SOME RESEARCH PROBLEMS OF »GANZ« WATER TURBINES*

By

Cs. FÁY

Research Engineer of the Hungarian Academy of Sciences at the Department for Hydraulic Machines of the University of Technical Sciences, Budapest

The industrialization increasing all over the world at a pace never seen before demanded a very significant increase of the energy supply. Hence the requirements raised against hydraulic machines including water turbines are steadily growing and, at the same time, calling for higher quality. The 90 years old manufacture of Hungarian water turbines (the firm *Ganz*) has also been faced with growing tasks the solution of which has in many cases been made possible only through experimental research. Such a multitude and variety of questions arose that they could not be solved by the Ganz Works themselves, and, therefore, the scientific ability and the laboratories of the University of Technical Sciences, Budapest were resorted to. A cooperation in scientific research has been achieved especially with the Department for Hydraulic Machines and with the Department for Fluid Mechanics.

In this brief discussion we shall deal in the first place with the adjustable-blade turbines manufactured to meet the demands in Hungary.

In case of the adjustable-blade turbines a machine unit may be divided into three distinct parts, such as the scroll case, the guide vanes and runner, and the draft tube. It is generally known that all of these parts involve such problems as can be solved — besides theoretical calculations and considerations — by means of experiments only.

I. The water flows to the turbine runner through the scroll case and the guide vanes. The water inlet is of confusor-type therefore the head loss in it is low. If, however, the velocity of the flow from the scroll case to the guide vanes is not uniform and is changing also its direction, the direction of the relative flow to the individual blades of the runner is varying in time : it becomes periodically pulsating. This phenomenon not only results in a reduction of the efficiency of the runner but may lead also to unpleasant operating disturbances: the unequally loaded runner may wear the lower guide bearing to oval, may ruin the stuffing box etc. Therefore it is of major importance to give a good shape to the scroll case.

The scroll case (Fig. 1) designed on the basis of theoretical considerations (for a constant vortex) was tested with air and water at the institute for Hydraulic Machinery. The effect of adjusting the guide walls having adjustable end, built into the entrance flume was checked on different scroll cases.

After suitable adjustment of the guide walls the investigations were continued on the equipment for turbine experiments (a larger scale model) of the Ganz Works. This time the adjustment of the fixed guide vanes was also carried out. Based on the data of previous measurements the angle and spacing of the fixed guide vanes were determined and checked by velocity distribution measurement.

* A considerable contribution to this paper was made by Mr. Ernest Trenka, Chief of the Department of Hydraulic Machines at the Ganz Works who was prevented from completing the manuscript by his trip abroad

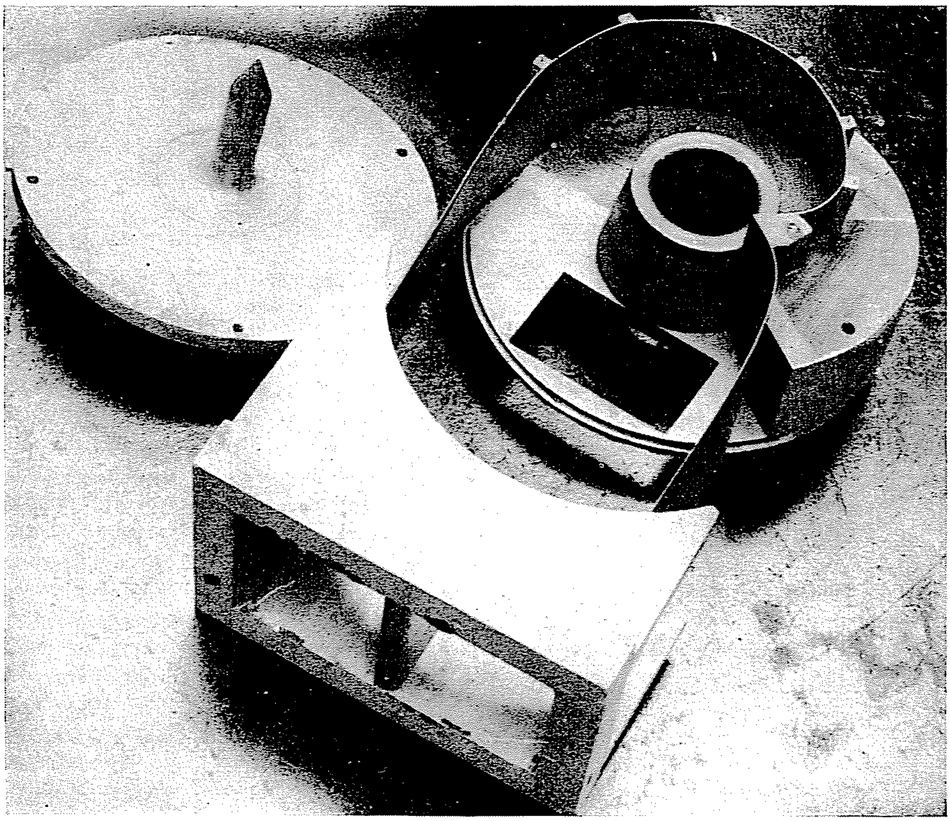

Fig. 1. a) Adjustable scroll case for investigations with air

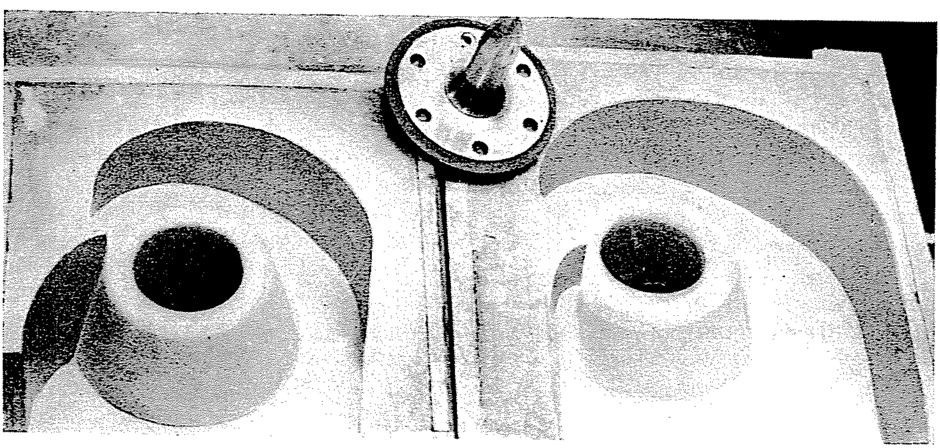

Fig. 1. b) Scroll cases for investigations with water

After this measurement small corrections were made on the vane angle adjustment whereby the optimum adjustment could be found. In Fig. 2 the distribution of meridian and vortex velocities before and after adjustment is shown plotted on the axis circle of the guide vanes. This measurement was carried out without guide vanes.

with a view of determining the lattice-characteristics [3]. Tests of assembled runners were made with the following equipments built in the turbine experiment laboratory of the Ganz Works: an equipment built between open water levels for measuring efficiency and a station built in a closed system for determining the cavitation characteristics.

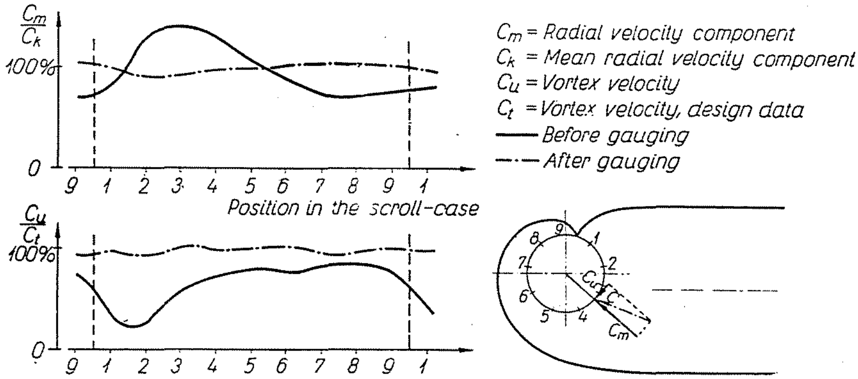

Fig. 2. Velocity distribution at the place of the guide vanes

II. The design of the runner is of extraordinary significance for both efficiency and cavitation characteristics of the turbine. The basis of designing the runner is the blade element (airfoil).

The Institute for Fluid Mechanics develloped under the leadership of Professor Gruber new types of airfoils which can bring about a specified pressure distribution thus being particularly advantageous in view of avoiding cavitation. [1]

For measuring the cavitation characteristics of blade elements an up-to-date cavitation-tunnel was built at the Institute for Hydraulic Machinery under the leadership of the late Á. G. Pattantyus [2]. By means of this tunnel the results of theoretical calculations are checked.

The hydrofoils in the turbine runner are arranged in lattice. In addition to the theoretical calculation of the lattice-correction, experimental measurements were carried out with air at the Institute for Fluid Mechanics

III. The kinetic energy of the flow leaving the runner will be reconverted into potencial energy in the draft tube. In case of high specific speed turbines from 20 to 40 per cent of the total energy enters the draft tube, therefore the head loss of the draft tube has to be reduced to a minimum. For determining the correct shape of the draft tube extensive series of experiments were carried out.

a) Conditions were investigated with air at normal inflow.

b) A vortex was generated with a small turbine (Fig. 3) and the efficiency was determined at different operating conditions with ten different types of draft tube.

c) By building the best types into the testing station of the Ganz Works accurate measurements were made on a larger-scale model assembled with different runners [4].

It is to be mentioned that an attempt was made to substitute the runner with a stationary lattice for testing the draft tube. The data obtained in this way could not, however, be

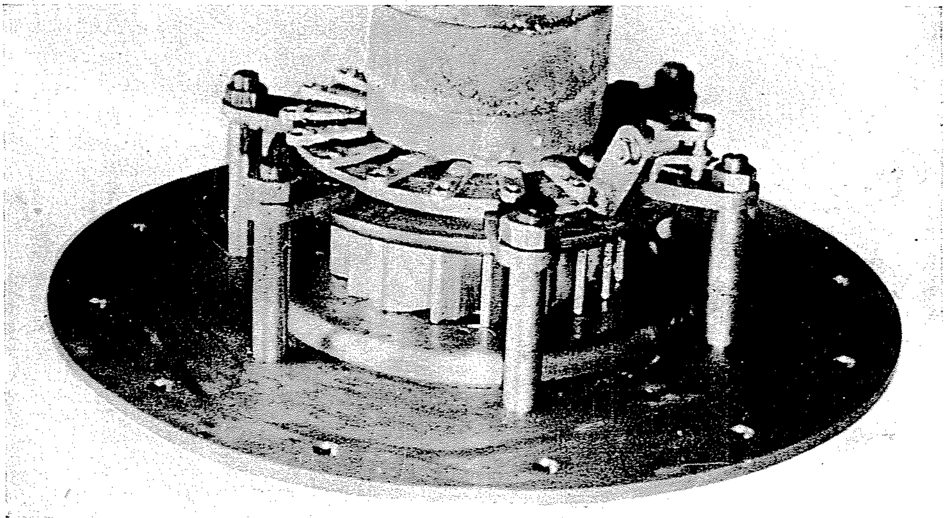

Fig. 3. Small-scale turbine for generating vortex *a)* guide vanes

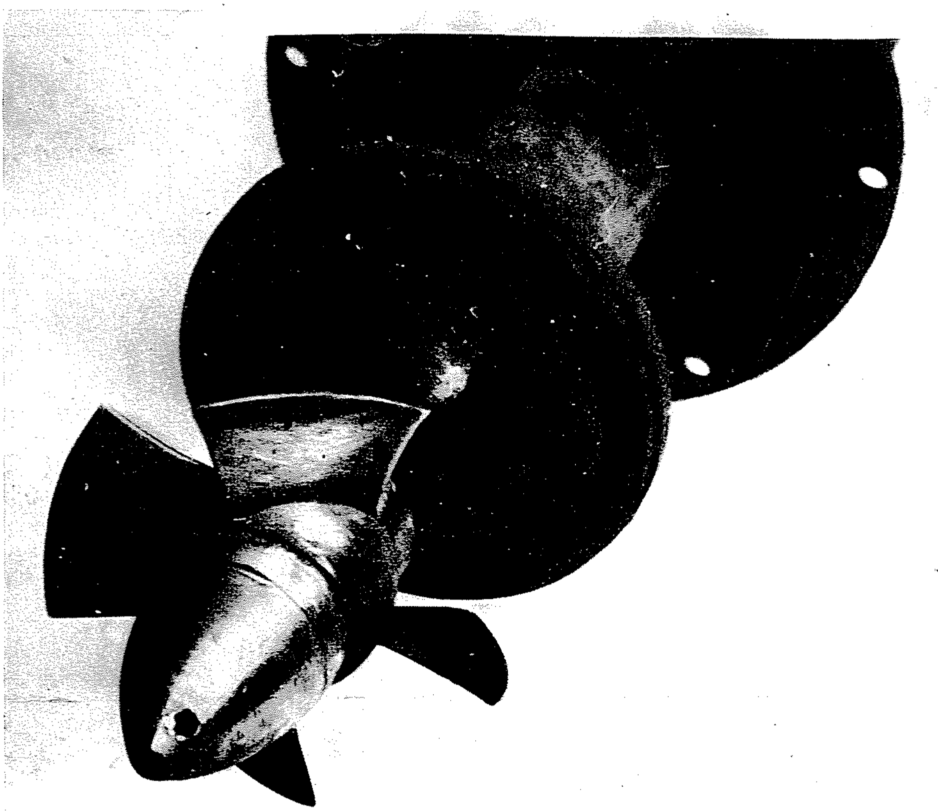

Fig. 3. b) runner with turbine cover

compared to the actual conditions, therefore this method was dropped.

IV. Based on the measurement data of the model the expected characteristics of the prototype turbine can be predetermined. For calculating the efficiency of the prototype turbine a great number of formulae are given in the literature. Detailed investigations were made also in this field mainly based on the loss analysing measurements of Kvyatkovsky [5]. In this formula the value of A is still a function of the parameters n_{11} and Q_{11}. By denoting the parameters of the maximum efficiency point Q^*_{11} and n^*_{11} and introducing the variables $x = Q^*_{11}/Q^*_{11}$ and $y = n_{11}/n^*_{11}$ the curves shown in Fig. 4 are obtained. In the figure the approximations of Ackeret ($A = 0{,}5$), Hutton-Blackstone, Voith, Escher Wyss and the curve determined by us based on the measurements of Kvyatkovsky are also indicated. We

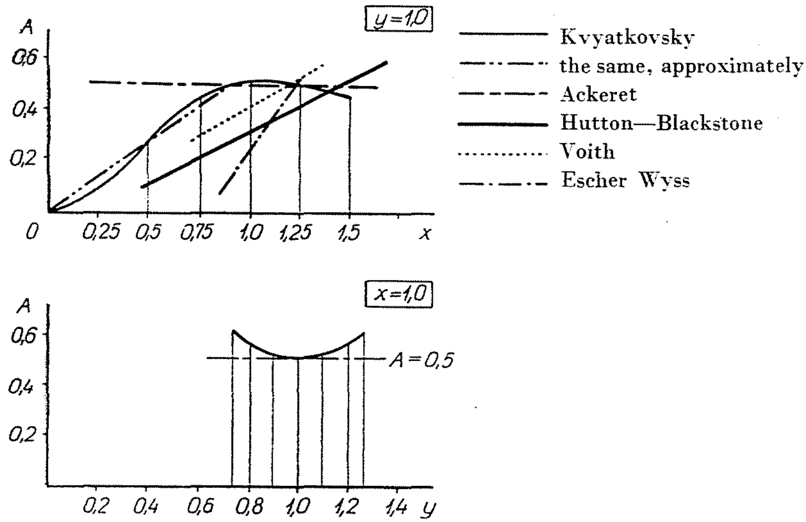

Fig. 4. Comparison of formulae for calculating efficiency

As the final result of the investigation a formula was obtained which gives results falling within the range limited by the data given in the literature not only for the maximum efficiency point of the complete characteristic including isoefficiency curves but also for a sufficiently wide section of the curve. If, in the course of calculating the efficiency, the mechanical losses are eliminated and the volumetric efficiency is assumed to be constant for both the model and the prototype turbine, then the following formula is obtained for the rate $v = \delta/\delta_{mod}$ of the head losses ($\delta = 1—\zeta$):

$$v = A + (1—A).\ (\mathrm{Re}/\mathrm{Re}_{mod})^{1/5} \cong A +$$

$$+ (1—A).\ (D/D_{mod})^{1/5}$$

approximated Kvyatkovsky's curve by the following formula:

$$A = 0{,}555\ x\ [1 + 3{,}2\,(y - 1)^2]\ \text{for}\ x < 0{,}9$$

$$A = 0{,}5\ [1 + 3{,}2\,(y - 1)^2]\ \text{for}\ x > 0{,}9$$

The range of validity is $0{,}75 < y < 1{,}25$. The formula holds true only for adjustable-blade turbines.

A special importance is given today to this question by the fact that it is expedient to carry out the acceptance measurements of turbines of very great discharge also on the basis of model measurements. Therefore, if in the course of model measurements, detailed loss-analysing measurements (mechanical, volumetric, scroll case, guide vanes, runner losses, furthermore friction, outlet and boundary layer losses of the draft tube) are made and the losses can reliably be separated, an absolutely reliable and accurate efficiency calculation can be carried out, the error of which can even be reduced to fall within two limits and is smaller than the ± 2 per cent error usual at the acceptance measurement of the prototype turbine. This method is on the one hand less expensive than the acceptance measurement, on the other hand it also gives information as regards flow conditions in the turbine.

V. Midget water-power plants are of considerable significance in this country. In the design of these plants low-cost and simplicity are decisive factors. The Ganz-Mignon turbines were designed especially for this purpose. The development of this type was carried out through no model measurements but the assembled prototype of the actual machine itself was tested. It was an interesting task to work out experimentally the optimum design — in view of control and efficiency — of the adjustable head cover used in place of the adjustable guide vanes and the adjustment to maximum sensitivity of the direct-acting mechanical speed regulator. The result is: the midget plant operating alone at constant head gives practically constant voltage at the cable end connection.

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