PROBLEMS OF PROVIDING RELIABILITY OF HIGH-CAPACITY TURBINES

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To provide operating reliability from the viewpoint of strength of hydraulic machines under the condition of an increase of the single capacity of the units and, consequently, increase of the specific loads and overall dimensions, it is required to refine the stress state of the most loaded assemblies and parts and the static and dynamic loads and characteristics of the materials determining the strength.

All these tasks are becoming especially urgent in connection with the fact that in a number of cases new requirements are being imposed on modern power equipment: the number of transients — starts, stops, and operation in a synchronous capacitor regime — is increasing considerably. Furthermore, when creating reversible pump-turbines it is necessary to provide operation in the pump regime and in transient regimes specific for this type of machine, during which the dynamic loads acting on the runner blades and guide vanes increase substantially.

At present the stress state of turbine parts has been studied rather thoroughly. The existing calculating methods based on the finite-element method (FEM) make it possible to determine the stresses accurately and to create a structure of equal strength. The existing programs realize calculations of three-dimensional, two-dimensional, and axisymmetric problems of the theory of elasticity of shells and bars and permit modeling the calculation scheme of the structure closest to reality.

At present the runners of mixed-flow turbines are calculated according to the finite-element program for shells. The calculation scheme includes the runner blade, lower rim, and runner hub. The blades of adjustable-blade runners are also calculated according to the finite-element scheme for shells. Preparation of the geometry and loads acting on the runner is carried out within the framework of one program preparing the data for machining blades on numerical control machines. The calculation scheme of a mixed-flow runner is shown in Fig. 1. Naturally, the indicated method has its limitations and shortcomings, but it enables a prompt analysis of several design variants. And the use of three-dimensional finite elements in calculations of mixed-flow runners and runner blades of adjustable-blade turbines makes it possible to substantially refine the stress-state with consideration of all geometric factors. At present the use of three-dimensional finite elements has a selective character and is used for highly loaded structures and assemblies. Figure 2 shows a finite-element mesh for the blade of an adjustable-blade turbine, including the blade flange, and Fig. 3 shows a part of the butterfly valve for a high-head hydrostation. The use of the FEM makes it possible to provide reliability of such complex combined welded constructions as the T-joints of headers of Pelton wheels, branch pipes, etc.

The FEM programs for two-dimensional and axisymmetric problems of elasticity theory became the basis for creating programs for calculating the stress—strain state of turbine covers, stators, etc. Figure 4 shows the picture of movements of the turbine cover for the case of normal operation of the unit.

The problem of providing vibration reliability of turbine blade systems from the viewpoint of preventing the resonance vibration of blades is urgent. This problem is especially important for the case of runners of propeller turbines whose blades are rigidly fastened on the runner hub.

To estimate the vibration reliability of the blades at the runner design stage, the natural frequencies of the blades are calculated for the first 3-4 modes with consideration of the effect of the apparent additional mass of the water and boundary conditions (effect of the gap between the blades and runner pit, effect of adjacent blades). The natural frequencies of the blades are compared with the frequencies of the disturbing forces (rotational, vane, blade frequency), and in the case of dangerous closeness the vibrations of the blades are tuned out.

Vibration reliability is evaluated also for the turbine stators. For this purpose the frequencies of flexural and torsional vibrations of the stay vanes are calculated with consideration of the apparent additional mass of water and these frequencies

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are compared with the frequencies of Karman vortices running off the trailing edges of the stay vanes. If necessary, tuning out is done by changing the geometry of the stay vanes.

Until recently the reliability of parts subjected to the effect of dynamic stresses was estimated by the factor of safety determined from the requirement of satisfying the margins with respect to fatigue strength with consideration of the effect of the corrosion factor. Such an approach does not make it possible to determine the effect of various turbine operating regimes on the accumulation of damage, to take into account its operation under various heads, and to examine the ability to operate in transient regimes. The effect of these factors can be taken into consideration if we proceed to an estimation of the life of the part.