Mathematical calculation of the optimal time to achieve operating parameters according to WCR when dosing corrective reagents into a double-circuit waste heat boiler with a parallel feedwater supply scheme

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Abstract. This article discusses the issues of estimating the time to achieve the normalized WCR indicators when dosing corrective reagents into a two-loop waste heat boiler, with a parallel scheme for supplying feed water to the circulation circuits. Calculations of the optimal time required to reach the regime parameters of the WCR when dosing amine-containing reagents are given. The article also provides calculations of the optimal time to reach the WCR regime parameters, depending on the feed water flow rate in each of the waste heat boiler circulation circuits.

1 Introduction

The development of modern domestic energy is inherently associated with the use of combined cycle plants for generating electricity. In CCGT schemes, waste heat boilers of various layouts (one, two and three-circuit) are used to produce steam, and waste heat boilers also differ in the scheme for supplying feed water to the circulation circuits (series and parallel schemes). This variety of waste heat boiler layouts leads to the fact that it is necessary to develop for each type of waste heat boiler its own scheme for dosing corrective reagents introduced into the circulation circuits to maintain the water-chemical regime and evaluate the optimal time to reach the operating parameters according to WCR.

2 Materials and methods

In this article, methods were used to calculate the behavior of impurities in the volume of circulation circuits of waste heat boilers based on the compilation of material balances of the behavior of impurities.

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3 Results

The rate of corrosion processes and the formation of deposits on the heating surfaces in waste heat boilers directly depends on the optimal management of the water chemistry regime [1]. The main entry point for corrective agents is either directly into the circulation drums or upstream of the feedwater pump into the circulation circuits. With the considered arrangement of waste heat boilers with a parallel feedwater supply scheme, feedwater is supplied to each circulation circuit separately, which makes it possible to dose corrective reagents to maintain the water-chemical regime, both into the circulation circuit drums and before the feed pumps. At present, when corrective treatment of the coolant, quite a lot of reagents are used, ranging from traditional WCR using hydrazine and ammonia, phosphates to the introduction of such reagents as chelamine, VTIamine, etc. into the water circuit.

An important characteristic of the behavior of an admixture in the volume of the waste heat boiler is the time of its residence in the volume of the boiler and the time it takes for controlled parameters to reach normalized WCR values. Figure 1 shows a schematic diagram of a double-circuit waste heat boiler with a parallel feed water supply scheme.

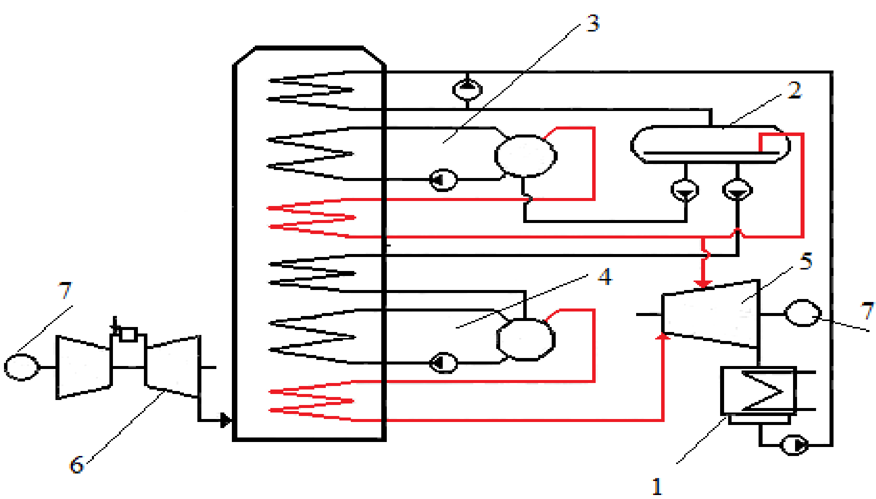

Fig. 1. Principal thermal diagram of a CCGT with a two-circuit drum-type CHP: 1-condenser, 2 - deaerator, 3 - low-pressure circuit of the CHP, 4 - high-pressure circuit of the CHP, 5 - steam turbine, 6 - gas turbine, 7 - electric generator.

When corrective treatment of feed water and maintaining normalized values, corrective reagents in the circulation circuit of the waste heat boiler, it is necessary to know how long these indicators will reach the normalized values. Obviously, corrective agents dosed into the feed water will behave similarly to impurities found in the feed water. In general, the change in the behavior of impurities in the circulation loop from time to time, if they are present in the feed water, can be described by a standard non-homogeneous differential equation of the first order 1 [2].

$$\frac{dC_{КЦ}}{d\tau} = \frac{D_{ПВ} \times C_{ПВ}}{V} - \frac{(D_{П} \times (К_{Р} - 1) + D_{ПВ}) \times C_{КЦ}}{V} \quad (1)$$

Where $C_{КЦ}$ is the impurity concentration in the circulation loop; $D_{ПВ}$ is the feed water flow rate; $C_{ПВ}$ is the impurity concentration in the feed water; $D_{П}$ is the steam flow rate from the circuit; K_{P} is the coefficient of impurity distribution in the circuit; V is the volume of the low pressure circuit.

When considering the organization of dosing of corrective reagents into waste heat boilers with a parallel feedwater supply scheme, it is necessary to take into account the proportion of feedwater that entered the circuit [3].

The time to reach the normalized WCR values is calculated as the ratio of the amount of impurities in the volume of the circulation loop of the waste heat boiler to the amount of impurities supplied with feed water, expression 2.

$$\tau = \frac{G_{КЦ} \times C_{КЦ}}{D_{ПВ} \times C_{ПВ}} \tag{2}$$

Where $G_{КЦ}$ is the water volume of the circulation circuit, m^3.

The ratio of the water volume of the circulation circuit to the feed water flow rate is the time for filling a given volume at a given feed water flow rate, and the ratio of the concentration of an impurity in the circulation circuit to its content in the feed water is a coefficient that takes into account the multiplicity of concentration of a given impurity in the circulation circuit.

For a waste heat boiler operating according to a parallel feedwater supply scheme, under stationary conditions, the time to reach the WCR regime parameters, taking into account the share of feedwater supply to the low pressure circuit. In general terms, for the low-pressure circulation circuit, it will be written in the form of equation 3, and for the high-pressure circuit, in the form of equation 4.

$$\tau_{КЦ1} = \frac{G_{КЦ1} \times C_{КЦ1}}{\alpha \times D_{ПВ} \times C_{ПВ}} \tag{3}$$

$$\tau_{КЦ2} = \frac{G_{КЦ2} \times C_{КЦ2}}{(1-\alpha) \times D_{ПВ} \times C_{ПВ}} \tag{4}$$

Where α is the proportion of feed water supplied to the low pressure circulation circuit $\tau_{КЦ1}$ is the time to reach the regime parameters of the low pressure circuit, $\tau_{КЦ2}$ is the time to reach the regime parameters of the high pressure circuit.

The optimal time to reach the regime values according to the WCR of the waste heat boiler with a parallel feed water supply scheme must be equal to the time to reach the regime parameters of each of the circulation circuits, which, in turn, must be equal to each other.

In practice, when performing calculations, instead of the volume of the circulation loop, the mass of water in the circulation loop and the mass flow rate of the coolant, steam and purge $G_{КЦ1}$ and $G_{КЦ2}$ are used - the mass of water in the circulation loop, kg. $D_{ПВ}$, $D_{П1}$, $D_{П2}$, $D_{ПР1}$ and $D_{ПР2}$ - mass flow rate of feed water, steam capacity of low and high pressure circuits, purge from low and high pressure circuits kg/s.

The steam capacity of each circulation circuit, related to the volume (mass) of water in this circuit, through the coefficient of vaporization, which depends on the flow rate of the coolant in the pipes of the circulation circuit, the length of the pipes of the circuit, and is equal to the ratio of the length of the circuit pipes multiplied by the number of pipes in the circuit to the linear velocity coolant flow in the circulation circuit, expression 5.

$$К_{ПАР} = \frac{l_{труб} \times n}{V_{ПТ}} \tag{5}$$

Where $l_{ТРУБ}$ is the length of one pipe; n is the number of pipes in the circulation circuit; $V_{ПТ}$ - the average linear velocity of the coolant in the pipe of the circulation circuit.

It should be noted that the vaporization coefficients for each circuit must be equal to each other.

Taking into account the coefficient of vaporization in each circuit, the optimal time to reach the operating parameters according to WCR for each circuit will be written in the following form (tquations 6 and 7):

$$\tau_{КЦ1} = \frac{G_{КЦ1} \times C_{КЦ1}}{\alpha \times D_{ПВ} \times C_{ПВ}} \tag{6}$$

$$\tau_{КЦ2} = \frac{G_{КЦ2} \times C_{КЦ2}}{(1-\alpha) \times D_{ПВ} \times C_{ПВ}} \tag{7}$$

Having expressed through material balances the behavior of impurities [4] in the volume of each of the circulation circuits of a double-circuit waste heat boiler with a parallel feed water supply scheme, we obtain equations 8 and 9.

$$\tau_{КЦ1} = \frac{D_{П1} \times K_{ПАР}}{\alpha \times D_{П1} + DC_{ПР1}} \tag{8}$$

$$\tau_{КЦ2} = \frac{D_{П2} \times К_{ПАР}}{(1-\alpha) \times \beta \times D_{П2} + D_{ПР2}} \tag{9}$$

With a parallel feedwater supply scheme, the circulation circuits are filled with feedwater simultaneously, therefore, the dosing of corrective reagents to maintain a given WCR is carried out separately in each circulation circuit. Thus, the time to reach the regime parameters according to WCR for each circuit must be equal to each other (equation 10 and 11).

$$\tau_{КЦ1} = \tau_{КЦ2} \tag{10}$$

$$\frac{D_{П1} \times K_{ПАР}}{\alpha \times D_{П1} + DC_{ПР1}} = \frac{D_{П2} \times К_{ПАР}}{(1-\alpha) \times D_{П2} + D_{ПР2}} \tag{11}$$

4 Discussion

The optimal time to reach the normalized WCR indicators can be calculated from the flow characteristics of the waste heat boiler, which makes it possible to take into account not only the readings of the chemical control devices for the quality of the coolant, but also to evaluate the behavior of the corrective reagents used to maintain the water chemistry regime. Calculation of the optimal time to reach the normalized indicators according to WCR reduces the likelihood of deposits on heat transfer surfaces and a decrease in the rate of corrosion processes in the structural materials of the waste heat boiler.

5 Conclusion

Based on the findings of this article, the following conclusions can be drawn:

- The time to reach the operating parameters according to WCR depends primarily on the flow characteristics, the steam capacity of each circuit and the purge.
- The condition for optimal operation of the waste heat boiler with a sequential feed water supply scheme is the equality of the evaporation ratios in each circulation circuit.
- When determining the time to reach operating parameters, it is necessary to take into account the behavior of impurities in the system boiling water - saturated steam.

References

1. O.I. Martynova, T.I. Petrova, L.G. Vasina, Calculation of water-chemical regimes of thermal power plants (Moscow Energy Inst., Moscow, 1985)
2. L.M. Butuner, M.E. Pozin, Mathematical methods in chemical engineering (Chemistry, Leningrad, 1971)
3. A.E. Verkhovsky, Mo He Zhuo, Evaluation of the reliability of the operation of waste heat boilers by the behavior of impurities in the circulation circuits, New in the Russian electric power industry, **10**, 18-23 (2020)
4. A.E. Verkhovsky, K.G. Gadzhiev, V.E. Kulov, A.A. Zonov, A.P. Pilshchikov, AungMyoKhin, Study of the behavior of phosphates during the operation of a drum boiler, New in the Russian electric power industry, **1**, 24-30 (2014)