ISSN 0040-6015, Thermal Engineering, 2013, Vol. 60, No. 8, pp. 567–572. © Pleiades Publishing, Inc., 2013.
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STEAM-TURBINE, GAS-TURBINE, AND COMBINED-CYCLE PLANTS AND THEIR AUXILIARY EQUIPMENT

Development of a Procedure for Substantiating Replacement Terms for the Condenser Tubes of Steam Turbine Installations

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Abstract—Results obtained from elaboration of a procedure for estimating replacement terms for the condenser tube systems of steam turbine installations are presented. Censored data processing methods are used in performing statistical assessment of replacement terms. The service life of condenser tubes blanked off in the course of turbine operation is assumed to be known (complete operation time), and that for tubes blanked off during the turbine repair process is assumed to be undetermined (censored operation time). The criterion for estimating the replacement term for a condenser tube system is defined as the ratio between the number of tubes blanked off during a repair and in the course of turbine operation. The procedure is validated by the results from a study on analyzing the damageability of tubes made of different materials for the condensers of 11 turbines with capacities ranging from 25 to 500 MW.

Keywords: steam turbine unit condenser, condenser tube replacement terms, statistical methods, censored data

DOI: 10.1134/S0040601513080016

The problem of substantiating replacement terms for the condenser tube systems of steam turbine installations(STIs) does not have a clear-cut solution as yet. An explanation to this is as follows. The failure criterion of a single tube is fairly obvious (degraded quality of the main condensate determined during operational monitoring or the occurrence of leaks in subjecting the condenser to hydraulic pressurization tests during the turbine repair), whereas a failure criterion for the condenser as a whole has not been formulated as yet. In some publications [1, 2], the replacement term is determined as the time by which 10% of tubes in the apparatus have been blanked off or as the apparatus service life (equal to 30 years for condensers). Such recommendations cannot be regarded as a reliable substantiation for replacing condenser tubes.

One characteristic feature relating to condenser tube failures (especially for tubes made of brass) is as follows. After a long period of normal operation characterized by a constant failure rate, there comes a moment when a large number of tubes fail abruptly in the condenser, so that the apparatus becomes in fact unable to perform its intended functions and does not allow further operation of the turbine unit. A need arises to make significant expenditures of money and take the STI out from operation for repair, which may take as long as a few months if the thermal power station is insufficiently prepared for condenser repair. The aim of this work is to determine the moment of time at which work on planning the financial and time resources for restoring (overhauling) the condenser should be started.

Economic models [3, 4], models representing the kinetics of corrosion damage inflicted to tubes [5, 6], and statistical models [6–8] using an approximation of the probability or other statistical indicators characterizing failures of individual tubes in apparatuses were applied for substantiating the replacement terms of the condenser tube systems.

In [3, 4], an economic approach to the problem of substantiating replacement terms for the tube systems of STI heat-transfer apparatuses was presented. Both of these works use an objective function defined proceeding from the equality between the specific operational costs for an apparatus with some of its tubes blanked off (increased consumption of heat by the turbine) and the specific operational and capital costs in the case of installing a new tube system or overhauling the old one.

Calculations of the optimal replacement terms for the tubes of different STI heat-transfer apparatuses performed out using modern procedures for carrying out technical-economic substantiation of measures taken in power engineering have shown that the cost of fuel at thermal power stations, the cost of tubes, and the STI operating mode have an essential effect on the replacement terms of the tube systems of heat-transfer apparatuses [1, 3]. According to the results of the performed calculations, the fraction of damaged heat-transfer surface at which it is advisable to replace condenser tube systems varies from 10–13% for condensing turbines to 12–25% for cogeneration turbines.

In [5], a model representing the kinetics of metal corrosion process was proposed for estimating the damageability of condenser tubes, according to which