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STEAM-TURBINE, GAS-TURBINE, AND COMBINED-CYCLE PLANTS AND THEIR AUXILIARY EQUIPMENT

Specific Features Relating to the Motion of a Rotor with Rubbing against the Stator

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Abstract—Specific features relating to the motion of a rotor with rubbing against the stator and the rolling of a rotor over the stator are considered. Conditions under which rolling of the rotor over the stator occurs and the kinematic and force characteristics of this phenomenon are investigated. Simple analytical solutions are obtained for a model assuming that an absolutely rigid rotor and an absolutely rigid stator come in absolutely inelastic contact with each other, which allow one to get a clear idea about the roll-over phenomenon. An attempt is made on the basis of the proposed model to understand some striking features of the accident that occurred in the 300 MW power unit at the Kashira district power station in 2002.

Keywords: instantaneous loss of balance, rubbing of a rotor against the stator, roll-over, direct and retrograde precession, turbine set destruction

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The transient vibrations arising when a rotor rubs against the stator and their consequences were considered in a number of works in connection with failures of turbine sets. In [1], a brief history of the most catastrophic global accidents was presented, and a list of main references devoted to this problem was given. Rubbing of a rotor against the stator is a phenomenon that frequently occurs during operation of power-generating and propulsion turbines and is caused by many design, erection, and operational shortcomings of these machines. The spectrum of consequences from rubbing is very wide: from damages inflicted to bearings and seals, which are rectified by a simple subsequent repair, to complete destruction of the turbine set. For the possibility of carrying out a scientific analysis of the consequences from emergency situations, it is necessary to have physical and mathematical models of interaction between the rotor and stator resulting from rubbing. Such a combined model constructed for the simplest rotor was presented, in particular, in [1, 2]. In [3], this model of a single contact was "built" into a shaft system with multiple supports, which is analyzed using the finite element method. With such an approach, it becomes possible to numerically calculate transient vibrations involving rubbing of a rotor against the stator in an arbitrary shaft system containing bearings with real static and dynamic characteristics.

This work is a continuation of [1] and is primarily devoted to studying the rolling of a rotor rolls over the stator based on a simple and clear analytical solution of the problem.

THE TRANSIENT ARISING AFTER AN ABRUPT LOSS OF ROTOR BALANCING (A QUALITATIVE ANALYSIS)

We will consider, in a generalized qualitative manner, the transient involving the motion of a rotor after an abrupt loss of balancing caused by loss of some mass (a broken torn away blade or another rotor fragment).

A first case. An abrupt loss of rotor balancing triggers transient unsteady vibrations *without rubbing of the rotor against the stator*. A quantitative analysis of such transient does not present any special difficulties (because the rotor mathematical model is available). Such an analysis was carried out in [1–4] and in some of our other publications, in which examples of the rotor cross-section center's trajectories are given.

The values of arising transverse forces and displacements are easily determined by calculation. The vibration amplitudes vary with time with some overshoot with respect to the level of stationary vibration. Their numerical values depend on the extent to which the rotor is detuned from resonances, on the eccentricity arising after the loss of balancing, on the location of the lost mass: near the node or near the antinode of the vibration mode or modes the eigenfrequencies of which are closest to the rotor rotation frequency at the moment when the balance is lost. If the loss of mass occurs at the node of a certain vibration mode, vibra-