IMPROVEMENT OF TURBINE BLADE SYSTEMS TO REDUCE CAVITATION EROSION

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In connection with the creation of ever more powerful and economical hydraulic turbines calculated for boosted operating regimes, the problem of increasing their reliability and life is becoming especially urgent.

Cavitation erosion of runners is often the cause of a marked decrease of the operating reliability of turbines and an increase of repair costs.

During the last 20 years considerable experience has been gained in theoretical, laboratory, and on-site investigations, making it possible to generalize the main directions in controlling cavitation erosion at the stage of designing and experimental operational development of the waterway of turbines.

During this period there were numerous studies of cavitation processes in mixed-flow and adjustable-blade turbines in regimes close to the design. As a result of these studies the following recommendations were determined for designing and experimental operational development of runners [1]:

- to obtain a pressure distribution on the suction side without "humps" and peaks;
- to conduct erosion tests of model turbines with the use of easily eroded coatings;
- combining the theoretical and experimental investigations, to reduce the rate of cavitation processes to a level such that ordinary stainless steels of type 06Kh12N3D are not eroded.

Mixed-Flow Turbines. Model erosion tests and experience of operating mixed-flow turbines show the presence on the rear surfaces of the blades of two characteristic zones of cavitation erosion: the first is at the trailing edge in the region of the lower rim and the second at the leading edge near the lower rim (Fig. 1a).

The existence of cavitation near runners of such type is regular, since with the existing practice of selecting the turbine setting on the basis of the critical "separation" cavitation coefficient, local cavitation not affecting the energy characteristics of the turbine exists, as a rule, in the runner.

Hydrodynamic calculations of flow past the blades of mixed-flow runners show the existence in the outlet section on the rear surface side of an extensive negative pressure zone, which is the place of formation of cavities (Fig. 2). The zone of a pressure drop is usually followed by a section of an increase of pressure, which corresponds to the place of collapse of the cavities.

To reduce the rate of cavitation it is necessary to reduce the absolute value of the negative pressure, i.e., it is necessary to change the form of the blade channel at the site of existence of the cavity.

The form of the blade channel, for example, on mixed-flow runner RO 115, was changed by profile surfacing on the face surface of the runner blade.

Hydrodynamic calculations of the modified runner RO 115M showed a marked decrease of the peak of negative pressure, decrease of the extent of the low-pressure zone along the length of the blade, and also a decrease of pressure in the zone of collapse of the cavity. Thus the pressure profile of runner RO 115M is more equalized compared with the pressure profile of runner RO 115.

Runner RO 115M was subjected to thorough investigations, which showed the following:

- the changes made in the form of the trailing edge of the blade almost completely eliminate cavitation erosion in zone 1;
- the efficiency at the optimum of the complete performance characteristic does not change;
- the values of the cavitation coefficient \( \sigma \) hardly changed;
- the discharge capacity of the runner decreases insignificantly, about 1%.

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An experimental check of the modification of the trailing edge on a prototype runner confirmed the results of the model tests: cavitation erosion in zone 1 was completely eliminated.

The occurrence of cavitation erosion in zone 2 cannot be determined with sufficient accuracy by existing calculation methods. The zone of negative pressure at that place is determined to a considerable extent by a local increase of meridian velocity of the turbine as a consequence of the unfavorable form of the lower rim in a meridian projection.

Theoretical investigations showed [1] that this zone is characteristic for a wide range of regimes and it is possible to affect it by changing the form of the blade profile while maintaining high energy characteristics only for blades of high-head turbines \( H = 230-500 \) m. This is due to the fact that the runners of such turbines have a relative outlet diameter \( D_2/D_1 < 1 \), which makes it possible to provide a smooth form of the lower rim with a small curvature and to obtain a smaller peak of the meridian velocities in the region of rotation of the flow at the lower rim.

To reduce the rate of cavitation erosion behind the leading edge of mixed-flow runner RO 230, the radius of the fillet on the leading edge of the blade at the place of joining of the rear surface of the blade with the lower rim was increased [1]. Model erosion tests showed that an increase of the radius of the fillet to \( R = (0.01-0.013)D_1 \) completely eliminates cavitation erosion in the region of the leading edge (erosion zone 2).

For low-head mixed-flow turbines \( H = 45-100 \) m, for which \( D_2/D_1 > 1 \), the peak of meridian velocities is considerably higher and it cannot be reduced by such a simple method.

The following design modifications are used with success for these turbines:
- delivery of air to the cavitation zones, for instance, for runner RO 662 [2];
- installation of distributing ribs, for instance, for runner RO 697a [3].

An effective solution was recently found for low-head turbines: by arranging the lower rim of the runner (cascade of the lower rim) below the region of high meridian velocities, it is possible to considerably reduce the rate of cavitation erosion on the leading edge of the blade.

This idea was realized structurally on a model runner RO 75M, which was moved down by \( 0.043D_1 \) compared with the usual runner RO 75. This provided smoothness of joining the runner rims with the gate apparatus and cone of the draft tube. Energy, cavitation, and erosion tests were conducted with this runner, which showed that the rate of cavitation erosion