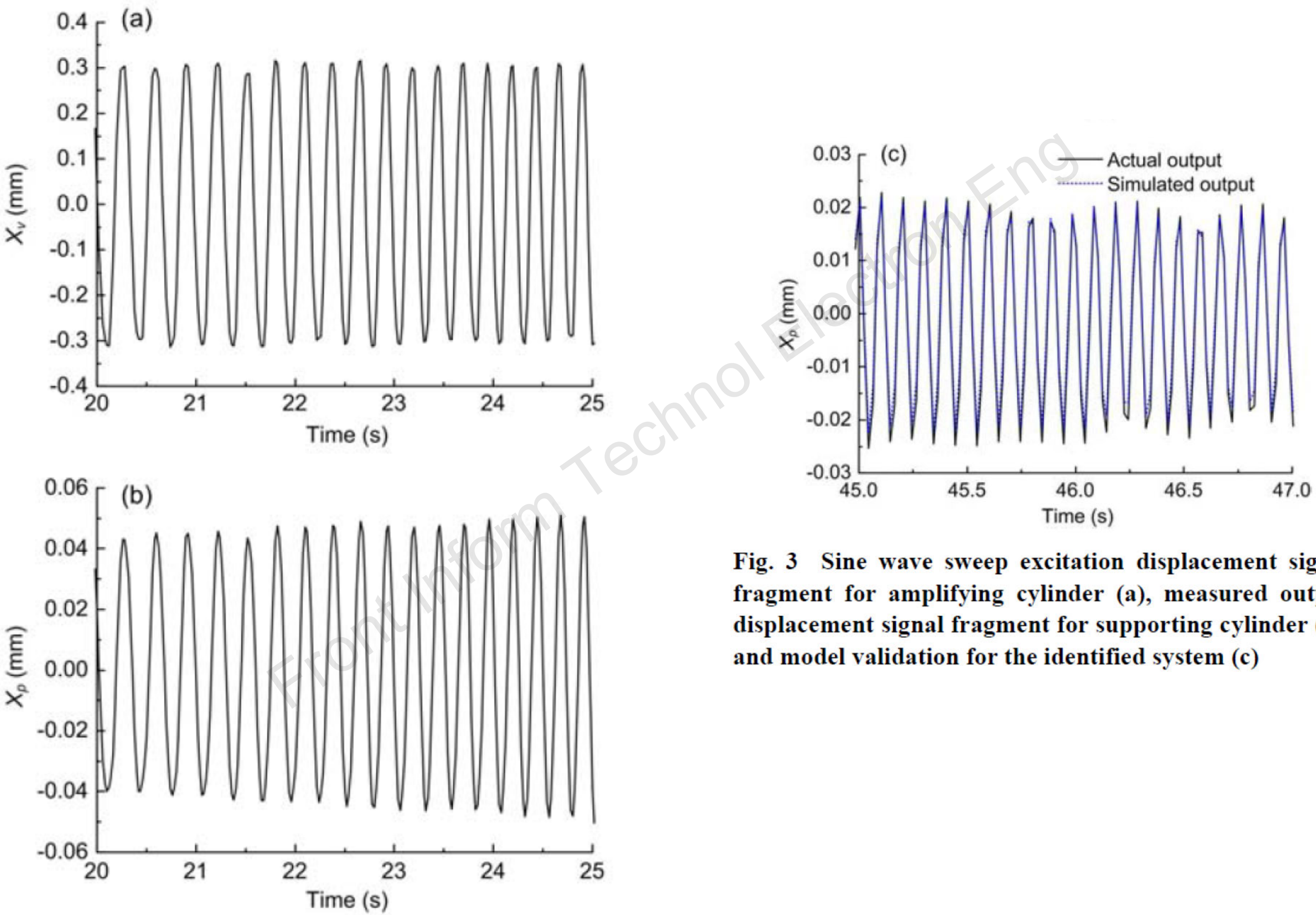

Fig. 3 Sine wave sweep excitation displacement signal fragment for amplifying cylinder (a), measured output displacement signal fragment for supporting cylinder (b), and model validation for the identified system (c)

System parameters identification and results

Table 1 Parameter identification results under different working conditions

Case index	ξ	ω_n (rad/s)	A ((rad/s)$^{-2}$)	B ((rad/s)$^{-1}$)	K	T (°C)	P_3 (Bar)	Position	Accuracy
1	0.3033	46.5	4.62×10^{-4}	0.01305	0.1173	25	3.50	Left	89.3%
2	0.2932	49.3	4.11×10^{-4}	0.01189	0.1072	25	3.63	Middle	86.8%
3	0.2841	56.3	3.15×10^{-4}	0.01009	0.1132	25	3.75	Right	90.3%
4	0.4102	43.5	5.28×10^{-4}	0.01885	0.1232	10	3.23	Left	85.3%
5	0.4056	44.3	5.09×10^{-4}	0.01831	0.1135	10	3.35	Middle	87.6%
6	0.3817	45.9	4.75×10^{-4}	0.01663	0.1203	10	3.45	Right	89.1%
7	0.5912	40.4	6.13×10^{-4}	0.02967	0.1132	−5	3.03	Left	90.5%
8	0.5867	41.2	5.89×10^{-4}	0.02848	0.1096	−5	3.08	Middle	86.3%
9	0.5812	41.7	5.75×10^{-4}	0.02787	0.1024	−5	3.16	Right	87.4%

QFT controller design procedure

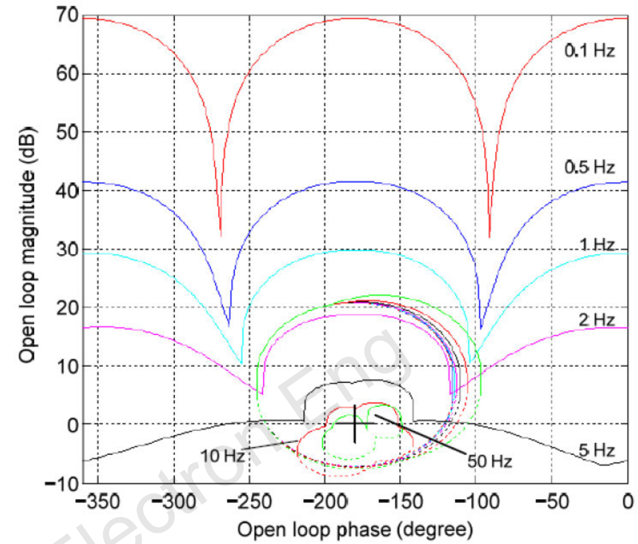

Fig. 6 The quantitative feedback theory (QFT) composite bounds in the Nichols chart

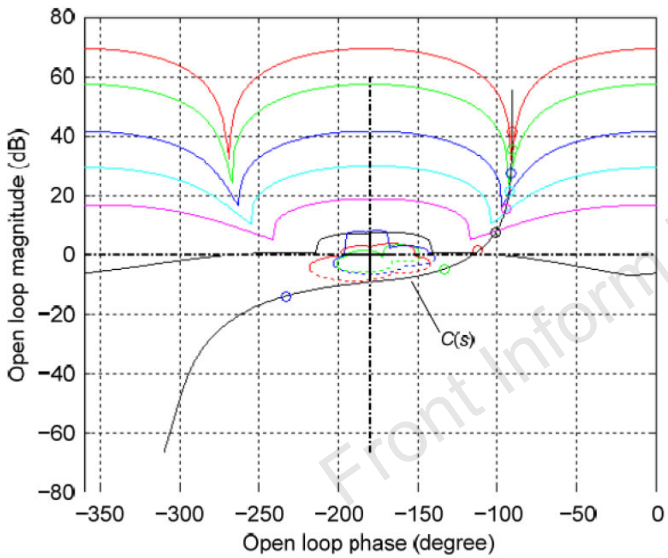

Fig. 7 The QFT loop-shaping results in the Nichols chart

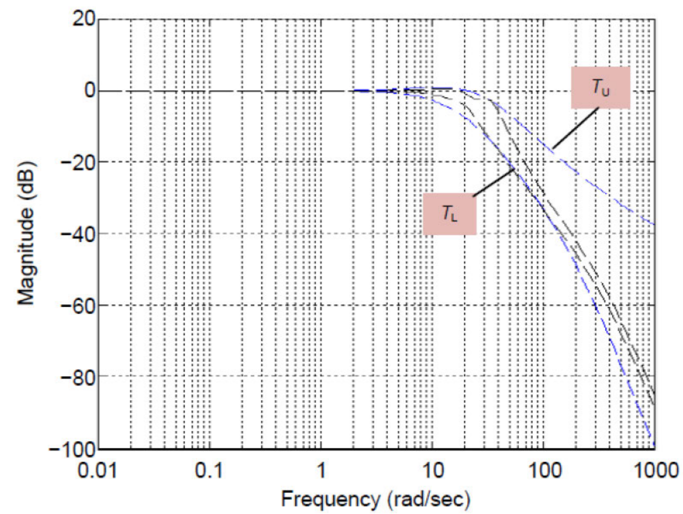

Fig. 8 The QFT pre-filter design results displayed as a Bode plot

Performance comparison

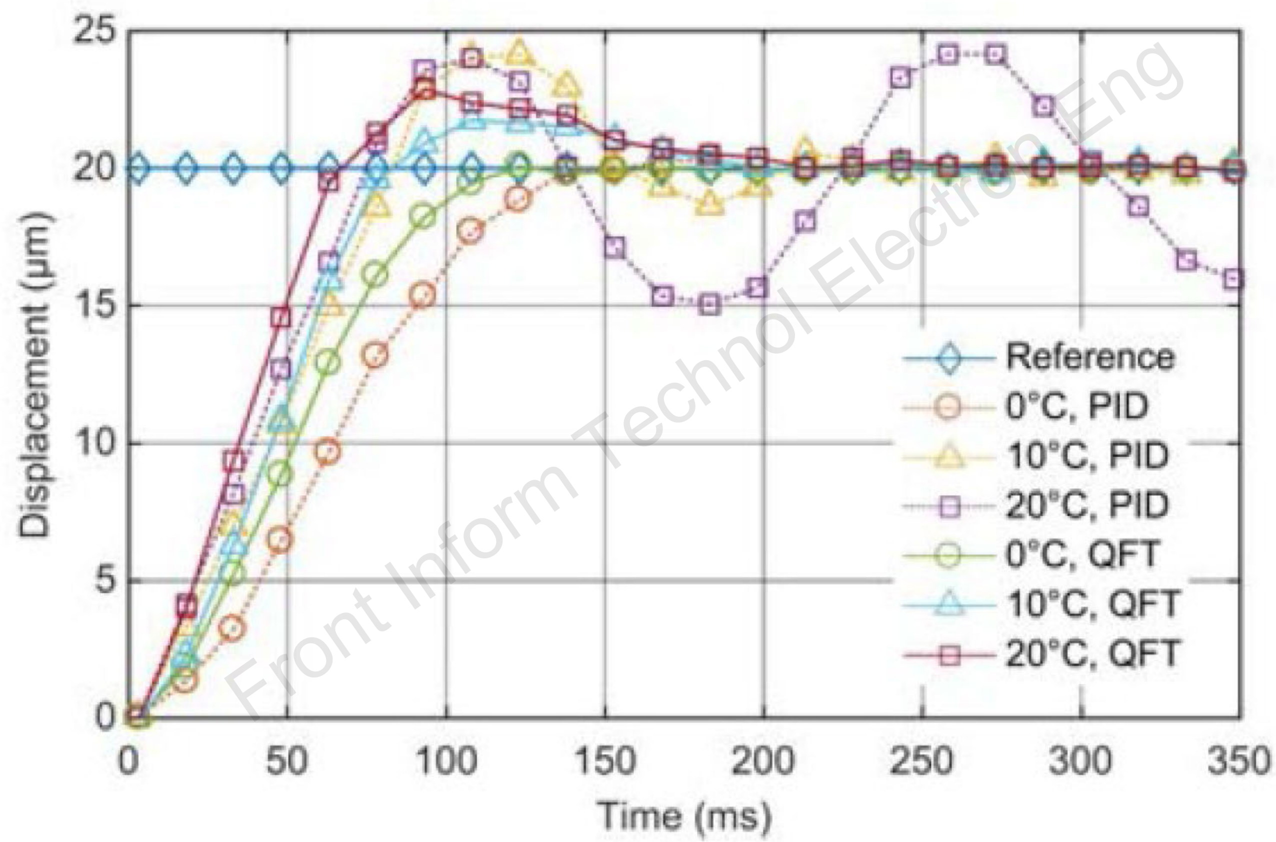

Fig. 10 The EHPCS closed loop step responses of PID and QFT controllers under different temperatures

Conclusions

- Using the quantitative feedback theory design framework, the robust control loop for the electro-hydraulic position control system was designed taking into consideration the parameter uncertainties.
- Experimental results shows that the proposed controller presents superior performance with a more robust stability than those of the PID controller.