



Analysis of The Transformation and Replacement of Centrifugal Pump of The Main Transformer Technology Water Supply System of a Giant Hydropower Station

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Abstract: Since the giant power station was put into operation, the centrifugal pump of the main transformer technology water supply system often has defects such as bearing oil tank oil leakage, large packing leakage, abnormal bearing noise, large vibration, motor bearing temperature rise, motor winding lead wire burning, etc., which affect the safe and stable operation of the equipment. In order to effectively solve the problems that often occur during the operation of the centrifugal pump, it was decided to carry out experimental modification of the centrifugal pump. In this paper, the centrifugal pumps before and after the transformation are compared, and the operating effect of the centrifugal pump after the transformation is analyzed. Through tests and long-term operation observations, it is shown that the experimental transformation of the main transformer centrifugal pump in the power station is scientific and reasonable, which provides a reference for the transformation and upgrading of centrifugal pumps in the industry.

Keywords: Giant Hydropower Station; Technical Water Supply Systems; Centrifugal Pump; Metal Laminated Flexible Coupling

1 INTRODUCTION

The development task of this mega hydropower station is mainly to generate electricity, taking into account flood control. In addition, there are comprehensive utilization benefits such as sand control, improvement of navigation conditions in the reservoir area and the river section under the dam. The main transformer cooling water source of all units comes from the technical water supply system, and the stability and reliability of the centrifugal pump provides a strong guarantee for the safe operation of the unit.

2 INTRODUCTION TO THE TECHNICAL WATER SUPPLY SYSTEM OF THIS GIANT HYDROPOWER STATION

The main transformer technology water supply system of this giant hydropower station adopts a single unit to supply water, and two single-stage single-suction centrifugal pumps are set up in parallel to supply pressurized water supply, and the two centrifugal pumps operate in rotation. The main transformer technology water supply pump room is located at the end of the busbar hole EL370m, and the installation height of the centrifugal pump is EL370m. The main transformer technology water supply system adopts tail pipe to take water, the water intake elevation is 337m, and the system drains to the tail adjustment chamber, the drainage outlet elevation is 394m. The specifications and models of the power cable for centrifugal pumps are ZB-YJV22-3×95+1×50. There are two operating conditions of centrifugal pumps, one is near the rated working condition point during the main transformer external power transmission, and the other is near the low-flow working point (away from the optimal working condition) during the main transformer inversion. The main transformer technology water supply system provides cooling water for the main transformer



cooler, and the fire water can be used as a backup water source for the main transformer technology water supply. Since the power station was put into operation, the centrifugal pump often has defects such as oil leakage from the bearing tank, large leakage of filler, abnormal noise of bearings, large vibration, rising temperature of motor bearings, and burning of motor windings.

3 COMPARISON OF NEW AND OLD CENTRIFUGAL PUMPS FOR MAIN-VARIABLE TECHNOLOGY WATER SUPPLY SYSTEMS

3.1 PARAMETER COMPARISON

TABLE 1 COMPARISON OF THE MAIN PARAMETERS OF NEW AND OLD CENTRIFUGAL PUMPS

serial number	Name	New pump	Old pumps
1	Rated flow	310m3/h	400m3/h
2	Rated head	36.5m	50m
3	Motor power	55kW	90kW
4	Insulation class	Grade F	Grade F
5	Degree of protection	IP55	IP54
6	Startup mode	Soft start	Soft start
7	Cooling method	Air cooled	Air cooled
8	Power supply	AC380V, 50Hz	AC380V, 50Hz
9	rotate speed	1450 ~ 1485rpm	1480rpm
10	Pump set rated point efficiency	≥80%	76%
11	version	Horizontal single suction pump	Horizontal single suction pump

The original design unit recalculated and checked the water supply of the main transformer technology according to the

actual working conditions after the power station was put into operation, adjusted the flow rate and head of the centrifugal pump, and calculated to meet the operating requirements of various working conditions such as the input of the main transformer cooler from 1 to 6 groups, and the lowest tail water level of the tail adjustment chamber of 376.412m. Because the main transformer has a considerable proportion of the time to run in the inverted state of the 1 group of coolers put into operation, there are certain requirements for the range of stable operation conditions of the centrifugal pump, and the adjusted parameters make the pump still in the optimal operating conditions when the 1 group of coolers is running, and the efficiency of the pump group is 72%. to between 78%.

3.2 CONFIGURATION AND STRUCTURE COMPARISON

TABLE 2 CONFIGURATION AND STRUCTURE COMPARISON OF OLD AND NEW CENTRIFUGAL PUMPS

serial number	Name	New pump	Old pumps
1	Centrifugal pump bearings	SKF	SKF
2	Centrifugal pump bearing lubrication	Thin oil lubrication, constant oil cup automatic oil replenishment	Thin oil lubrication
3	Supporting motor	Siemens	Siemens
4	Electric motor bearings	SKF	SKF
5	impeller	Duplex steel ASTM A890 Gr 3A	2Cr13
6	Impeller sealing ring	2Cr13	2Cr13
7	Pump shaft	2Cr13	45# steel (tempered).
8	Pump body	ZG230-450	QT250
9	Bearing housing	WCB	QT250
10	Coupling	Metal laminated flexible coupling	HT250, rubber

serial number	Name	New pump	Old pumps
11	Shaft seal	Mechanical seal (BURGMAN).	Packing
12	base	20mm thick steel plate is integrally formed	Channel steel tailor welding

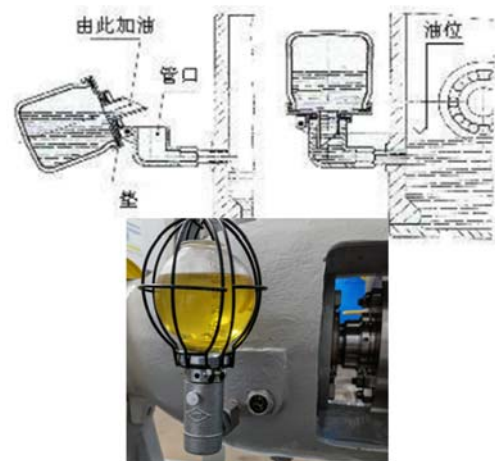


FIGURE 1: CONSTANT OIL CUP

The old centrifugal pump bearing oil tank has successively suffered from defects such as deformation of the tank cap and observation window, oil seepage of the observation window, and oil leakage of the end cover, which require frequent oil replenishment, and there has also been a phenomenon of bearing burn due to lack of oil. The new pump bearing oil tank is made of cast steel WCB, which has higher strength and is not easy to deform, and the oil tank cap is made of stainless steel and has the function of respirator; The bearing adopts thin oil lubrication, and the bearing oil tank is equipped with a constant oil cup, which has the function of automatic oil replenishment and automatic oil level control, eliminating the trouble of frequent oil replenishment of the old pump.

Compared with the old pump, the high-specification material has higher strength and more wear resistance, ensuring that the ability to withstand pipeline vibration is stronger, and the hydraulic performance of the pump itself is maintained at the design level for a longer time. Old centrifugal pumps used to crack the pump body due to vibration.

The new pump uses a metal laminated flexible coupling to connect the pump and drive, which absorbs small misalignment of axial, radial, and shaft centerline offsets. The old pump coupling is completely eliminated from frequent damage and must be replaced every year, and the new coupling has stronger alignment adjustment performance.

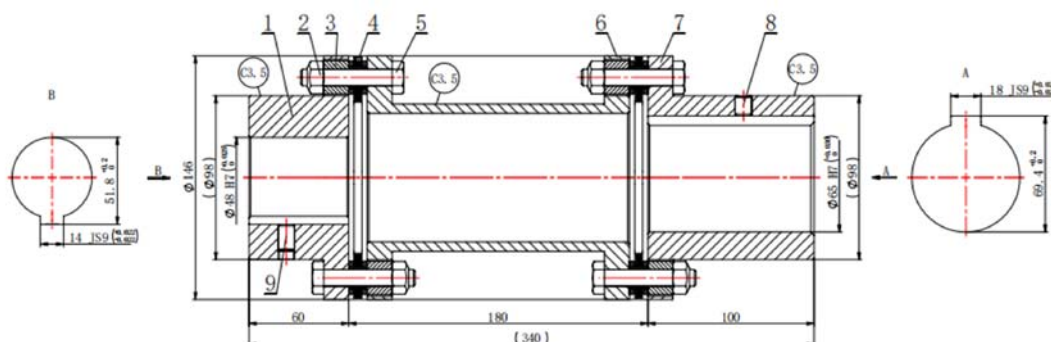


FIGURE 2: METAL LAMINATED FLEXIBLE COUPLING

The new pump base is made of 20mm thick steel plate integrally formed, the original channel steel strength is low, cannot effectively resist centrifugal pump and pipeline vibration, and most of the channel steel base rust and thinning is serious, the base is only connected to the foundation through expansion bolts, vibration resistance and stability are poor. The new pump base has high strength, is fixed with chemical anchors, and the anchor holes are drilled to the depth of the first stage concrete.

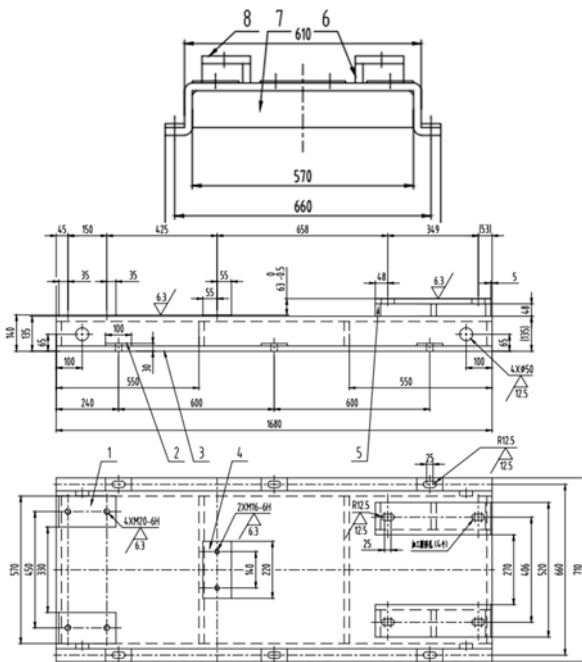


FIGURE 3: NEW PUMP BASE

The new centrifugal pump is CZ series standard chemical pump, its performance and size comply with DIN24256/ISO5199, bearing frame, shaft, packing box, and impeller form a mounting unit module, different specifications of pumps can be fully interchangeable, saving spare parts reserve costs. At the same time, after removing the separable coupling, the mounting unit module consisting of the bearing frame, shaft, packing box and impeller can be disassembled without disassembling the pipe and motor.

4 NEW PUMP INSTALLATION

In order to ensure safe operation, the installation process should be fast, simple and accurate. When preparing for assembly, the following 3 points need to be considered:

- (1) Prepare appropriate lifting equipment, good lighting equipment and movable power sockets in advance, so that the pump can be easily accessed from either side.
- (2) The pump flange and all open interfaces should be protected by plastic plugs or blind plates before the pipeline is installed.
- (3) The installation foundation is woolen and cleaned up to make it firm and dry.

4.1 INSTALLATION OF PUMPS AND MOTORS

For the base separated by the pump and the motor, it is necessary to install the pump first, and then adjust the motor.

4.2 NEW PUMP FOUNDATION TRANSFORMATION

The width of the original concrete pier is not enough to support the new pump base, it needs to be widened on the edge of the original base, the newly widened base is welded with the steel structure of the original concrete base, the bottom of the angle steel is filled with concrete, and the lower end of the angle steel is welded with channel steel sheet, and the other end is fixed with expansion bolts with concrete to ensure the support strength of the new base. The horizontality and height of the newly made concrete piers are roughly the same as the original concrete steel structure.



FIG. 4 SCHEMATIC DIAGRAM OF CONCRETE FOUNDATION POURING AND ANGLE STEEL FIXATION

Installation considerations:

- (1) The concrete around the pier should be knocked off to a suitable range for angle steel installation and concrete filling.
- (2) Check whether the horizontality of the angle steel is significantly bent before construction, and replace it if it is unqualified.
- (3) Check the horizontality of the angle steel with a horizontal ruler during the welding process to prevent structural deformation during the welding process, resulting in unqualified levelness.

4.3 NEW PUMP PRE-INSTALLATION

To pre-install the pump, the position of the 6 bolt holes of the pump foundation should be determined first, and the center line of the inlet flange of the pump and the center line of the water inlet should basically coincide. Then the concrete foundation is drilled, the chemical reagent is filled to close the anchor, and the pump inlet and outlet pipelines are configured.

Due to the presence of a steel mesh under the concrete foundation, ordinary drill bits cannot drill through the rebar, so the drill bit uses a spliced drill bit welded by a steel plate alloy drill bit and a rhinestone drill bit for drilling. Before the bolt hole is injected with chemical agents, the hole wall must have a rough surface and no contamination, remove loose particles, dust or oiled concrete, and all surfaces where the base will come into contact with the grout must be clean, remove rust, paint or other attached materials. The chemical anchor can only be used under force after 24 hours of closure.

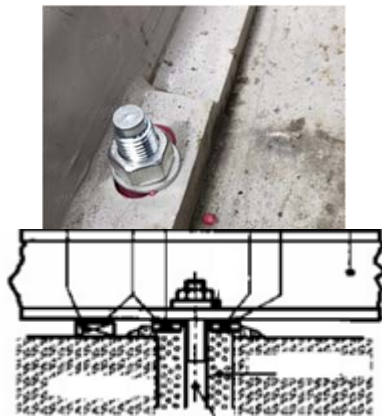


FIGURE 5 SCHEMATIC DIAGRAM OF INSTALLATION PROCESS

4.4 NEW PUMP INSTALLATION

After the chemical anchor is stabilized, the pump is formally installed, the pump base and the pier foundation should be gapless, if there is a gap, add a metal gasket at the gap, and the lower edge of the angle steel is welded and fixed with anchor bolts to enhance the structural strength of the concrete pier; Finally, tighten the bolt at the pump base, check the levelness of the pump base within 0.05mm/m, and tighten the pump inlet and outlet flange bolts.

After the overall installation of the pump is completed, the metal laminated flexible coupling is installed. Flexible couplings require careful correction of the shaft line, and carelessness in correction will lead to damage to the coupling and damage to pump and motor bearings. Finally, Mobil DTE 746 Superturbine oil was added to the pump bearing to two-thirds of the oil window, the pump bearing oil cup was filled with oil, the motor was measured to ground, and the phase-to-phase insulation was greater than 500MΩ.

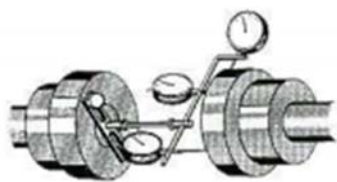


FIGURE 6 IS MORE COAXIALITY



FIGURE 7: INSTALLATION EFFECT OF NEW AND OLD CENTRIFUGAL PUMPS

5 NEW PUMP TEST

After the installation of the new pump, the following tests should be carried out:

- (1) Steering test, the motor steering is consistent with the direction of the pump casing marking arrow.
- (2) Operation test, the pump runs smoothly, no abnormal sound, the mechanical seal and its lubricating water system work normally, and there is no leakage at each connection.
- (3) Flow, pressure and current check, pump stable operation flow, outlet pressure, motor current within the normal value range.
- (4) Vibration intensity test, vibration intensity does not exceed the design value.
- (5) Noise test, the noise value does not exceed the design value.
- (6) Stop the pump, the process of stopping the pump is gentle and there is no abnormality.

5.1 FLOW TEST

TABLE 3 CENTRIFUGAL PUMP FLOW TEST DATA

Constituenc s	XX unit different groups of coolers turn on the main pipe flow record					
Open a single cooler	1#	2#	3#	4#	5#	6#



Constituencie s	XX unit different groups of coolers turn on the main pipe flow record					
Flow rate (m ³ /h).	239	238	239	240	241	242
Pipe pressure (unit: MPA).	0.38					
Turn on the three coolers	1# 、 2# 、 3#	2# 、 3# 、 4#	3# 、 4# 、 5#	4# 、 5# 、 6#	5# 、 6# 、 1#	6# 、 1# 、 2#
Flow rate (m ³ /h).	328	328	329	330	332	331
Pipe pressure (unit: MPA).	0.29					
Turn on the four coolers	1# 、 2# 、 3# 、 4#	2# 、 3# 、 4# 、 5#	3# 、 4# 、 5# 、 6#	4# 、 5# 、 6# 、 1#	5# 、 6# 、 1# 、 2#	6# 、 1# 、 2# 、 3#
Flow rate (m ³ /s).	340	342	341	344	343	344
Pipe pressure (unit: MPA).	0.28					
Turn on the five coolers	1# 、	2# 、	3# 、	4# 、	5# 、	6# 、

Constituencie s	XX unit different groups of coolers turn on the main pipe flow record					
	2# 、 3# 、 4# 、 5#	3# 、 4# 、 5# 、 6#	4# 、 5# 、 6# 、 1#	5# 、 6# 、 1# 、 2#	6# 、 1# 、 2# 、 3#	1# 、 2# 、 3# 、 4#
Flow rate (m ³ /s).	345	346	345	348	345	347
Pipe pressure (unit: MPA).	0.27					
Turn on the six coolers	1#、2#、3#、4#、5#、6#					
Flow rate (m ³ /s).	346					
Pipe pressure (unit: MPA).	0.27					

Since there are not enough straight pipe sections before and after the installation of the technical water supply flow meter, the flow measurement deviates from the real value. Electromagnetic flowmeter generally requires 5 times the pipe diameter and above straight pipe section before and after, the current flowmeter inlet has no straight pipe section, the length of the outlet straight pipe section is about 140mm, and the pipe diameter is DN200mm. According to the factory test data of the centrifugal pump, the measured flow rate is lower than the real value.

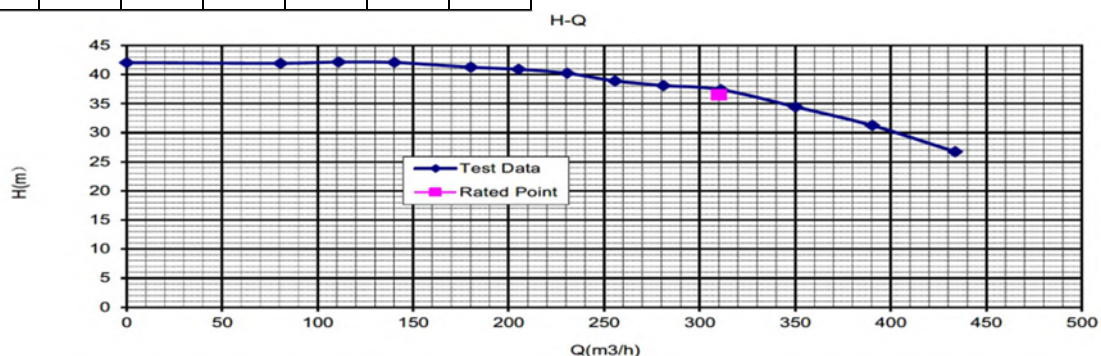


FIGURE 8 H-Q DIAGRAM OF FACTORY TEST OF NEW PUMP

According to the pump factory flow head curve, when the head is 27m, the flow rate should be about 430m³/h. The cooling effect of the main variable cooler mainly depends on the cooling

water flow, according to the actual operating effect, the new pump operating flow rate meets the cooling requirements.

5. 2 VIBRATION TEST



According to the actual measurement on site, the vibration value of the old and new pumps is compared as follows:

TABLE 4 VIBRATION TEST DATA OF CENTRIFUGAL PUMPS

Pump type	Main transformer pump vibration value (unit: mm/s).		
	level	Axial	radial
XX unit 1# pump	0.3	0.3	0.1
XX unit 2# pump	0.3	0.6	0.4
Old pump mean	2.19	2.42	1.52

The above data are recent measurements, all taken from the normal power generation operation of the unit, the centrifugal pump is in a good operating condition, it can be seen that the vibration value of the old pump is 7~15 times that of the new pump. In addition, from the perspective of external operation, the vibration of the centrifugal pump is closely related to the water level of the tail adjustment chamber, and further observation remains to be seen.

5.3 TEMPERATURE TEST

After the installation of the new pump, it has not experienced the test of high temperature in summer, and from the recent inspection data, the temperature of the new pump motor and bearing is 10~30 °C lower than that of the old pump.

6 MAINTENANCE AND UPKEEP

During the use of the pump, the smoothness and vibration of the pump operation should be checked. The vibration can be evaluated using the JB/T8097-95 standard.

Rolling bearings can be monitored with a monitor that measures impact pulsation. Pay attention to the noise during normal operation, if there is vibration, abnormal noise or observe some other fault phenomena, you should stop immediately to find out and eliminate the cause of the fault. Check the alignment of the coupling during shutdown (according to operational needs) (at least once a year) and re-align if necessary. If it is not due to changes in the piping system or the degradation of pump performance caused by scale in the pipe, it may be caused by wear of the internal parts of the pump, and it must be stopped and serviced.

Mechanical seals usually have a small amount of leakage. Special instructions on seal leakage are still necessary, and the amount of seal leakage depends on many different factors (e.g. size, material, pumping medium, temperature, etc.). When the

sealing fluid has a large leakage, it can be concluded that the seal is damaged, and it should be stopped for maintenance immediately, and the damaged parts must be replaced. Each time the seal is removed and removed, the auxiliary seal (e.g. O-ring) must be replaced, and the dynamic and static rings must be replaced together.

Centrifugal pumps are often subjected to high pressures due to continuous operation and large axial or radial forces, so the appropriate amount of lubricating oil is a prerequisite for long bearing life and trouble-free operation. Lubricating oil must not contain other impurities, acids or resins.

7 CONCLUSION

At present, the new centrifugal pump has a relatively short operating time, lacks the test of long-term operation, and lacks sufficient operating data to compare with the old centrifugal pump. From the current operating situation, the flow rate and head meet the main variable operation requirements, and the vibration value is significantly reduced. Due to the improvement of the shaft seal type and the bearing oil tank refueling and replenishment method, the daily maintenance workload has been significantly reduced, and maintenance-free has basically been achieved. The use of integral steel plate base and metal laminated flexible coupling makes the coaxiality of the pump group not easy to deviate, and the normal service life of the coupling is more than 5 years, so the annual maintenance workload is also greatly reduced. The new pump reduces the flow rate and head parameters, which will make the main transformer in better working conditions when it is inverted, whether it is vibration, noise, or the number of trouble-free working hours of the pump, it will be substantially improved.

The new centrifugal pump is running well overall, with zero defects and zero maintenance so far. Subsequently, with the accumulation of running time, further analysis, comparison and verification will be done.

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