Numerical methods for power equipment tube bundles vibrations studying

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Abstract. Calculations of the steam generator model tubes are considered. Dynamics calculation research for those tube bundle model was worked out. Displacements, velocities, accelerations and amplitudes root-mean-square values of tubes vibration acceleration functions were determined as well as their dependences on structural and operational characteristics were investigated. The design parameters include: tube spans length, gape size in tubes nodes coupling and spacer grids, tube radius position.

Introduction
One of the most important various purposes power equipment safety problems is vibrations of its elements problem, with 30% power units stops due to heat exchangers breakdowns. This is due to both heat exchange tubes and their arrangement vibrations intensity, and the resulting vibration wear. Maximum heat exchange tubes vibrations in the bundles occur in coolant cross flow around. At heat exchangers design stage there are complicated problems of flow and tubes interaction modeling and additional calculation difficulties comes from gaps (occur when assembling) presence in spacing grids. Direct measurement of hydrodynamic forces is quite difficult and time consuming. In the experiment, as a rule, the response characteristics of the tube bundle model are obtained: displacement, velocity, acceleration, oscillation frequency. Setting up an experiment for each new type of steam generator requires additional costs and time consuming therefore creating mathematical models and software tools problems becomes so urgent which make it possible to automate the processes of modeling and analysis of hydrodynamically excited tube bundles vibrations. Mathematical modeling advantage in heat exchange equipment tube bundles dynamics investigation is optimizing the structural and operational characteristics of heat exchange equipment possibility.

Problem statement and solution
In the article, to obtain the numerical results given below, a mathematical model of heat exchange tubes vibration is used, presented in authors works [1, 2].

Under the influence of cross flow tube structure elements are under the action of vortex and hydroelastic excitation mechanisms while the external forces acting on the structural element will be: inertia force, lift force, drag force, hydroelastic force and hydrodynamic damping force [1, 2].
In tube bundles, tubes are separated during assembling by spacing grids, mounted with gaps. Linear system vibrations are significantly different from those of systems with structural nonlinearity. Intermediate supports in the used equations of tube bundles oscillations are replaced by impulse forces through the Heaviside function [1, 2]. Structural elements make circular movements, so the direct impact model is not suitable therefore taking into account the tubes impact with annular supports, an oblique impact model with normal and tangential components of the supports reaction force is taken [2, 3]. Due to these gaps presence, tubes hydroelastic oscillations are able to be excited by such eigenforms, in which some of the supports are not effective. In this case, the vibration amplitudes are limited by impact in these supports, and such restrictions are nonlinear. In intermittent contacts of tube with support case, a sliding impact wear mechanism takes place, such wear is much more intense than pure fretting wear with constant contact. In tube vibration process inside the spacing grid hole can occur abrasion and material removal from the surfaces of both the tube and spacing grid surface in the hole.

![Image of tubes movement trajectories](image)

**Figure 1.** The tubes movement trajectories.

The main accent in wear studies is on the dynamic analysis of heat exchanger tubes taking into account their real spacing.

When studying the tube systems vibrations, we mean that among the factors affecting the wear, the structural ones are the most important. They are diametrical gap between the tube and the intermediate support, the supports number and location. In the second place, as a consequence of the first group presence, the dynamics group factor is considered such as type of tube movement, tube deflection under the influence of flow, frequency and amplitude of impact forces at the contact point. As an example in Figure 2 the dependences of the impact forces amplitudes in contact with intermediate support on the gaps size and approach flow velocity are given. Numerical experiments results (Figure 2) show that radial gap value has a significant influence on interaction between tube and support normal force values (contact forces), friction paths and bending stresses in the tube, which is confirmed by experimental data [1]. The observed studied parameters fluctuations are characterized by the presence of "mismatched" extremes when approach flow velocity changes.
Figure 2. The normal force dependence on the radial gap in supports and approach flow velocity for a series with a step $q = 2.5$.

Conclusions
Our method makes it possible to study the amplitude-frequency characteristics of steam generator tube bundles from their structural operational parameters. Assess important for resource forecasting tube bundles vibrations parameters (contact load at intermediate supports, tubes sliding path in supports, stresses).

References

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