New flowing system in cooling system axial-flow pump in a hard coal electric power plant

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Abstract. This article presents the new construction of a centrifugal impeller pump which supplies the cooling system in coal power plants. The article also shows the history of producing this kind if pumps for unified 125 MW and 200 MW power units which dominate in Poland. The process of numerical analysis and conventional calculations leading to the improvement of qualities of the flowing system exceeding literature indicators are presented. The article shows the problems which appeared during assembling the pump in its target workplace. The results of the measurements of the pump flowing system in its target workplace are presented.

1. Cooling system pumps in polish power engineering

The development of traditional engineering, especially of high powers after the World War II in the 1970s brought designs of axial-flow and mixed flow pumps used in cooling systems. The pumps in cooling systems produced in Poland did not have license but pumps supplying steam boilers were licensed. The system used in power plants burning coal had high capacity between 145 and 36000 m³/h for mixed flow pumps (type D) and between 420- and 32000 m³/h for axial-flow pumps (type P) and work at individually selected head of the pump between 7,5 and 90 m for mixed flow pumps and between 4 and 13 m for axial-flow pumps [4, 7, 8, 17, 18]. Duty point for a pump was set depending on accepted cooling system from a river, a lake or an artificial water basin. Accepting the standards of 125 MW and 200 MW power units allowed unification of pumps which were constantly modernized after operation observation. Because of the political situation in our country the cooling pumps from the USA and Western Europe were not used. We used only Polish products and sometimes products from the Eastern Europe. Smaller power plants and thermal-electric power stations on the area regained after the war, prewar constructions were used postgerman, permanently installed in the foundation (for example Marcel thermal-electric power station in Radlin).

After 1989 during political and economic changes new power units of earlier standards were not built for almost 20 years. Verified types of pumps were not used. It was explained by the necessity of increasing the efficiency of energy systems and the requirements of consortiums that were building the power plants. The result is that changed and modernized cooling systems had different producers and different designs. Different conditions of mounting pumps are connected with adjusting buildings to pumps and correction of pumping systems. It means higher full LCC (life cycle costing) in spite of attractive price of the first
purchase. The pumps delivered to users must be regularly checked and used parts must be changed. Our local pump producers that had to face the difficulties of economic transformation limited their production or disappeared from the market. It was wrongly believed that efficient constructions can be designed only outside Poland, for example in Germany, England or the USA.

**GRUPA POWEN WAFA-POMP** SA is the exception that exists on our difficult local market. After hard times it develops its original activity connected with designing pumps. The company was created from joined liquidated factories (Pump factories in Warszawa- WAFAPOMP S.A., Świdnica-ŚFPomp Sp. z o .o. and Zabrze- Fabryka Pomp POWEN Sp. z o. o.) which during the communist times were monopolists in production of individual types of pumps and service of different types of industry.

Polish power engineering between 2015 and 2019 was based on 200 MW power units. Those times there were 50 units of that type. The amount of hours when the unit was used required modernization or change for the new technology. The real alternative was to build new power units. New high power coal power units in Opole and Koziencie were built with delay. The idea of building new coal power unit in Ostrołęka was rejected. It was planned to build a gas power plant. The biggest unit in Jaworzno was not completed because of technical reasons. The authorities that had different political approach planned changes in energy producing technology. Unfortunately the ideas were not realized. Nuclear power plant was not built because there were not any ideas for localization, technology and financing. It is a general problem in Europe. In EU countries the requirements for safe working conditions during making the reactors are increased and parts of the constructions which are already made are removed (Flamanville, France, and Olkiluoto, Finland). Properly working power units are closed because of non-technological apprehension (Phillipsburg, Germany). There are situations where nuclear power units are not used (Zwentendorf, Austria). The RES technology which is strongly promoted in Western Europe does not fulfil the requirements of delivering high power on time because of chimeric character of the sources of energy (sun, wind) and the lack of profitable high power accumulators [19].

The answer to the needs of the market and the fact that pumps in coal power plants were worn out, between 2015 and 2019 a new project appeared. Its result was the new construction of cooling system pump. This pump fulfilled client’s high requirements and it was not necessary to change the workplace in the power plant. The basic requirement was the pump work with high capacity at low suction head and increased efficiency. This task was difficult and demanding.

**2. Modernization of axial-flow pumps (type P)**

Axial-flow pumps (type P) were produced in alternative designs adjusted to the design of pumping station. Figures 1 and 2 show examples of pumps. Figure 1 shows low mounting of pump 180P19 and figure 2 shows high mounting of the same pump.

Axial-flow pumps used as cooling water pumps in traditional power units have controlled angles of setting the impeller blades. Thanks to that fact it is possible to adjust the parameters of work to the present needs of the unit. First controlling systems required stoppage of the pump to set the blades angle. It was caused by the fact that there were not any possibilities to overcome much higher forces in blades during motion. This kind of solution was problematic [1, 2, 9, 10]. Nowadays the system with worn gear and hydraulic system are used. In the systems with worn gear the precision of regulation depends on drive parameters. In hydraulic systems the change in engine design is required. It is necessary to hollow the shaft to put high pressure hydraulic hoses there. The changes also include mounting of the rotating joint and sealing elements of the system what can be problematic [3, 6, 11]. The promising technologies for improving the quality of the surface layer of pump elements are the methods of alloying [20–22]. The alternative to those systems is the system shown in Figure 3. This system, just like the hydraulic one, has appreciated by users fluidity and facility of control and it is not difficult to assemble in contrast to the system used now.
Figure 1. Pump 180P19 with low mounting.

Figure 2. Pump 180P19 with high mounting.

Figure 3. New control system of blade-setting angle in the impeller.
The control can take place during standstill or when the pump works. The blades angle is remotely-controlled by external control system (for example DCS) which is connected with the laser sensor (4) and outer hydraulic oil feeder. The sensor (4) has to show the plane motion of the piston (14) in the cylinder (2) as the blade-setting angle.

The basic parts of the control mechanism are the piston (14) and the cylinder (2). With the help of external oil system the oil under pressure is delivered to the upper or lower chamber in the cylinder (2). The motion of the piston (up or down) depends on which chamber (lower or upper) the oil is delivered to. The value of piston movement can be measured with the mechanical indicator (29) with the value shown as the blade-setting angle on the pitch (33) or by the laser sensor (4).

The operating principle of the mechanism is that rotational speed of the engine is transferred by the clutch (6,7) on the shaft (16) to the hydraulic unit and the impeller. The impeller blades are regulated by the pole (17) which moves up or down with the piston (14). The piston moves only by reciprocating motion. The bearing system (42) and the pusher (27, 32) do not let the rotational movement of the shaft be transferred to the piston.

The bearing system is spray-lubricated or put in oil bath in bearing chamber (130). The oil is cooled by the cooling system (40). The indicator (45) shows the level of the oil in the chamber (130). The temperature is measured with a thermometer (53).

The bearing system lets the piston move in reciprocating motion and it transfers the motion on rotating pole (17) without changing the load of the axial bearing in the pump. The bearing system is set on the intermediate shaft (16) by a sleeve (9) which rotates with the shaft by using parallel key (43). The sleeve can move along the intermediate shaft (16) [12, 14, 16].

**Figure 4.** The scheme of demolishing foundation to mount new cooling water pump 180P19 for 200 MW unit.
Figure 5. The scheme of demolishing foundation to mount new cooling water pump 180P19 for 500 MW unit.

Changes in power requirements throughout a year and decrease of water level in rivers in summer when the demands for cooling are much higher than in winter connected with the necessity of increasing the efficiency of systems producing energy caused changes in work parameters required by power plants. For a couple of years, in biddings for modernization of cooling water pumps there have been requirements for higher capacity, higher head of the pump, operation without cavitation at lower suction head, higher efficiency. The increase of work parameters caused the increase of ceiling load because of higher hydraulic forces and bigger weight of used higher power engines. During each modernization the analysis of the ceiling load capacity was carried out to check if additional structural reinforcement of the pumping station is necessary [5, 11].

The starting point in modernizing the construction was the full changeability of the stand what decreased the interference in existing pumping station construction. It also made using the existing machines connected with the pumps possible. Figures 4 and 5 show the plan of demolition during the modernization of cooling water pumps for 200 MW and 500 MW units.

The increase of capacity and stand changeability which meant maintaining the outer diameter required increase of speed on particular intersections what made the suction properties worse. They had to be corrected because of lower water levels in rivers. The shape of supply chamber and the outer diameter of the flowing system mounting were supposed to be without any changes. On the inlet to the impeller only the shape of the hub was modernized. The changes in the hub are shown in Figure 6 [13, 15].
Figure 6. The impeller unit in pump 180P19 before and after modernization:
1 – impeller blade, 2 – impeller hub, 3 – slide, 4 – lever, 5 – fairwater, 6 – external impeller sleeve, 7 – internal impeller sleeve, 8 – pilot sleeve, 9 – pilot sleeve, 10 – disc, 11 – nut, 12 – impeller blade nut.
The significant increase of parameters was achieved by innovative design of impeller blades and diffuser and modernization of elbow insert what is shown in Figure 7.

**Figure 7.** The picture of elbow insert in pump 180P19 after modernization.

**Figure 8.** The flowing system in pump 180P19:
1 – layer- lower part; 2 – layer- upper part; 3 – bearing sleeve; 4 – diffuser; 5 – bushing; 6 – impeller unit; 7 – pole.
The starting point to design the flowing system was 2D analysis of innovative counting method results. Then 3D geometry and CFX analysis were prepared.

3. Problems with mounting pump in the workplace of the previous pump

Full changeability of the stand lets the pump parameters increase only by changing internal parts, but during the modernization, which theoretically should be carried out without any problems, there are difficulties caused by designing changes made by pump users during long using and adjusting the pump to requirements of internal repair services. The example of such changes can be access openings which some users introduced to pumps they used (Fig. 9).

![Figure 9. Access openings and sediment in the flowing system after proper using.](image1)

In places where the pumps were used local repair services made construction changes inconsistent with the producer’s recommendations. Figure 10 shows welded parts of the pump. Their permanent connection was rejected by the pump designers.

![Figure 10. Welded connection of pump elements during local repairing by unauthorised services.](image2)

Pumps which were first designed according to the same documentation after years of using in different places turn to be new modified constructions. These pumps are a big challenge for the designers and services when they have to exchange elements in the pump. Some of changes made by users had unfavorable influence on the pump efficiency.

The real problem is maintaining the requirements of EN ISO 9906 for demanded measurements grades during both capacity and pressure measurements. During pressure measurements it is difficult
to find required distance between the pump branch and the place of measurement. Also the pipes leading to the collector are often choked. During efficiency measurements the requirements connected with keeping specific length of line segments in front of and behind flowmeter are not kept and it is not certain that there are not any leaks between the pump and the flowmeter. The example of a leak is shown in Figure 11.

![Figure 11. Leak of water on new throttle of pumping system.](image)

It was a leak in new throttle which separated modernized pump from the collector. It was not certain that the throttles of the other pumps working on the same collector as the modernized one are leak proof and the indications on the flowmeter during testing show real capacity of the pump. The answer to this problem is testing the pump at the producer’s test stand. The requirements for higher efficiency with higher measurements grades appearing in biddings without certainty that the measurements at the power plant show real parameters were one of the reasons to create Research and Development Centre in 2014. This makes testing pumps that have power between 0.2 kW to 5 MW possible. The biggest diameter of the outlet branch can be 2000 mm. Figure 12 shows the stand which was built to test series of pumps P and D.

![Figure 12. The stand to test pumps P and D on new testing station in GRUPA POWEN-WAFAPOMP S.A.](image)
Table 1 shows the table with measurements of cooling system pumps before and after modernization and changes. In the power plant in Kozienice 4 pumps in units 9 and 10 were changed. The measurements made by independent research centre confirmed obtaining expected effect. In the power plant in Polaniec 1 pump was changed obtaining effective desired change of parameters.

Table 1. The comparison of pump parameters before and after modernization.

| Location of the power plant | Block power | Modernization | Volume flow (m³/h) | Head (m) | Rotation speed (rev/min) |
|-----------------------------|-------------|---------------|--------------------|----------|--------------------------|
| Kozienice                   | 500MW       | Before        | 30 000             | 10.6     | 370                      |
| Kozienice                   | 500MW       | After         | 29 000             | 14       | 370                      |
| Polaniec                    | 225MW       | Before        | 30 000             | 9.6      | 370                      |
| Polaniec                    | 225MW       | After         | 30 000             | 15       | 370                      |

4. Conclusion
The process of calculating and designing new flowing system in the cooling system pumps described in this article was planned to take 1 year. Practically the complexity of designing process and long process of numerical calculations on models, which results were reliable, took 2 years. Designers appreciate the meaning of numerical programs to make machines efficiency higher. They also emphasize that it takes a lot of time to achieve desired results mainly because of constraints of numerical machines. Realization of purchase order for pumps which because of their size are not available immediately required cooperation between scientists and designers.

GRUPA POWEN-WAFAPOMP S.A. with its long experience and modern technological facilities made the designing and making of new flowing system efficient.

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