Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)

A cutterhead energy-saving technique for shield tunneling machines based on load characteristic prediction

Cite this as: Xu Yang, Guo-fang Gong, Hua-yong Yang, Lian-hui Jia, Qun-wei Ying, 2015. A cutterhead energy-saving technique for shield tunneling machines based on load characteristic prediction. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 16(5):418-426. [doi:10.1631/jzus.A1400323]

JZUS-A

Background

Fig. 1. Shield tunneling machine

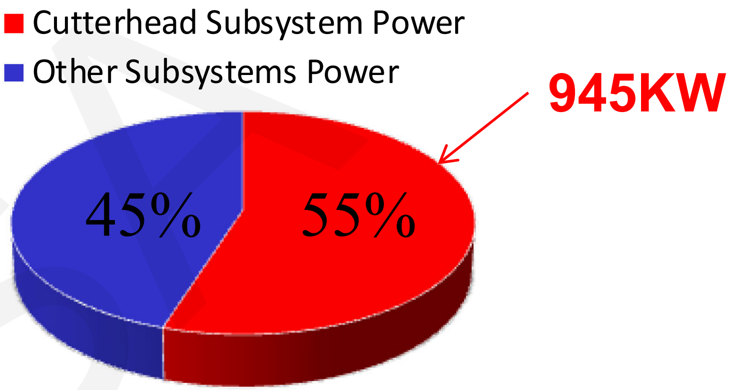

Fig. 3. Installed Power Distribution of a CTE6250

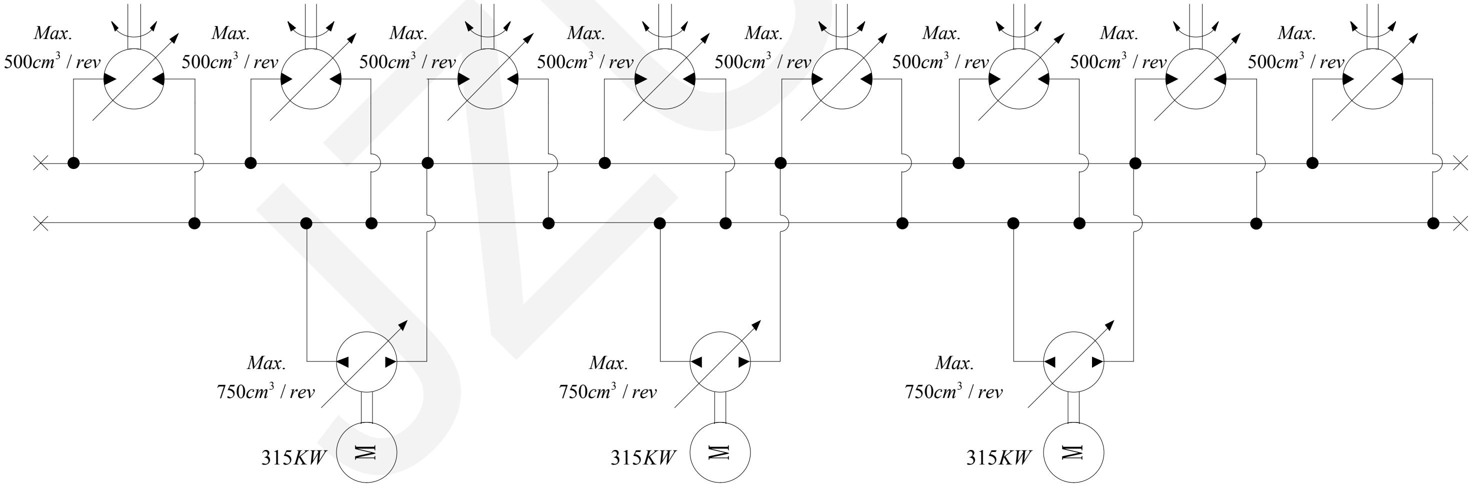

Fig. 2. A simplified cutterhead hydraulic driving system of CTE6250

Reprinted from (Xing et al., 2010) with modification, Copyright 2010, with permission from Zhejiang University Press

Cutterhead load characteristic prediction

Field Data → Wavelet-based Preprocessing → Grey Model GM(1,1)

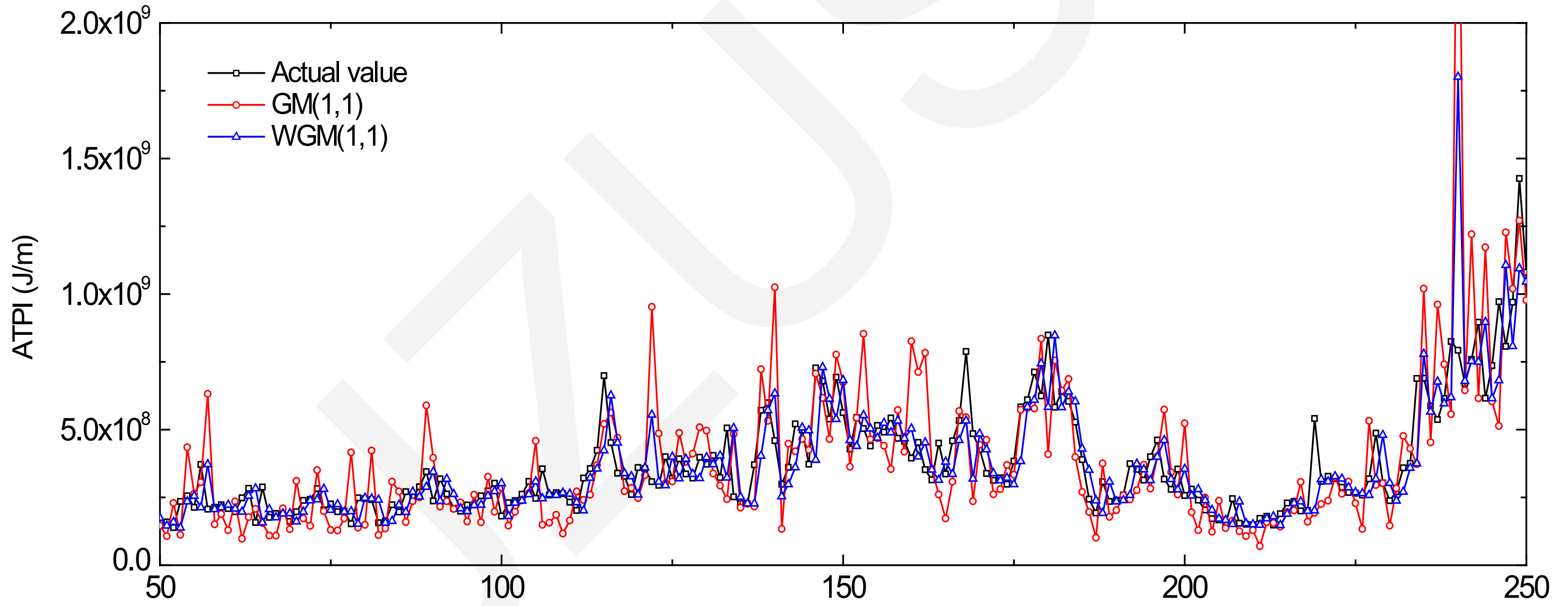

Fig. 4. Forecasted ATPI using GM(1,1) and WGM(1,1) with M=8, N=8

JZUSA

Cutterhead efficiency optimization

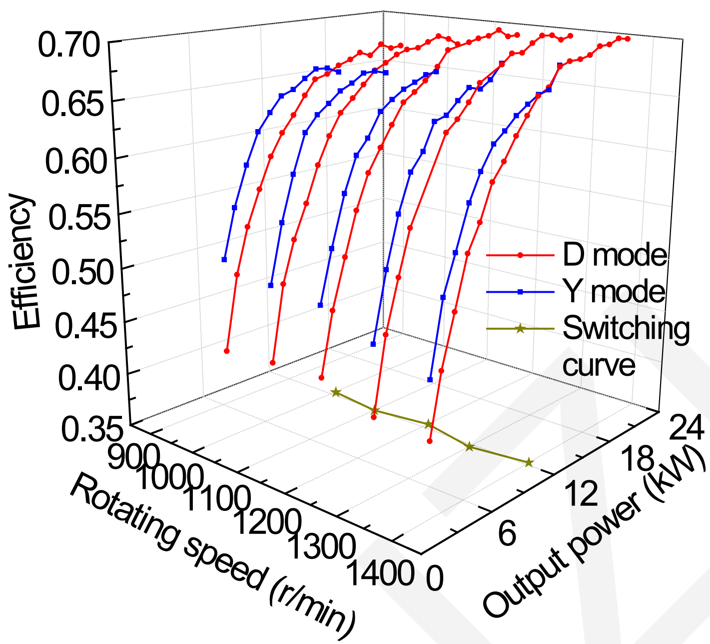

Fig. 5 Efficiency and switching points, with different controlled cutterhead speeds

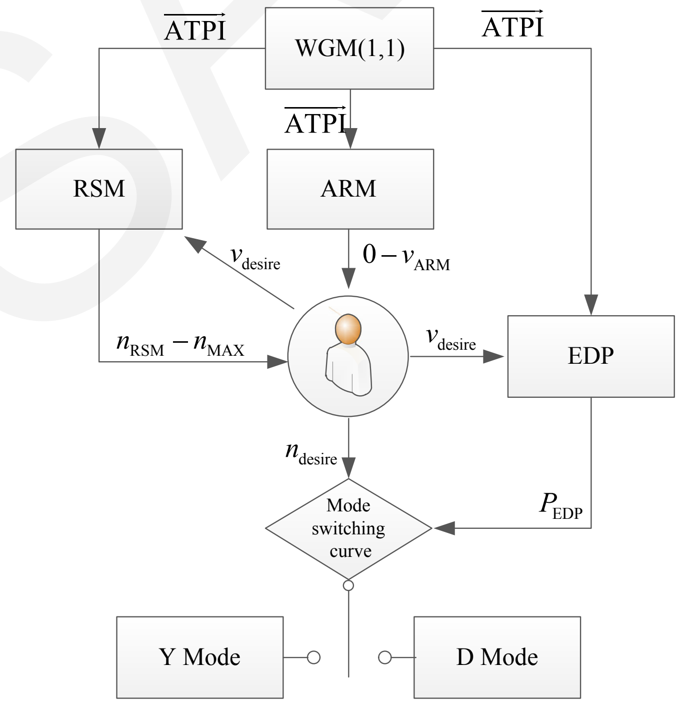

Fig. 6 Cutterhead mode control strategy

Cutterhead efficiency optimization

Table 1 Numerical computing results of the CMCS with $\eta_e = 0.6$, $\eta_s = 1.3$, $\lambda_n = 807.4$, and $\lambda_p = 3.17 \times 10^{-2}$

Ring No.	CTE6250						Experiment platform		
	Forecasted ATPI ($\times 10^5$ kJ/m)	v_{ARM} ($\times 10^{-3}$ m/s)	Assume $v_{desire}=v_{mean}$ ($\times 10^{-3}$ m/s)	P_{EDP} ($\times 10^2$ kW)	n_{RSM} ($\times 10^{-2}$ rad/s)	Assume $n_{desire}=n_{mean}$ ($\times 10^{-2}$ rad/s)	P_{EPEDP} (kW)	$n_{EPdesire}$ (rad/s)	Mode
60	2.23	1.96	0.79	2.29	3.82	15.9	7.26	128	Y
110	2.63	1.66	0.87	2.97	4.96	15.8	9.41	128	Y
160	5.04	0.87	0.85	5.57	9.28	15.5	17.66	125	D
210	1.50	2.91	1.03	2.01	3.35	15.7	6.37	127	Y

Table 2 Experiment results analysis

Approach	Ring No. 60		Ring No. 110		Ring No. 160		Ring No. 210	
	Output (kJ)	Efficiency (%)	Output (kJ)	Efficiency (%)	Output (kJ)	Efficiency (%)	Output (kJ)	Efficiency (%)
Without CMCS	1300	51.0	1458	56.6	2542	64.9	928	53.0
With CMCS	1301	57.8	1458	61.5	2542	64.9	928	57.0

Cutterhead efficiency optimization

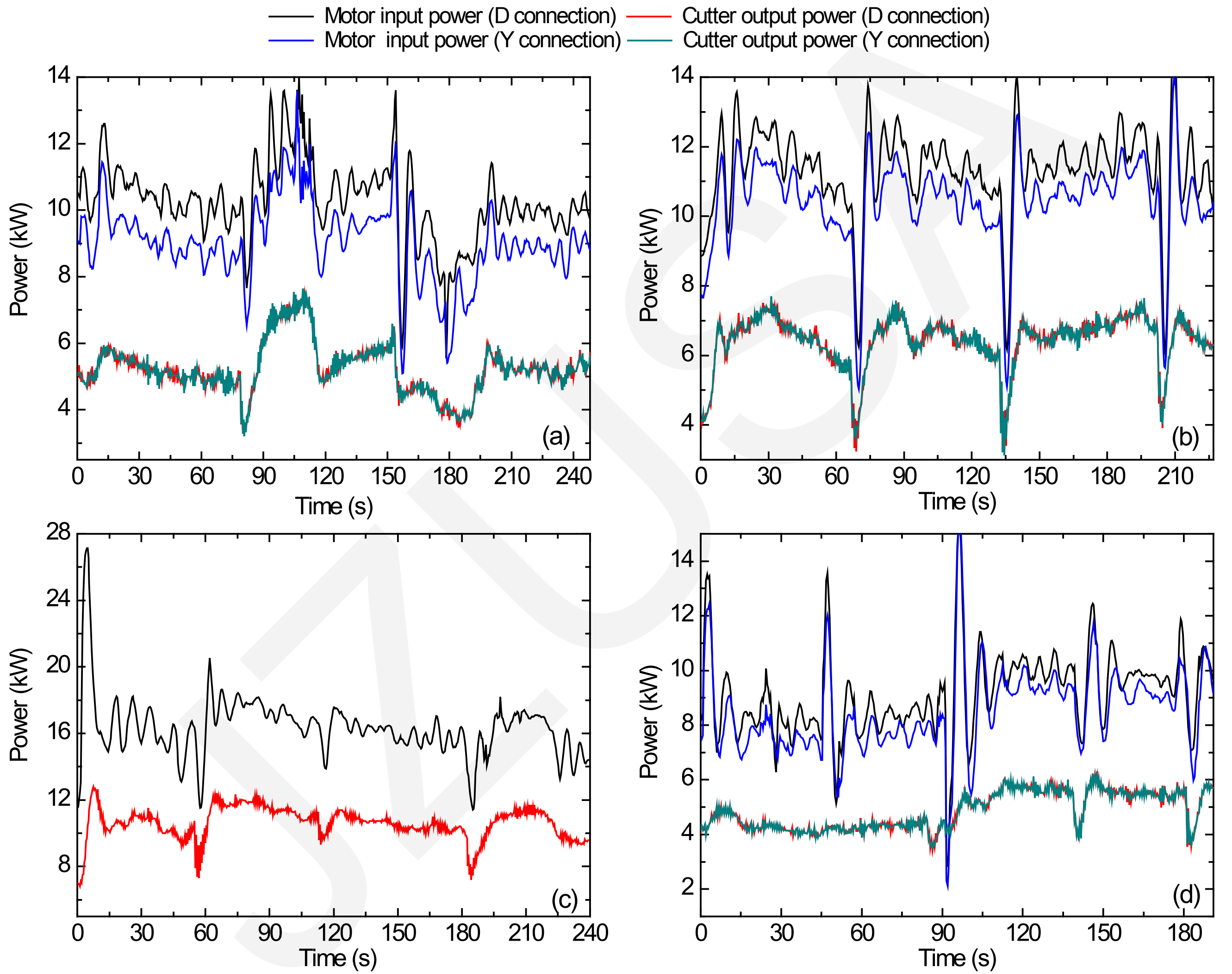

Fig. 7 Experiments based on field data

(a) Ring No. 60; (b) Ring No. 110; (c) Ring No. 160; (d) Ring No. 210

Conclusions

In this paper, we propose a mode control strategy for a shield cutterhead hydraulic driving system based on a load characteristic forecast method. The following conclusions can be drawn:

1. The wavelet transform preprocessing can help the GM(1,1) to improve performance in forecasting the cutterhead load characteristic. The WGM(1,1) is an effective method for forecasting the cutterhead load characteristic.

2. The change of stator winding connection is a simple and efficient technique to improve the efficiency of cutterhead hydraulic system.

3. The CMCS can provide the operator with recommendations about the advance rate range and cutterhead rotation speed range, which will be helpful in developing a reasonable construction plan for the next ring. The stator winding connection can also be optimized according to the construction plan. Consequently, CMCS has shown a satisfactory energy-saving performance in the field data-based experiments.

JZUS-A