# ENERGY TECHNOLOGY OF ASSESSMENT OF DYNAMIC LOADS IN HYDRAULIC TURBINES

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**https://doi.org/10.5281/zenodo.10088365**

**Abstract.** Determining dynamic loads is an important step in assessing the strength, reliability and service life of water turbines. The variety and complexity of dynamic processes in the flow part of hydraulic units cause great difficulties in their formalization and numerical simulations, even for the steady state near the best efficiency point. Experimental methods for determining dynamic stresses in the critical elements of full-scale water turbines, especially the blade impeller system, are expensive, and the equipment must be shut down for long periods of time to carry out preparatory work. Model tests are usually carried out only in the design phase, which does not reflect all the peculiarities of the operation of hydraulic units in a hydroelectric power plant. The technology proposed in this article for determining the actual dynamic stresses in the blades of a water turbine enables a quick estimate "from above" based on the turbine's hill chart. The technology is based on the relationship between the level of dynamic disturbance flow in the flow part of the water turbine and the total energy losses affecting the efficiency value for this regime, as well as on the linear dependence of the maximum stresses in the blade on the power for the specified head values and rotation speed. A comparison of the experiments and estimations conducted by the author proves the validity and feasibility of the proposed technology.
**Keywords:** hydroturbine; strength; reliability; lifetime; dynamic loads; hill chart.

**Introduction.** Assessing the strength, reliability and service life of hydraulic turbines (HT) is an urgent task at all stages of the equipment life cycle; it covers a whole range of theoretical, computational and experimental work. One of the important stages of this complex is the calculation substantiation of the resource characteristics of the GT, determined primarily by the stress-strain state (SSS) of the resource-determining elements, primarily the impeller (PI). As the experience accumulated over many years[1,2] in the operation and repair of hydraulic turbines shows, dynamic stresses have a leading influence on the decrease in reliability and resource characteristics, including the appearance of cracks in resource-determining elements. Their level significantly depends on the operating mode of the hydraulic unit (HU), its design and individual characteristics determined by the conditions of installation and repairs performed.

The high level of uncertainty of the loads actually acting on the elements of the gas turbine and the wide range of changes in operating factors (power, pressure) explain why the problem of determining the SSS of the resource-determining elements of the gas turbine has not yet been fully resolved.

**The concept of an energy technology to dynamic loads assessment**

The technology proposed in the research is based on the energy characteristics of the turbine, linking the efficiency of the actual operating mode with the level of effective dynamic stresses in the rotor blades. It allows for a quick calculation "from above" based on the operational characteristics of a hydraulic turbine, assessing the integral impact of parasitic (not involved in the useful work of the turbine) vortex flow structures and not reflecting the features of the ongoing processes.

As is known, during the operation of a gas turbine, not all the energy of water is used to perform useful work.

The total power losses are determined by the coefficient of performance (COP) η of the hydraulic turbine, which for most powerful GTs when operating at optimal/nominal parameters lies in the range of 0.8–0.95. In practice, the relative loss of watercourse power ΔNi in this mode can be approximately estimated using the formula [3, 4].

$$\frac{\Delta N_i}{N_i} = \frac{1-\eta_i}{\eta_i}$$

As a first approximation, with a known flow rate Q through the turbine and operating pressure, the efficiency ratio can be calculated using the known formula:

$$\eta = N/(\gamma g Q H)$$

The amount of total energy losses depends on the type and layout of the turbine, its size, speed, operating mode, design features, manufacturing and installation technology, as well as a number of other factors. It is customary to distinguish the following groups of energy losses:

hydraulic losses associated with vortex formation during water flow through the turbine, overcoming various hydraulic resistance (viscous friction) in the flow part of the turbine and loss of kinetic energy at the outlet of the draft pipe;

volumetric losses, which characterize the flow of part of the liquid through the gaps between the moving and stationary parts of the unit, and for PL turbines also the leakage of water through the gaps between the blades and the impeller hub;

disk losses caused by the movement of the non-working surfaces of the impeller in water (friction of the outer surfaces of the rims and seals of the radial-axial (RA) impeller on water; rotation of water in the gaps between the impeller and the stationary elements);

mechanical losses caused by friction in support units (guide bearings, thrust bearing) and shaft seals; Typically, mechanical losses of GT include losses in the turbine bearing (TB) and shaft seals, as well as half of the losses in the thrust bearing.

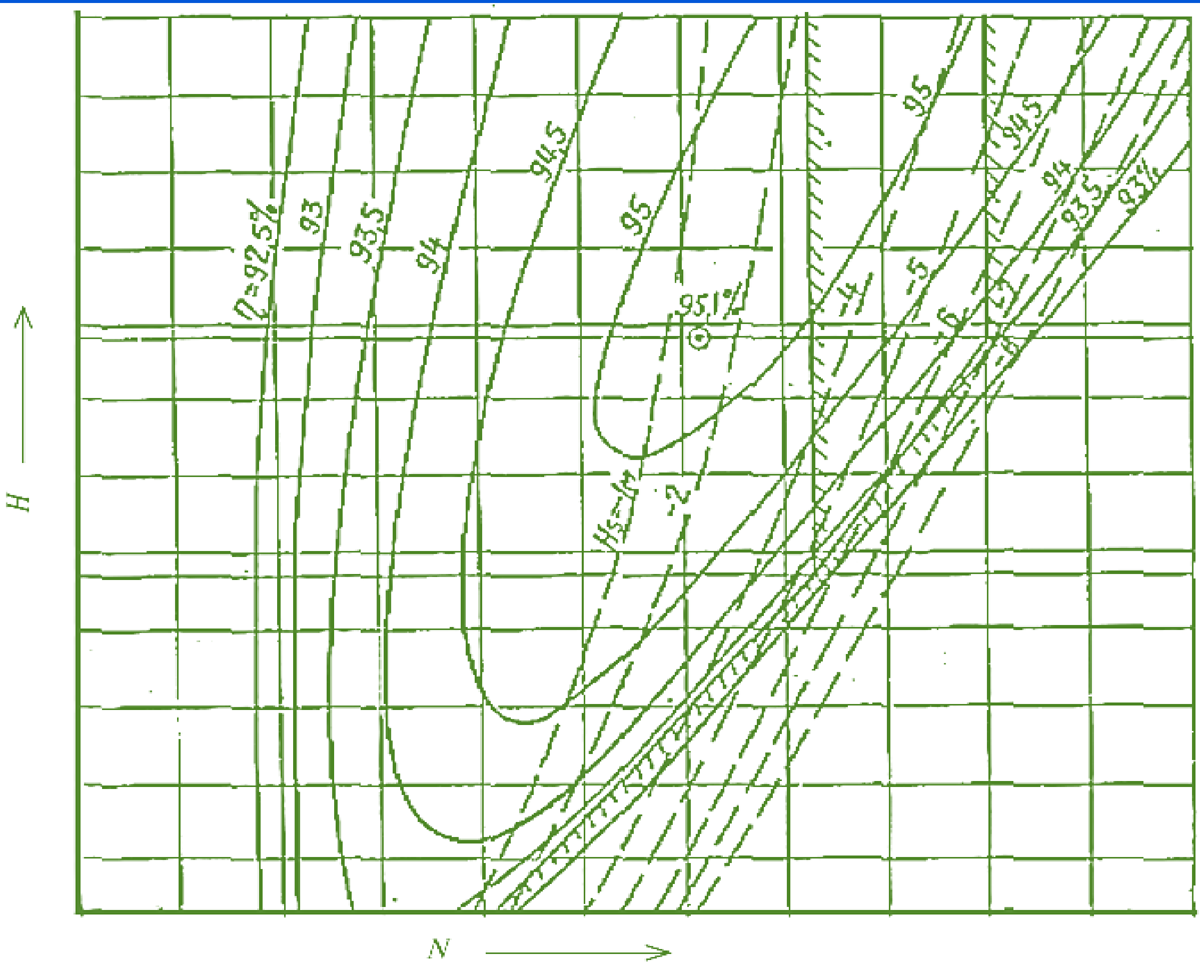


Fig. 1. Example of hydraulic turbines Hill chart

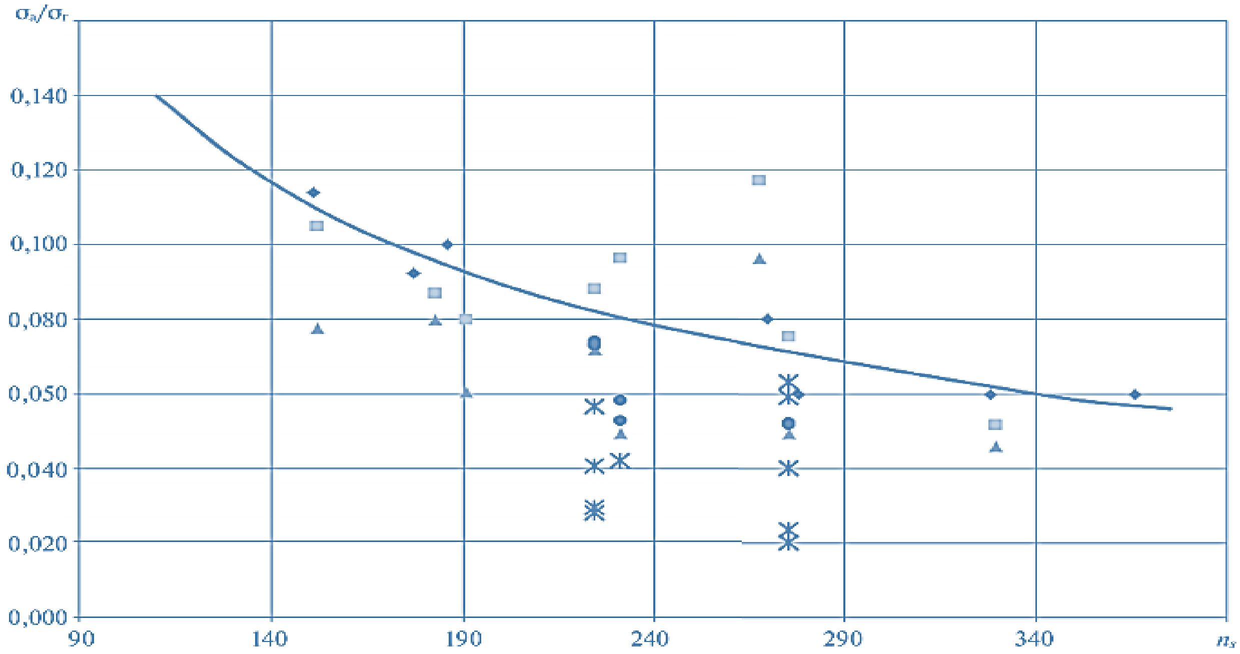


Fig. 2. Relative dynamic stresses in Francis turbines

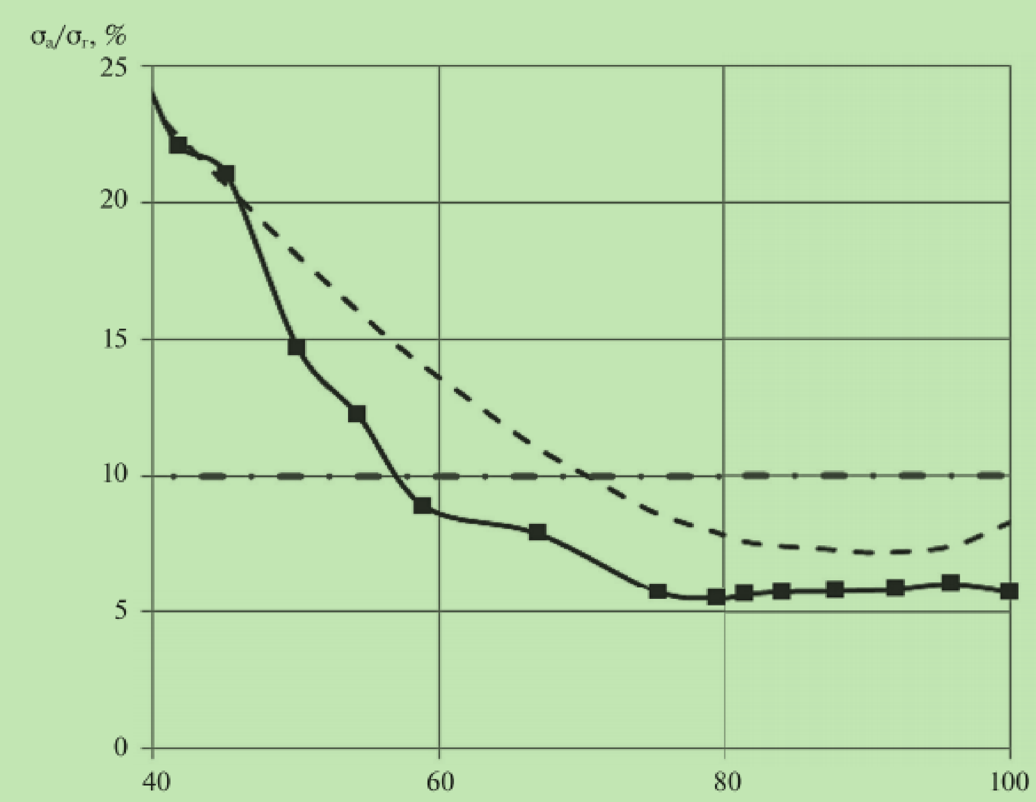


Fig. 3. Comparison of calculation and experiment

**Conclusion**

The proposed algorithm for determining dynamic loads based on the energy technology gives good results and has a sufficient degree of conservatism. Combined with its simplicity and ease of use, this allows for refined calculations of dynamic loads without expensive full-scale strain gauging, which increases the reliability of resource estimates.

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