The Reconstruction Experience of the 60-KCS Condenser for Deaeration Intensification

Artem Vodeniktov and Nataliya Chichirova

1 Introduction

The modern regenerative surface condensers usually guarantee a low concentration of dissolved oxygen in the steam turbine feed water. However, the old steam turbines with the unsatisfactory conditions of the vacuum system and the high level of the air leakages cannot provide the required quality of the condensate. This problem is typical for the cogeneration turbines that usually work with a low steam flow rate into the condenser during the heating period. Reducing the steam flow rate into the condenser leads to the deterioration of the condensate deaeration conditions and increasing the dissolved oxygen concentration [1].

The efficiency of the steam turbine and the fuel consumption do not depend on the value of the dissolved oxygen concentration, but the long-time work of the steam turbine feedwater system with high dissolved oxygen concentration increases the risk of the failures of the main and auxiliary equipment of the power plant unit. The condenser efficiency is considered in [2–6] via formulas and equations. In [7–10], the results of the experimental studies are presented. The threat of financial losses from unscheduled downtime leads the power plant personnel to look for ways to ensure the proper deaeration of the condensate inside the steam turbine condenser over the entire load range.

Nowadays, there are no innovative deaerating devices for steam surface condensers. Modern deaerating hot well constructions are based on the concepts proposed in the 60s of the last century. The ability of the condenser to remove the dissolved oxygen is determined at the design stage. In the first half of the twentieth century, non-regenerative condensers were used. They usually had the tube bundles with high hydraulic resistance on the steam side without regenerative

A. Vodeniktov (✉) · N. Chichirova
Department of Thermoelectric Plants, Kazan State Power Engineering University, Kazan, Russia

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passages for good contact between the steam and the condensate. Using the regenerative condensers allowed to increase the contact area and time between the condensate draining from the pipes and the steam. This led to a decrease in the supercoiling of the condensate and, as a result, to a decrease in the dissolved oxygen concentration. Also, the rational tube pattern allows for increasing the efficiency of the steam turbine condenser [11, 12]. Thus, according to [12], the replacement of the base tube pattern with the optimized tube pattern allowed to reduce the shell-side pressure drop.

Other studies are dedicated to the investigation of the operational condition of the steam surface condensers [13–15]. In the work [16], a CFD-based estimation method was employed to study the effect of the thermal resistance of fouling on the power output of a condensing turbine unit. This work contains the dynamics of pipe fouling and a recommendation for the tube-cleaning period.

The next step in improving the deaeration capacity was the use of the deaerating hot wells. In the designs of the condensers for the Soviet and foreign turbines, this solution has been used for more than 60 years. Depending on the flow path of the condensate and the heating fluid, deaeration devices of the condensers are classified by film type, nozzle type, jet type (when water moves in steam), and bubbling type (when steam moves in the water). Similar devices are used on K-500-60/1500 HTGZ (Fig. 1), K-300-240 LMZ, and T-175/210-130 UTZ, and many other turbines [1]. As the experience of operation has shown, these devices allow maintaining the required concentration of the dissolved oxygen in the main condensate at the most operating regimes of the steam turbine.

The regime analysis of the surface condenser was considered in the work [17]. The results show a negative correlation between dissolved oxygen concentration in the

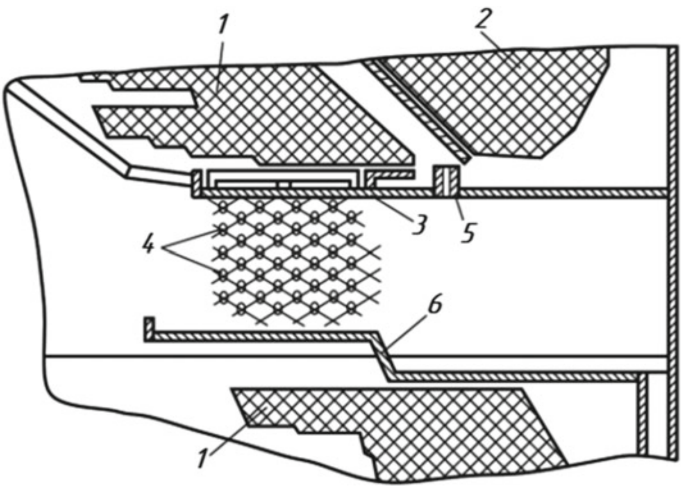

Fig. 1 Deaerating device of the K-22550 HTGZ surface condenser. 1—tube bundle, 2—air cooler, 3—water distributing sheet, 4—uncooled tubes, 5—non-condensable vent, 6—water collecting sheet

feedwater and the cooling water temperature. The surge of the concentration of the dissolved oxygen was found in the water temperature of about 11 °C. However, for the most numerous cogeneration turbines, PT-60-130/13 LMZ and T-100/110-130 UTZ, deaeration devices of condensers are not widely used. This fact encourages the power station personnel to develop unique deaerating devices and use such solutions as the external deaerating hot well.

2 Description of the Steam Turbine PT-60-130/13 LMZ

The modernization of the steam turbine with the deaerating hot well was carried out on the PT-60-130/13 turbine of the Naberezhnye Chelninskaya TPP equipped with a 60-KCS condenser. The layout of the low-pressure feedwater system of the turbine unit is typical—it includes six low-pressure surface-type heaters and the heat exchangers of the main ejectors (A and B) (Fig. 2).

The considered low-pressure feedwater system has the cascade drain of the steam condensate from heaters. Depending on the working regimes, it can be directed into the condenser or, via the pumps, can be returned into the feedwater system after the second surface heater.

The 60-KCS condenser has a transverse arrangement. It is made of a two-way, single block; the cooling surface area is 3000 m^2. The nominal steam flow rate into the condenser is 160 t/h [18]. As the exploitation of similar turbines shows, with an increase of the steam flow into the condenser, an improvement in the deaeration process is observed. However, the results of the deaerating tests for these turbines model are still not presented.

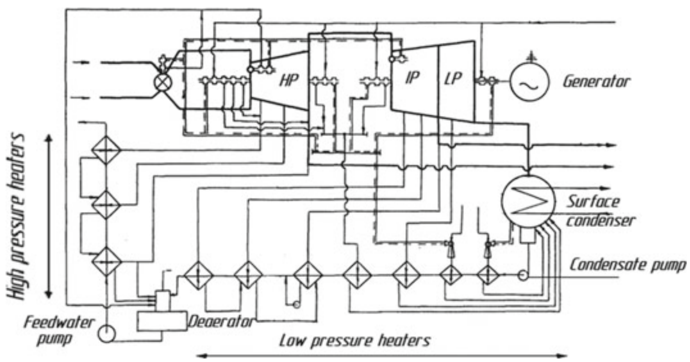

Fig. 2 Layout of steam turbine PT-60-130/13

2.1 Description of the Deaerating Hot Well

The described turbine is equipped with a deaerating hot well. This work was a part of the investment program in 2009. The external deaerating hot well was developed and installed by the Ecotech company. This hot well is designed to remove the dissolved oxygen from the steam turbine feedwater to protect the feedwater system from corrosion. The typical regime, when the high concentration of dissolved oxygen can be found, corresponds to the heating regime with a high steam flow rate to the district water heaters and the low steam flow rate into the condenser.

The design of the considered deaerating hot well is based on the two-stage condensate deaeration scheme, which includes first processing on a buried bubbling device, and then processing on a bubbling sheet in a thin layer. The long period of operation of the deaerating hot well has confirmed the high reliability of the two-stage deaeration scheme, which provides a low dissolved oxygen concentration in the condensate with its overcooling and variable turbine operating modes. The scheme of the hot well is shown in Fig. 3.

The specific steam flow rate for the deaeration in the external deaerating hot well is about 0.1 t/h. The vapor flow rate does not exceed 1 t/h, which does not impose significant restrictions on the power generation of the turbine unit.

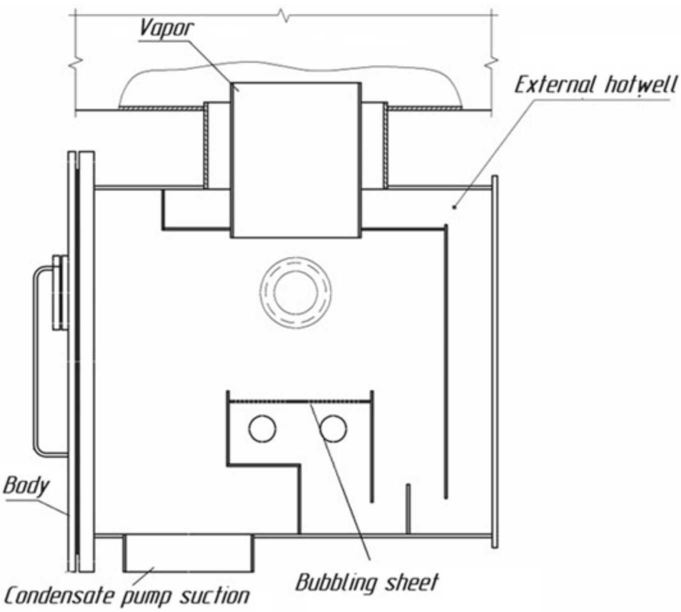

Fig. 3 Drawing of the external deaerating hot well

3 Thermal Test Description and Results

There is no special thermal test code for the external deaerating device. The usual working regime of the steam turbine was used for the estimation of the external deaerating hot well efficiency. Turbine electric load was 56 MWt, and the initial dissolved oxygen concentration was 27 mcg/l. The next steps were included:

11:00. The oxygen concentration was measured with the heating fluid valve fully closed;
11:30. The heating fluid flow rate was 5 t/h. Slow decreasing of the oxygen concentration has begun;
12:05. The heating fluid flow rate was 5.5 t/h. The dissolved oxygen concentration value of 15 mcg/l was reached;
12:30. At the end of the thermal test, the dissolved oxygen concentration value of 8 mcg/l was reached.

The graph of changes in the oxygen concentration and condensate temperature during the test period is shown in Fig. 4.

The above results indicate the device's operability and its effectiveness as a vacuum deaerator. An increase in the condensate temperature was followed by a decrease in the concentration of the dissolved oxygen. The necessary dissolved oxygen concentration (20 mcg/l) was reached after about 50 min from the experiment started. The results of thermal tests of the external deaerating hot well show that its operation is most effective at low steam flow into the condenser. This recommendation is confirmed by the experience of the operation and deaeration tests of the

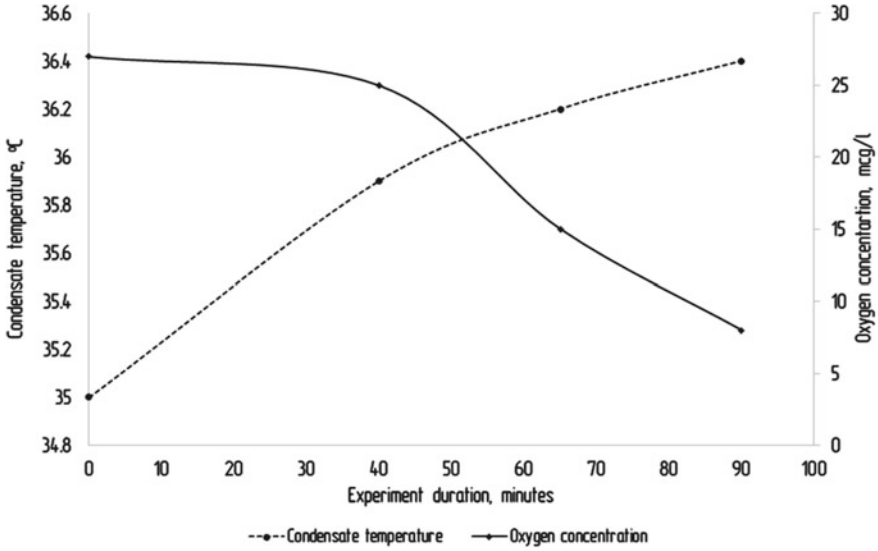

Fig. 4 The dynamics of oxygen concentration and condensate temperature changes

condensing turbines. Thus, according to [19], with an increase in the steam flow to the condenser, the amount of dissolved oxygen in the main condensate will decrease. For most condensers, the quality of the main condensate deteriorates with a steam load of 50% or less of the nominal value.

4 Conclusions

1. The design of the external deaerating hot well made by the "Ecotech" company allows achieving the concentration of the dissolved oxygen below the values established by the rules of technical operation.
2. This design, despite its simplicity and efficiency, has some disadvantages. The bulkiness of the device, which leads to an increase in the volume of the vacuum system, creates a potential danger of increasing the amount of air suction into the vacuum system.
3. It is recommended to turn on the hot well in the modes with a small flow rate of the steam into the condenser. This mode is typical for the operation of a heat-generating turbine according to a heat load schedule with a closed diaphragm, which, together with the high flow rate of the makeup water into the condenser, makes it difficult to obtain high-quality condensate in the steam turbine condenser.

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