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RESEARCH AND APPLICATION OF OPTIMIZATION TRANSFORMATION OF CIRCULATING WATER PUMP IMPELLER

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Abstract

The reasons why the circulating water pump can only operate at less than 30 % of the outlet quick-closing valve opening are analyzed . The turning ratio law is used to calculate and analyze the turning size of the impeller. A plan for turning and modifying the circulating water pump impeller is proposed, which enables the circulating water pump outlet quick-closing valve to be fully opened and the motor current to operate within the allowable range. The economic efficiency of the circulating water pump impeller after modification is calculated, achieving the purpose of energy saving and consumption reduction. This study aims to analyze the causes of these inefficiencies and propose a solution by modifying the impeller through turning and recalibration. The turning ratio law was applied to calculate the appropriate size of the impeller, ensuring full valve opening while maintaining the motor current within permissible limits. Post-modification results demonstrated enhanced economic efficiency, reduced power consumption, and improved pump performance, achieving energy savings and consumption reduction. The study concludes that impeller turning is a practical and effective method for optimizing circulating water pump operations in thermal power plants.

Keywords: circulating water pump; cause of overcurrent ; impeller turning calculation; impeller transformation; energy saving; consumption reduction

Introduction

The circulating water pump is an important auxiliary machine of the thermal power unit, and its energy consumption accounts for 1% to 1.5% of the power consumption rate of the thermal power unit. In the actual operation process (Adi Dharma & Garniwa, 2022; Liu et al., 2024; Ma et al., 2015; Muhammad, 2020), the circulating water pump of the Kendari generator unit has problems such as the mismatch between the outlet head of the pump and the system, the deviation between the actual flow and the designed flow, the operation of the pump deviates from the working point, and the low efficiency (Augustyn, 2012; Shu et al., 2018; Yang et al., 2016). Therefore, it is very necessary to improve the quality and efficiency of the circulating water pump. There are four main transformation methods for energy saving and consumption reduction of the circulating water pump in the power plant. The first is to change the circulating pump motor to double speed, the second is to turn the impeller diameter, the third is to change the frequency regulation of the circulating pump motor, and the fourth is to reselect the pump impeller. This paper uses the operating parameters of the Kendari 50MW unit to analyze the cause of the overcurrent of the circulating water pump, and proposes a method of turning the impeller to address this cause (Arun Shankar et al., 2016; Khoeini & Tavakoli, 2018; Zhou et al., 2016). Through the data analysis after the transformation, this method meets the circulation water volume demand of a single unit and a single pump, the current of the circulating water pump is reduced to within the design range, the power consumption of the circulating water pump and the power consumption rate of the plant are reduced, and the quick-closing valve at the outlet of the circulating water pump can be fully opened (Bai et al., 2017; Li, 2011; Matlakala et al., 2019; K. Wang et al., 2017). Moreover, the study aims to analyze the causes of these inefficiencies and propose a solution by modifying the impeller through turning and recalibration.

Unit Overview

The circulating water system of Kendari Power Plant adopts an expanded unit system. Each unit is equipped with two circulating water pumps with 50% capacity and a circulating water supply main pipe. The circulating water supply main pipes of the two units are connected after the electric butterfly valve at the outlet of the circulating water pump (Khamudkhanov et al., 2020; H. Wang & Wang, 2019; Zwierzchowski et al., 2022). The two units share a return water main pipe, and a siphon well is set at the end. When the two units are in operation, the circulating water systems of the two units are connected, three pumps are in operation, and one pump is on standby. The operating current of the three pumps is about 123A (rated current 128.4A). Since the full opening of the outlet door will cause the circulating pump motor to overcurrent, the outlet doors of the three circulating pumps in operation are limited to 30%. When the single unit is in operation, the outlet connection door of the circulating water supply main pipe is closed, and the two circulating water pumps of this unit are in operation, and the outlet doors of the circulating pumps are limited to about 30%. Due to the limited outlet door opening operation, the water flow direction is changed, and the anti-corrosion layer of the outlet valve and pipeline is eroded, resulting in frequent leakage. The limited door operation also causes the pump to deviate from the operating point and low efficiency of Unit D of Kendari Power Plant as an example for analysis. The main technical specifications of the steam turbine are shown in Table 1, the main technical specifications of the circulating water pump are shown in Table 2, and the main technical specifications of the circulating water pump motor are shown in Table 3.

Table 1. Main technical specifications of steam turbine

project name	Steam Turbine Design Technical Specifications
Unit Type	Model: N 56 —— 8.83 /535
Rated power/MW	56 MW
Main steam pressure/MPa	8.83 ±0.5MPa
Main steam temperature/°C	535 °C
Main steam flow t/h	2 08.5 t/h
Exhaust pressure MPa	0.00 84 M Pa

Table 2. Main technical specifications of circulating water pump

project name	Design technical specifications for single circulating water pump
Circulating water pump operation mode	Two machines and three pumps in parallel Single machine and two pumps in parallel
Flow rate/ M³/h	7070 M³/h
Lift/M	37M
Shaft power/KW	1000KW
Pump efficiency/ %	87%
Impeller average diameter/mm	759,5 mm

Table 3. Main technical specifications of circulating water pump motor

project name	Fixed speed motor
Rated voltage/KV	6000KV
Rated power/KW	1000KW
Current/A	128.4A
Power Factor	0.82
Speed/r	743r

1) Analysis of the causes of overcurrent in circulating water pump motor

The design head of the circulating water pump is 37 meters, see Figure 1, and the design circulating water flow rate of single unit operation is 13860m³/h, see Figure 1

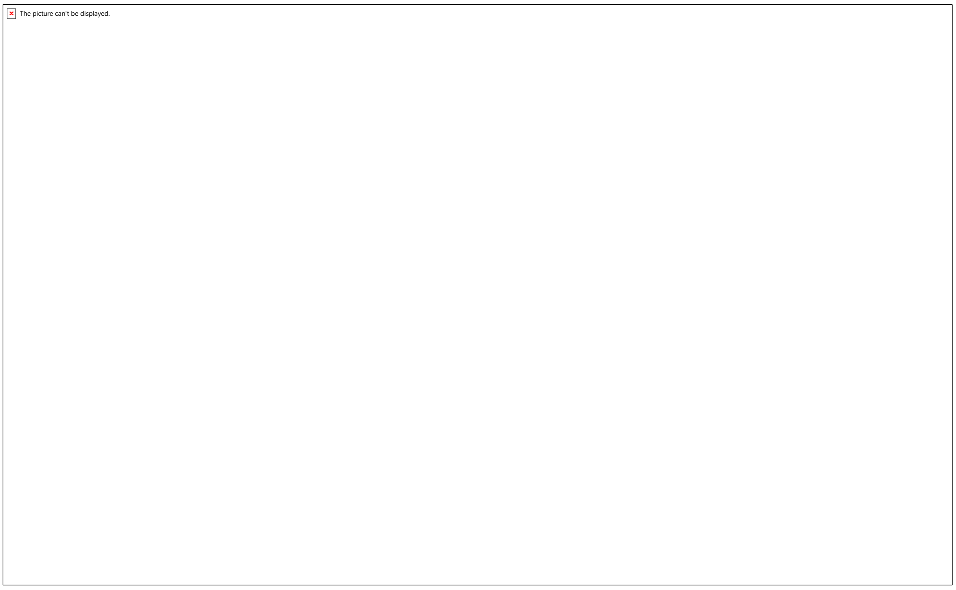


Figure 1. Design Head

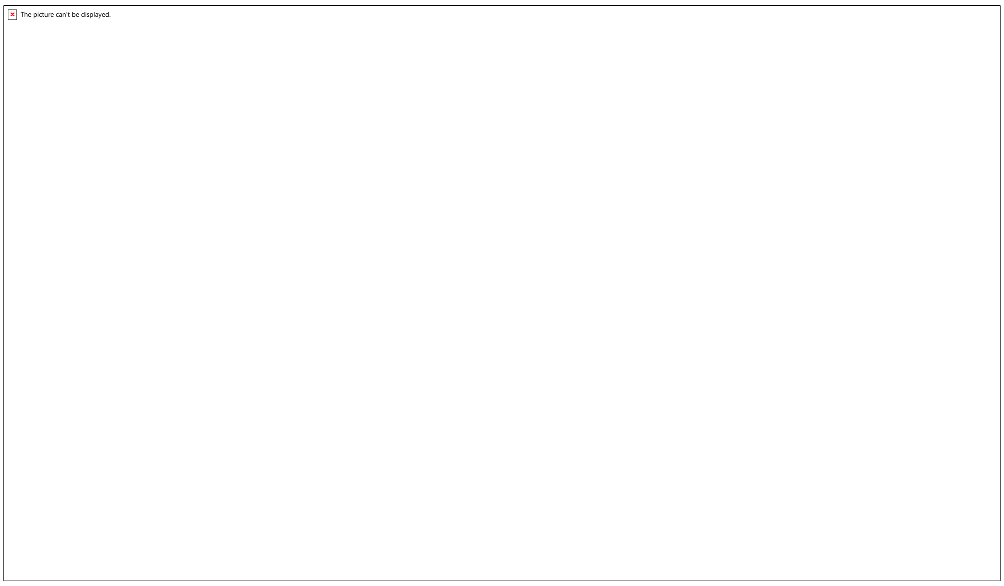


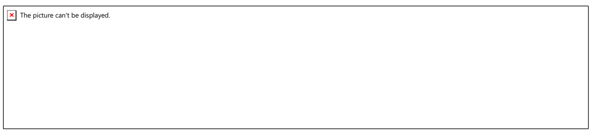
Figure 2. Circulating water pump flow

According to the current operating status of the unit, the operating parameters of the dual-machine single pump and single-machine dual pump were actually tested on site. When the opening of the circulating water pump outlet hydraulic control butterfly valve was at 30%, the outlet main pipe pressure was 0.2Mpa and the flow rate was about 20000T, which fully met the condenser vacuum demand. This reflects that the design parameters of the circulating water system have a large deviation from the actual operating parameters. The design parameters of the circulating water pump are greater than the actual requirements of the system, resulting in the circulating water pump having to operate with limited parameters, otherwise the motor will overcurrent.

2) Impeller turning amount calculation and economic analysis

The cutting amount of the impeller outer diameter can be calculated by using the universal cutting law of the water pump impeller.

The cutting law is calculated as follows:



Where: Q1—flow rate before turning the outer diameter, m^3 / s;
H1—lift before turning the outer diameter, m;
P1—shaft power before turning the outer diameter, kW;
D1—impeller outer diameter before turning, mm;
Q2—flow rate after turning the outer diameter, m^3 / s;
H2—lift after turning the outer diameter, m;
P2—Shaft power after turning the outer diameter, kW
D2—Outer diameter of the impeller after turning, mm.

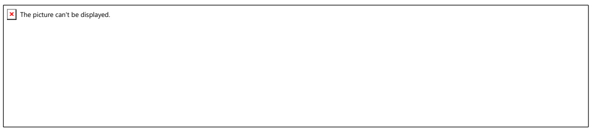
The formula calculates that the outer diameter of the circulating water pump impeller is 25mm. According to the above calculation results, the relevant water pump manufacturer is commissioned to turn the outer diameter of the circulating water pump impeller by 25mm. After that, the current of the D circulating pump motor drops to 121A, the outlet hydraulic control butterfly valve can be fully opened, and a single machine and a single pump can meet the condenser vacuum above -92,5 kPa, saving one circulating pump operation.

The solution of turning the outer diameter of the impeller reduces the current of the circulating water pump to within the design range, ensuring the safe and stable operation of the circulating water pump, and at the same time increasing the economic benefits of the unit to a certain extent. Based on the calculation that a single circulating water pump runs 365 days a year, the unit can save plant electricity consumption annually: P = 365×24×UI (720) = 8.76 million kW·h. Based on the current on-grid electricity price of 0.77 yuan/kW·h, the cost can be saved by 6.75 million yuan per year.

Research Methods

1. **Affinity Laws Calculation**

   Affinity Laws for predicting performance changes due to impeller trimming.
   Affinity Laws:



   Method: Predictions made using these law before impeller trimming.
2. **Experimental Testing and Performance Analysis**
   To evaluate the effect of impeller trimming on pump performance, such as efficiency, head, flow rate, and power consumption.
   Method:
   Conduct baseline testing of the pump with the original impeller.
   Incrementally reduce the impeller diameter by cutting around 5%, 10% (based on prediction using affinity laws)
   Perform tests after trim, measuring key performance parameter.
   Tools: Flow meters, pressure gauges.

Result and Discussion

Data pump production test and analysis report can be seen in the Figure below.

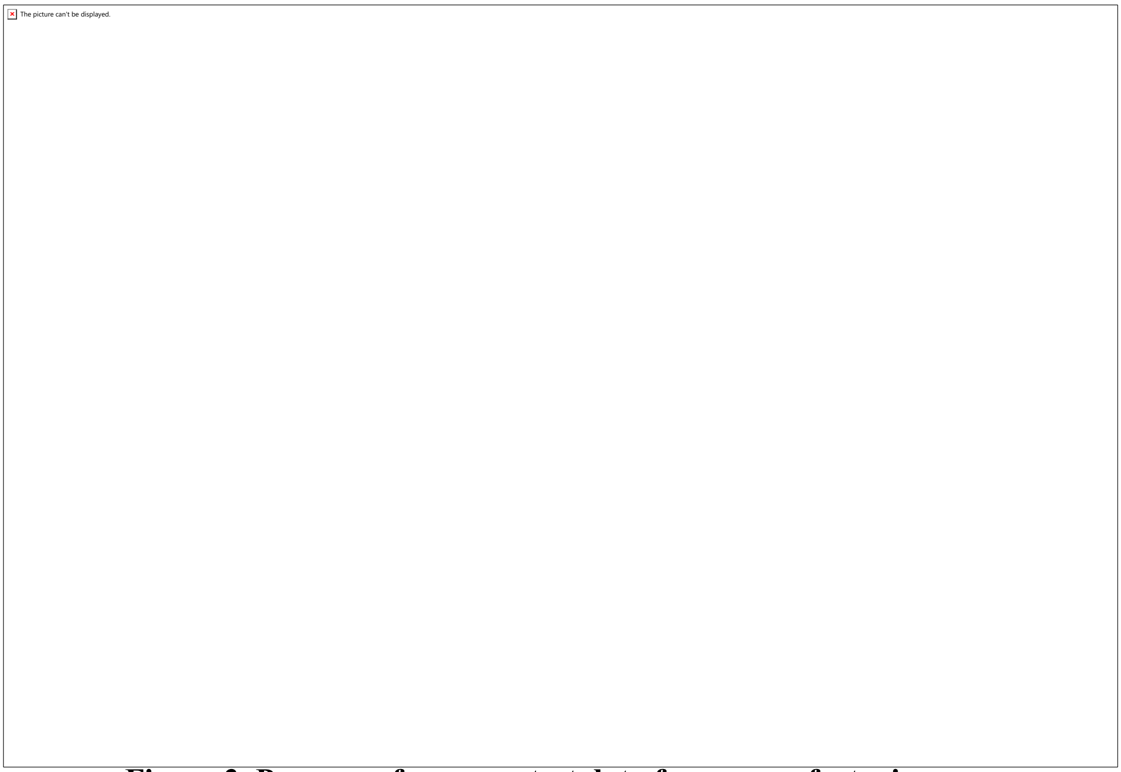


Figure 3. Pump performance test data from manufacturing

Initial data collection was carried out to determine the initial pump performance parameters, the first test was carried out on the CWP D pump. It can be seen in the figure below, the flow rate readings fluctuate greatly due to inaccurate measuring instruments.

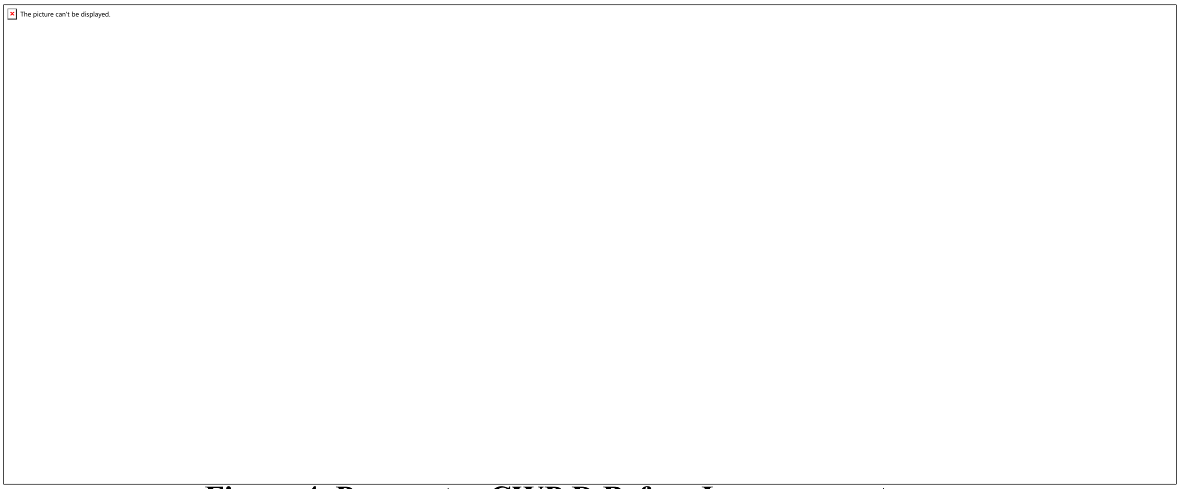


Figure 4. Parameter CWP D Before Improvement

First Test

The first test was carried out on the CWP D pump. The test was carried out by cutting the impeller to a depth of 25mm (around 6.6%) for each blade with a rectangular model.

Approach using affinity laws:
D1 (Average Diameter) : 759,5 mm

$$Q2/Q1 = D2/D1$$
$$Q2/9225 = 709{,}5/759{,}5$$
$$Q2 = 8617\ m^3/h$$

Impeller trimming was conducted using CNC machine.

The picture can't be displayed.

Figure 5. Impeller Trimming First Test on CWP D

The results of the tests carried out can be seen in the figure below.

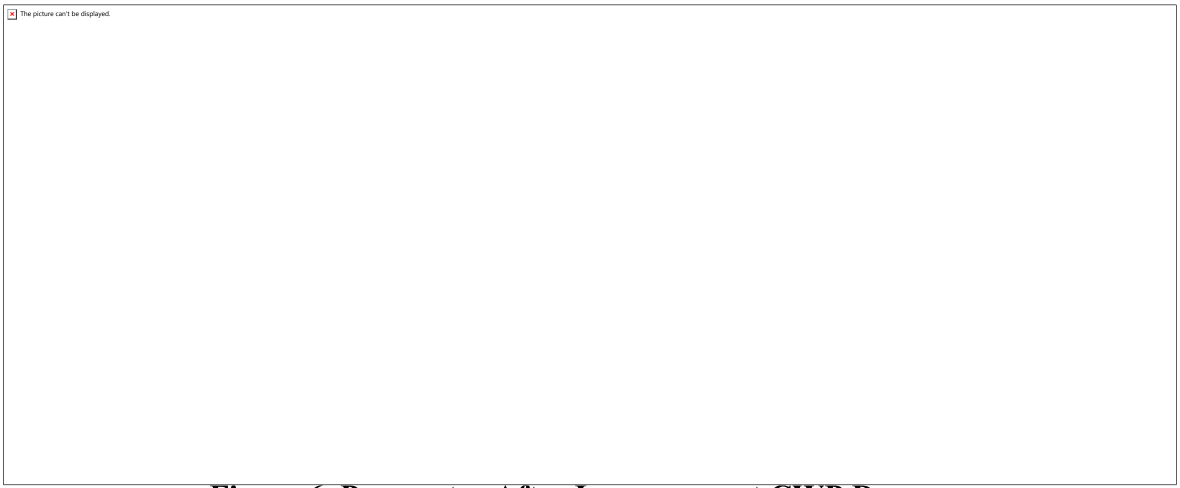


Figure 6. Parameter After Improvement CWP D

It can be seen from the test results after cutting the impeller

1. Effect of impeller trimming is a reduction in the flow rate. There is reduction of flow 571 m^3/h in fully opening of outlet valve.
2. The outlet pressure of pump in fully opening of outlet valve is still same 0,19 MPa for both before and after improvement.
3. Motor current is decrease from 134,1A to 125,4 A in fully opening of outlet valve. After several months running, motor current is decrease to Around 121-122 A
4. The occurrence of noise on the impeller side is due to cavitation, this is related to the square-shaped impeller cutting model. After several months of operations, the noise disappeared.
5. During the test, single pump was tested for supply cooling water to condensor. The vacuum condenser were still good in the range of - 92,5 kPa and steam exhaust temperature of turbine was 41-42°C.

Conclusion of improvement CWP D successful, in fully open position of valve the motor current is below the rating current at the name plate 128,4 A. The cooling effect on the condenser is good even with a single pump. Increase the unit efficiency with reduce auxiliary consumption.

Second Test

The second test was carried out on CWP B, the cutting model was changed to a circular arc to avoid cavitation problems, The total area of the impeller cut is also slightly increased with the aim of reducing motor current, related to motor reliability. Impeller cutting depth is 30 mm with circular arc model (around 7,1 %).

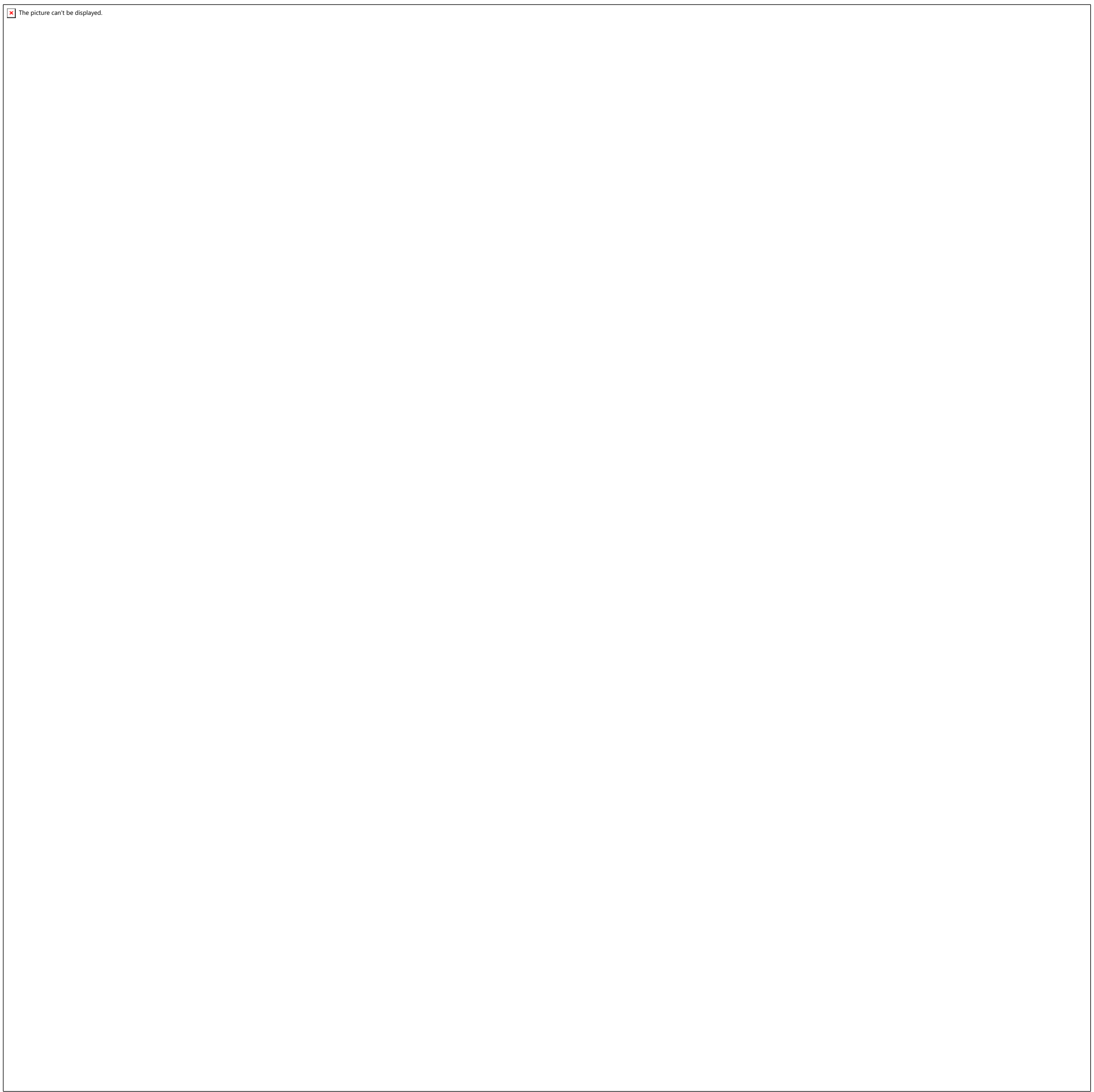


Figure 7. Impeller Trimming Second Test on CWP B

Test result were obtained in fully opening of outlet valve

Outlet pump pressure : 0,16 MPa

Motor current : 120 A

Vacuum Condensor : -91,6 kPa

Exhaust Temperature : 42°C

Condensor circulating water inlet pressure : 0,06-0,07 MPa.

The flow rate parameter is not a reference because it is very fluctuating.

Noise due to cavitation no longer occurs.

The conclusion at improvement at CWP B, all parameters are good. Single pump mode can create a good cooling effect on the condenser system. The model of trimming impeller at picture 2 is successfull and has been applied to CWP C and CWP A

Conclusion

It was analyzed that the cause of overcurrent in the circulating water pump motor was design reasons. The designed circulating pump head was 37 meters, and the actual required head was 20 meters, which exceeded the actual head by 17 meters. The operation of the outlet door was restricted to prevent the motor from overloading. Aiming at the cause of overcurrent in circulating water pump, a transformation plan of turning impeller was proposed. After turning the outer diameter of circulating water pump impeller by 25mm, the current of circulating water pump was within the design range and the outlet valve of circulating water pump could be fully opened for operation. After the impeller turning transformation of the circulating water pump, the operation mode of single machine two pumps and double machines three pumps was changed to single machine single pump operation mode, which saved one circulating water pump operation throughout the year. Calculated based on 365 days of operation per year, the factory electricity consumption can be saved by 8.76 million kW·h and the cost can be saved by 6.75 million yuan, which has considerable economic benefits.

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