DEVELOPMENT OF SOVIET HYDROTURBINE ENGINEERING

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UDC 621.224.001.5

In the most developed countries, power systems and associations have grown so much that, as a rule, they can accept energy from generating units of practically any capacity. Further growth of power systems is also basically oriented toward construction of large electric plants equipped with high-capacity units. At present there is in hydropower a natural trend toward harnessing the energy resources of the world’s largest rivers. The successes of hydroturbine engineering in the world are so important that at the present time there are no technical problems which could limit the individual capacity of hydraulic units. The industrial enterprises may also, in principle, manufacture units of any size. For this reason the problem lies only in the economic expediency of selecting any individual unit capacity to be fabricated for hydroelectric plants. The development of hydraulic units of very high capacities is now of chief importance in hydroturbine engineering.

For each type of turbine there is evidently a maximum unit capacity, which is the most advisable capacity for the given level of development of science and industry. Any increase in unit capacity of hydraulic turbines is dependent upon the solution of several technical problems which are sometimes extremely complex; some of them are general for all types of hydraulic turbines, some are inherent only to the specific types.

For hydraulic turbines of any capacity and of all types, the power qualities are important, but for hydraulic turbines of very high capacities these qualities are most important because each additional efficiency percentage has a considerable effect. The efficiency of modern hydraulic turbines reaches 94-96%. As is known, the efficiency is somewhat lower in Kaplan turbines than in Francis; however, the mean operating efficiency is higher in the former. For this reason, there is a natural trend toward moving Kaplan turbines into the zone of higher heads, shoving aside Francis turbines. One of the successful solutions to this problem is the use of diagonal-type turbines.

For multiunit hydroelectric plants, it is necessary each time to investigate very carefully the selection of the type of hydraulic turbine because in many cases flatness of the characteristic curve of a single unit offers no advantage, for all practical purposes. Moreover, in some cases the client prefers to install propeller turbines at the hydroelectric plant, because of their higher specific speed and lower cost. For hydroelectric plants with large head fluctuations, Kaplan turbines are, as a rule, preferable; however, under these conditions propeller turbines are sometimes competitive. Kaplan turbines may prove to be preferable because of their operating conditions during the initial period when construction of the hydroelectric plant has not been completed and the head is substantially below the design value. In these cases it is essential to make an economic comparison of different periods elapsing before commissioning, and the advisability of installing more expensive and complex equipment to satisfy the extended time for completion of the hydroelectric plant is not evident.

The power indices of hydraulic turbines are extremely important, especially large turbines, and in many cases they substantially affect the selection of the type of equipment for the plant. The solution to the problem of ensuring high-power indices is divided into two stages: in the first, it is indispensable to make a highly elaborate model of the turbine at a laboratory; in the second, it is necessary to obtain a sufficiently satisfactory agreement between the form and dimensions of the prototype turbine and the model. As the equipment dimensions increase, the second problem becomes extraordinarily complicated. In recent years much has been done at the factories to improve the fabrication accuracy of runners, scroll cases, stators, and guide vanes for hydraulic turbines. Nonetheless, this problem has not been definitively solved. In the near future, the factories are shifting

Leningrad Metal Factory Association. Translated from Gidrotekhlicheske Stroitel'stvo, No. 4, pp. 2-5, April, 1977.

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to the use of new industrial equipment which will make it possible to increase the fabrication accuracy of turbine blades and to improve methods for measuring them.

For integral checking of the results achieved in the prototype, it is essential to determine the turbine's efficiency at the hydroelectric plant. However, in the writer's opinion, this measurement would make sense only if the measurement accuracy of the prototype efficiency is increased accordingly. For this purpose, at the Soviet hydroelectric plants it is evidently necessary to shift to more refined methods for measuring the efficiency than those presently being applied. At the same time, full-scale measurements are necessary for evaluating the accuracy achieved in fabricating the turbine passages. If it turns out that the accuracy is sufficiently high, then measurement of the prototype efficiency of the turbines should be discarded and, instead, careful control of fabrication of all elements of the internal passages of turbines, including concrete elements, should be ensured. In the near future it will be expedient to issue well-grounded norms for errors in the fabrication of all such elements and, in accordance with the requirements of such norms, perhaps to revise the techniques for fabricating the basic elements of hydraulic turbines and to supply industrial and construction organizations with the required equipment.

It is indispensable to systematize model investigations at the different laboratories. For this purpose it is sufficient to test the same model at all main stands in the nation and to obtain an exact coordination of the results. In addition, it is time to develop a standard stand for carrying out guarantee tests of finally-worked-out turbine models and measuring all the characteristics required for design. The laboratory stands should be equipped with modern instruments for all the necessary measurements and observations.

The efficiency of modern hydraulic turbines is very high. From international experience it is evident that the maximum has not been reached because there is a continual increase in efficiency, in any case, on models at laboratories. It is difficult to state to what extent it is possible to achieve this increase in model efficiencies under field conditions, since for all conditions the accuracy in measuring full-scale efficiency is lower than in the laboratory. It is possible that any increase in efficiency, which is in principle very important, is practically never attained, and that it plays a role mainly in the competition among the manufacturing firms for orders.

A no less important problem for all types of hydraulic turbines is that of the long-term reliability of the equipment. It becomes especially aggravated for high-capacity units when failure of one, even in a large power system, may disturb the normal operation of the system. The reliability problem is a multiple-plan one and it relates to the turbine design, fabrication quality, type and quality of the materials used, and correct operation. Let us dwell on some of these aspects.

The history of the development of hydroturbine engineering is involved with the solution of the cavitation problem. Work on this is always being carried out. However, for all practical purposes solving this problem reduces to achieving the objective that the runners and other turbine elements not be destroyed by cavitation. It is primarily essential to work out blade systems having such characteristics that, under the operating regimes, cavitation bubbles do not form on the blades, or that, if they do form, they do not cause pitting (taking into account the use of protective coatings). At the present time, the runner hubs for Kaplan turbines are being fabricated from bimetallic sheets whose working surface consists of stainless austenite steel. This is quite sufficient to prevent pitting, although the level of slit cavitation, from which destruction of the hubs has been caused, remains unchanged. Coatings made from special stainless steel having a high corrosion resistance have been developed for the blades. It is necessary to arrange for the production of this steel and to perfect the techniques for applying the coatings. In some cases, the runners are made entirely from stainless steel.

In order to prevent blade pitting it is extremely important to improve the accuracy of blade-system fabrication: increasing this is even more important than the obtaining of high turbine power characteristics. In some turbines, pitting of individual blades has been observed, although on the whole the runners did not pit. From measurements of blades which have been pitted it has not been possible to detect tolerance differences overstepping the sufficiently exacting limits. To all appearances, the best method for evaluating the cavi-