INTRODUCTION

During the operation of hydroelectric plants which have been operating for a long time, there is frequently the need for partial modernization of the equipment. Such modernization does not call for replacement of the entire hydraulic unit, is carried out simultaneously with major repairs, and is comparatively simple. However, its effect is extremely significant and lies in the increase in the operation reliability of the hydraulic units and the hydroelectric plants on the whole, as well as in the increase in the equipment mobility and economy.

The partial modernization of hydroelectric plant equipment includes, in particular, the modernization of such assemblies as the thrust bearings, the speed governing system, and others.

In this article, the authors examine the problems of modernization of thrust bearings of hydraulic units and the speed governing systems of hydraulic turbines.

MODERNIZATION OF THRUST BEARINGS OF HYDRAULIC UNITS

The use of thrust bearings under high general and specific loads for large vertical hydraulic units led at first to an increase in their number of instances of damage. They were among the least reliable parts of hydraulic units. This has made it necessary to modernize several thrust bearings. Modernization is being carried out in three directions: structural improvement, development of auxiliary devices for repair, adjustment and regulation, and use of new materials.

The structural improvement of the bearings is being carried out by the manufacturers and the operating personnel at the hydroelectric plants. As a result of this work, at several plants the following measures intended to increase the operating reliability of thrust bearings have been introduced: two-layered split segments have been developed which have made it possible to significantly reduce their temperature deformation; high-temperature bushings have been installed around the heads of the supporting bolts, which have made it possible to reduce the crushing of spherical supporting surfaces; a pressure-lubrication system to the segment friction surfaces has been installed, which has improved the thrust bearing operating conditions when starting and stopping the units; segments with a copper sublayer have been developed which have improved the cohesion between the babbitt and the segment base; more effective oil coolers have been introduced; and several other measures have been implemented.

The development of auxiliary devices for repair, adjustment, and regulation of thrust bearings is carried out by the operating personnel at the hydroelectric plants, as well as by the adjustment and research organizations. Various devices have been developed which substantially facilitate the operation of thrust bearings, namely: different mechanisms for regulating the loads on the segments (indicator—level, hydrostatic); highly sensitive temperature control systems with automatic temperature recording; self-powered rigs for fine-finishing and polishing disks to mirror surface without disassembling the bearings; and various other devices.

All these devices, which considerably facilitate the operating conditions and increase the reliability of thrust bearings, are, as a rule, made by the operating personnel or, at their request, by local enterprises. It is necessary that the factories in charge of manufacture of the generators supply such devices for the new and modernized generators.
The use of new materials for modernization of thrust bearings tends in two directions: fabrication of segments made of new materials with babbitt coatings still being used on the friction surfaces, and development of segments with synthetic coatings on the friction surfaces. At the V. I. Lenin Sibelektrotyazhmarsh Factory, a technique has been worked out for applying babbitt to an aluminum alloy and segments were fabricated from such an assembly for the thrust bearings at some hydroelectric plants. Tests and experience with operation of such thrust bearings demonstrated their high operating quality. In comparison with steel segments, under equal operating conditions the temperature of these segments is lower because of the greater thermal conductivity of aluminum. The higher the temperature, the greater the difference. Thus, for the thrust bearings of the units of the Dneprodzerzhinsk and Palakorg hydroelectric plants, which have low rotational velocities and a temperature of about 60°C, the replacement of steel by aluminum segments yielded a temperature reduction of 1-2°C, whereas for the thrust bearings of the units of the Nurek hydroelectric plant, which have a high velocity and a temperature of about 80°C, such a replacement resulted in a temperature drop of 5-6°C.

Aluminum segments with babbitt coatings are more reliable than steel segments, since the coefficients of thermal expansion of aluminum and babbitt are practically equal, and during heating practically no separation forces develop between them. On the other hand, steel has a coefficient of thermal expansion half as high as that of babbitt, and during heating forces are developed which detach the babbitt from the steel base. Separation of the babbitt from the steel frequently occurs in hydroelectric practice. During operation aluminum segments are considerably more convenient, since they are three times lighter than steel. All the above-mentioned advantages of aluminum segments are indicative of the expediency of their substitution for steel segments of thrust bearings.

During the last few years, work has been carried out to introduce segments with polyfluoroethylene resin coatings on the friction surfaces. This type of resin possesses a low friction coefficient when paired with different materials. Whereas in a thrust bearing with babbitt-coated segments the friction coefficient at starting is 0.16-0.20, in segments coated with such a resin it is in the order of 0.05-0.07, i.e., lower by a factor of 3. This considerably improves the startup conditions of the thrust bearing and makes it possible to develop thrust bearings for high specific loads, without applying special pressure systems for forcing lubricant to the friction surfaces when starting.

At the present time there are two types of thrust bearing segments with polyfluoroethylene resin coatings: synthetic metal--ceramic segments developed by the Institute of Machine Science of the Academy of Sciences of the USSR (S-1-U material)* and elastic metal--plastic segments, developed by the S. P. Korolev Kuibyshev Aviation Institute (EMP segment).†

The S-1-U material of the Institute of Machine Science is a composition of metal and plastic. On a metal (brass) base, a porous layer of bronze powder (granules), impregnated with polyfluoroethylene resin, is applied. The total thickness of the layer applied on the metal base and impregnated with the resin is 2-3 mm. The metal imparts high strength and dimensional stability to the material, and the resin provides lubrication and reliable operation with a relatively small thickness of the lubricant layer.

Segments lined with the S-1-U material were tested in thrust bearings at two existing units — the fishway unit of the Twenty-Second Congress of the CPSU Volga hydroelectric plant (thrust bearing under a 315-ton load with 12 segments) and a unit of the Upper Svir hydroelectric plant (two-row thrust bearing under a load of 1500 tons, with 24 segment pairs). The tests and long operating experience indicated high reliability of the thrust bearing with synthetic metal--ceramic segments. The thrust bearing of the Upper Svir hydroelectric plant was tested under specific loads of over 90 kg/cm² and it has been in operation for some 10 years. During this period the unit underwent about 4000 startups. The segments were not repaired or adjusted and they were inspected periodically. The operating experience during this period was extraordinarily light and smooth also, exceptionally easy was the turning of the rotor with a crane even when the lubricant was removed from the thrust bearing pan without greasing the segments. It should be noted that the thrust bearings of the Twenty-Second CPSU Congress