Economic Operation Analysis of Circulating Water Pump in a Power Plant

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Abstract. This paper calculates the main indexes of circulating water pump in a power plant, such as flow rate, head, shaft power and efficiency, and shows the test results. The results reach the guaranteed value of design technical specifications.

1 Introduction

The circulating water system in a power plant adopts the recirculating unit water supply system with natural ventilation cooling tower. Each unit is equipped with two double-speed motor circulating water pumps, one cooling tower with 100% capacity, one circulating water supply and return water pipe, one backwater ditch, four flat screen filters and connecting pipe valves. The system includes two connecting pipes and two electric valves between the two main pipes of circulating water supply, and several cast iron gates between the two backwater ditches.

The operation condition of circulating water pump is as follows, one unit operates with two pumps in summer; two units operate with three pumps in spring and autumn; one unit operates with one pump in winter or under low load. The circulating water system optimization is described in literature [1]-[4].

This paper calculates the flow rate, head, shaft power and efficiency of the two circulating pumps, and verifies whether they reach the guaranteed value given by the designed technical specifications, and draws the relating curves, and takes the results as an important reference for the formulation of overhaul plans.

2 Test Conditions and Calculating Method

2.1 Test Conditions

In order to adjust the flow rate of water supply, the outlet valves of circulating cooling water is respectively opened to 100%, 50% and 40%. Under each opening condition, the operation mode of circulating water system is switched to the isolated unit operation mode.

2.2 Calculating method

2.2.1 Head

$$H = \frac{P_2 - P_1}{\rho \times g} + \frac{V_2^2 - V_1^2}{2 \times g} + Z_2 - Z_1 \quad (1)$$

H—head, m;

P₁—pressure of inlet, Pa;

P₂—pressure of outlet, Pa;

ρ—average of density, kg/m³;

g—gravity acceleration, 9.81m/s²;

V₁—inlet velocity, m/s;

V₂—outlet velocity, m/s;

Z₁—central elevation of inlet pressure gauge,

m;

Z₂—central elevation of outlet pressure gauge,

m.

2.2.2 Effective power

$$P_u = \frac{G \times H \times g}{3600} \quad (2)$$

P_u—effective power of pump, kW;

G—export flow, t/h.

2.2.3 Efficiency

$$\eta = \frac{P_u}{P_{gr} \times \eta_{gr}} \times 100\% \quad (3)$$

η—pump efficiency, %;

P_{gr}—input power of motor, kW;

η_{gr}—motor efficiency, %.

3 Analysis of test results

3.1 Test data and calculation results of circulating water pump

The original data and calculated result of A and B circulating pumps is respectively shown in Table 1 and table 2.

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Table 1.Performance test data and calculation results of pump A

project	unit	content						
Number of condition	/	1	2	3	4	5	6	7
Operation mode of circulating water pump	/	Low speed of pump A, high speed of pump B	high speed of pump B	high speed of pump A, high speed of pump B	Low speed of pump A, high speed of pump B	Low speed of pump A, high speed of pump B	Low speed of pump A, high speed of pump B	high speed of pump A
Condenser outlet valve opening	%	100	100	100	100	50	40	100
Outlet pressure of pump A	mH ₂ O	28.03	/	30.64	28.2	29.98	31.79	23.24
input power of motor	kW	/	0	3049	2178	2112	2090	/
motor efficiency	%	94.3	94.3	94.3	94.3	94.3	94.3	94.3
shaft power	kW	/	0	2875	2054	1992	1971	/
Total flow	m ³ /s	18.14	12.41	19.99	18.55	16.62	14.24	11.81
Flow of pump A	m ³ /s	7.65	0	9.99	7.89	6.46	4.98	11.81
head	m	22.53	0	24.67	22.56	24.27	26.18	17.92
available power of pump A	kW	/	0	2418	1746	1538	1279	2076
Efficiency of pump A	%	/	0	84.1	85.0	77.2	64.9	/

Table 2.Performance test data and calculation results of pump B

project	unit	content						
Number of condition	/	1	2	3	4	5	6	7
Operation mode of circulating water pump	/	Low speed of pump A, high speed of pump B	high speed of pump B	high speed of pump A, high speed of pump B	Low speed of pump A, high speed of pump B	Low speed of pump A, high speed of pump B	Low speed of pump A, high speed of pump B	high speed of pump A
Condenser outlet valve opening	%	100	100	100	100	50	40	100
Outlet pressure of pump B	mH ₂ O	27.33	22.18	29.08	27.33	28.99	31.1	/
input power of motor	kW	/	3157	/	3271	3282	2902	0
motor efficiency	%	94.3	94.3	94.3	94.3	94.3	94.3	94.3
shaft power	kW	/	2977	/	3085	3095	2737	0
Total flow	m ³ /s	18.14	12.41	19.99	18.55	16.62	14.24	11.81
Flow of pump B	m ³ /s	10.49	12.41	9.99	10.65	10.17	9.26	0
head	m	22.53	16.94	24.67	22.56	24.27	26.18	0
available power of pump B	kW	/	2062	/	2357	2421	2378	0
Efficiency of pump B	%	/	69.3	/	77.1	78.2	86.9	0

Based on the data, calculation results and the performance curve of the circulating water pump provided by the manufacturer, the head, shaft power and efficiency of the circulating water pump under different operating flow rates are shown in Table 3 to Table 6.

According to the calculation results, the curve is drawn. Flow-head curve and flow-efficiency curve of pump A and B are shown in figure 1 ~ figure 4 respectively.

Table 3.High speed performance data of pump A

project	unit	content			
flow	m ³ /s	9.99	8.85	5.59	7.24
head	m	24.67	28.35	32.91	30.50
shaft power	kW	2875	2896	2781	2821
efficiency of pump	%	84.1	85.0	64.9	76.8

Table 4.Low speed performance data of pump A

project	unit	content			
flow	m ³ /s	4.98	6.46	7.89	8.91
head	m	26.18	24.27	22.56	19.62
shaft power	kW	1971	1992	2054	2037
efficiency of pump	%	64.9	77.2	85.0	84.2

Fig. 1. Rate of flow-head curve of pump A

Fig. 2. Rate of flow-efficiency curve of pump A

Table 5.High speed performance data of pump B

project	unit	content			
flow	m ³ /s	12.41	10.65	10.17	8.82
head	m	16.94	22.56	24.27	27.91
shaft power	kW	2976	3058	3095	2811
efficiency of pump	%	69.3	77.1	78.2	85.9

Table 6.Low speed performance data of pump B

project	unit	content			
flow	m ³ /s	7.87	9.07	9.50	11.07
head	m	22.2	19.3	17.94	13.48
shaft power	kW	1991	2193	2166	2128
efficiency of pump	%	86.1	78.3	77.2	68.8

Fig. 3. Rate of flow-head curve of pump B

Fig. 4. Rate of flow-efficiency curve of pump A

3.2 Figures and tables Analysis of test results

3.2.1 Flow and Head Allowance of Circulating Water Pump

According to GB/T 3216-2005 Rotodynamic pumps Hydraulic performance acceptance tests Grade 2, the flow tolerance coefficient of pump is $\pm t_Q$, $t_Q=0.08$; the head tolerance coefficient is $\pm t_H$, $t_H=0.05$. Tolerance coefficients t_Q , t_H guarantee points Q_G and H_G . By comparing the test results, guarantee value stipulated in the contract and relevant tolerance values specified in the standards, the guaranteed value of flow and head is evaluated.

As is seen from figure 5 and figure 6, the flow-head curves of pump A and pump B intersects with the tolerance cross. Therefore, the flow rate and head of pump A and pump B is guaranteed.

Fig. 5. Evaluation of guaranteed efficiency of pump A

Fig. 6. Evaluation of guaranteed efficiency of pump B

3.2.2 Circulating Water Pump efficiency

According to GB/T 3216-2005 Rotodynamic pumps Hydraulic performance acceptance tests Grade 2, the efficiency tolerance coefficient of the pump is $\pm t_\eta$, $t_\eta=0.05$. Tolerance coefficient η is applicable to guarantee points Q_G and H_G . By comparing the test results, guarantee value stipulated in the contract and relevant tolerance values specified in the standards, the guaranteed value of flow and head is evaluated. The calculation result is shown in table 7.

Table 7. Examination results of circulating pump efficiency

Test point	Calculation efficiency(%)	Design efficiency (%)	$(1-t_\eta) \cdot \eta_G$	Examination results
High Speed Design Performance Points of Pump A	85.1	87.8	83.41	Achieving Requirements
Low Speed Design Performance Points of Pump A	85.1	87.7	83.32	Achieving Requirements
High Speed Design Performance Points of Pump B	84.76	87.8	83.41	Achieving Requirements
Low Speed Design Performance Points of Pump B	84.76	87.7	83.32	Achieving Requirements

4 Conclusion

From the previous analysis of various indicators of circulating water pumps, the following conclusions can be drawn:

1) The flow rate, head and efficiency of the circulating pump A and B meet the guaranteed value of their design technical specifications.

2) When circulating water pump runs in parallel, it can meet the requirement of circulating cooling water quantity under design condition. For summer condition, further test certification is still needed.

References

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