THE SZEWALSKI INSTITUTE OF FLUID-FLOW MACHINERY, PAS (IMP PAN)

CENTRE FOR MECHANICS OF LIQUIDS,
DEPARTMENT OF HYDRAULIC MACHINERY

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EXPERIMENTAL AND NUMERICAL INVESTIGATION OF HYDRO-KINETIC TURBINES

Laboratory research

Research on prepared hydrokinetic turbine models was carried out in IF-FM PAS flow tunnel. Cross section of experimental chamber of the test rig is square-shaped sized 0.425 x 0.425 m. Circulating pump enables to perform measurements with maximum average water flow velocity in the chamber up to 5 m/s.
The test stand equipment enables to measure the rotational speed (*n*) of the tested turbine runner, average water flow velocity in the tunnel chamber (V_∞), turbine output torque (*M*) and the axial (trust) force exerted by the turbine runner (*T*).
Measurement of average water velocity in a chamber, V_∞ was processed indirectly with the use of calibrated tunnel confusor. In order to achieve this, the difference between height of water columns at the inlet and outlet cross sections of tunnel confusor (ΔH) was measured with precise differential manometer, and the average water velocity was calculated on the basis of relationship $V_\infty = f(\Delta H)$ derived from calibration.

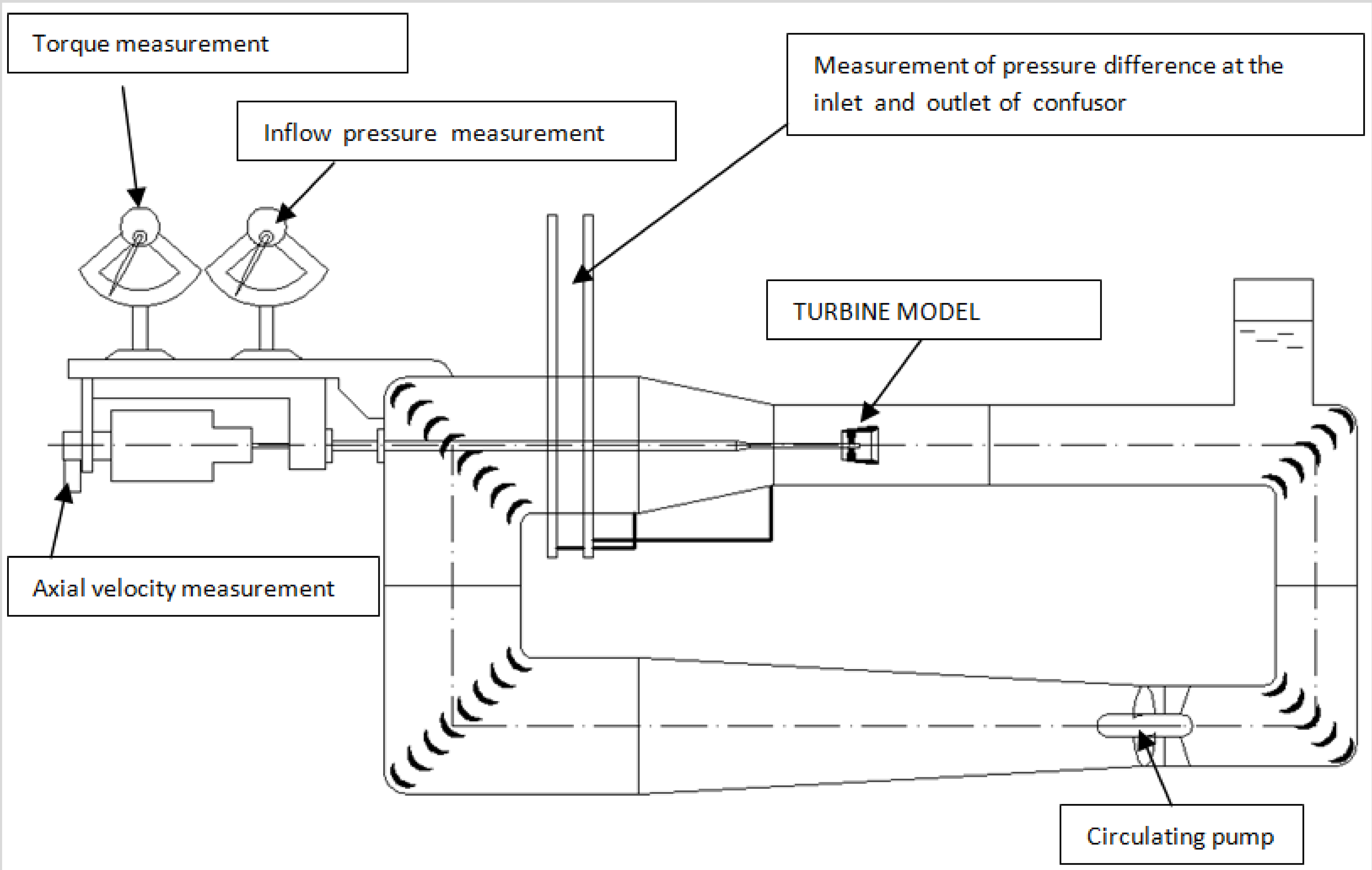

Fig. 1. The scheme of a test stand.

Calculation method

The calculation method developed for solving the problems of flow analysis of a given hydrokinetic turbine model (of D diameter) is based on the vortex lattice method (VLM). In this method (which proved useful in predicting hydrodynamic characteristics of screw propellers) the flow of incompressible and inviscid liquid is assumed to be axisymmetric in the whole studied flow region excluding some of the singularities. In these areas the strong vortex concentration appears, which result mainly from the friction effects. The used method consists in discrete distribution of the so-called horseshoe vortices in singular regions. This type of vortices are composed of the bound and free vortices.

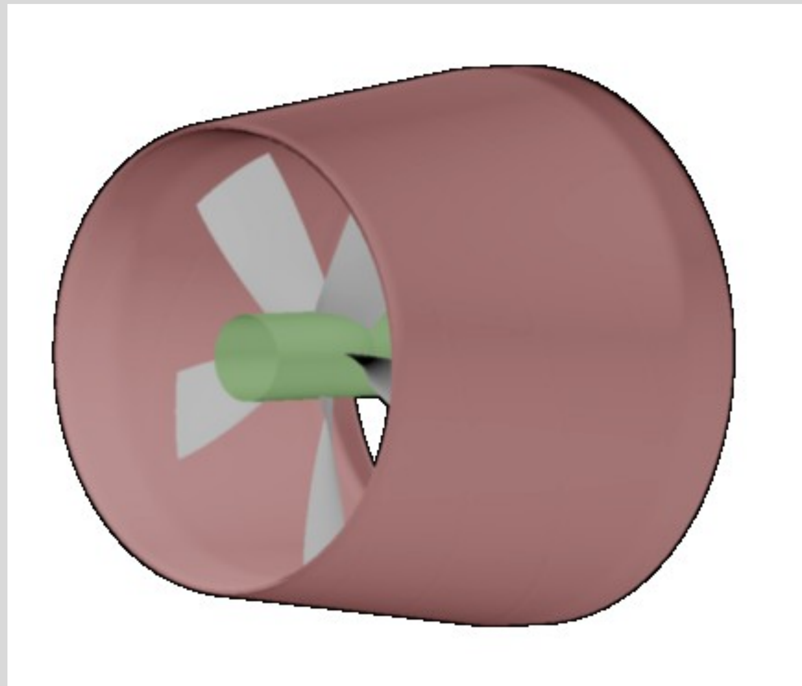

Fig. 2. An assumed physical model of hydrokinetic turbine.

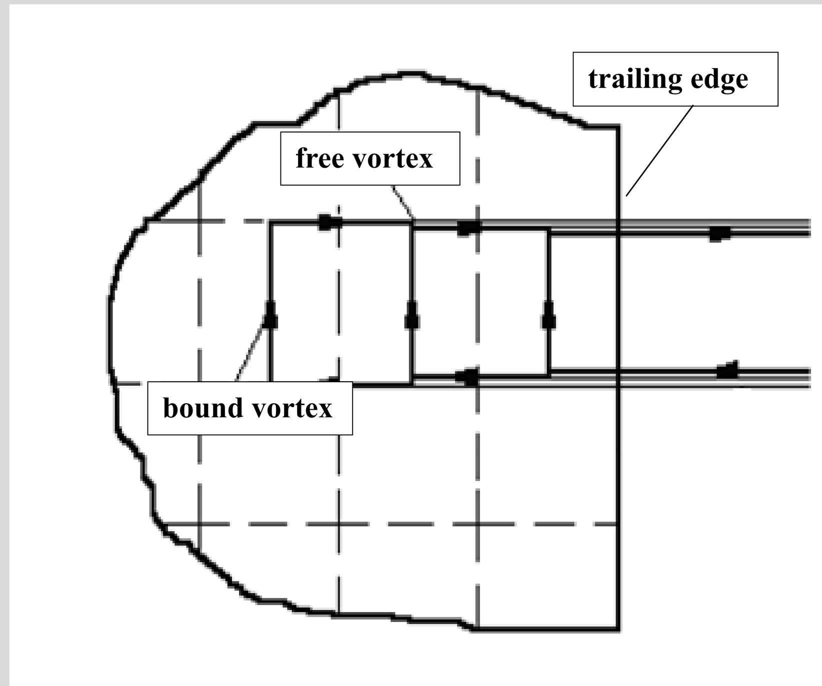

Fig. 3. Calculation mesh with a given discrete whirl filaments marked schematically.

Non-dimensional factors of torque $\boldsymbol{K_M}$, thrust $\boldsymbol{K_T}$, energy utilization rate of liquid stream $\boldsymbol{C_E}$ and advance ratio $\boldsymbol{J}$ are defined by following formulas:

$$K_M = \frac{M}{\rho n^2 D^5} \qquad C_E = \frac{2\pi n M}{0.5\rho V_\infty^3 0.25\pi D^2} = 16\frac{K_M}{J^3}$$

$$K_T = \frac{T}{\rho n^2 D^4} \qquad J = \frac{V_\infty}{nD}$$

The satisfactory from engineering point of view agreement between values of non-dimensional coefficients calculated using the developed program and obtained from laboratory measurement for three turbine models and for wide load range, was found.

Calculation and laboratory results

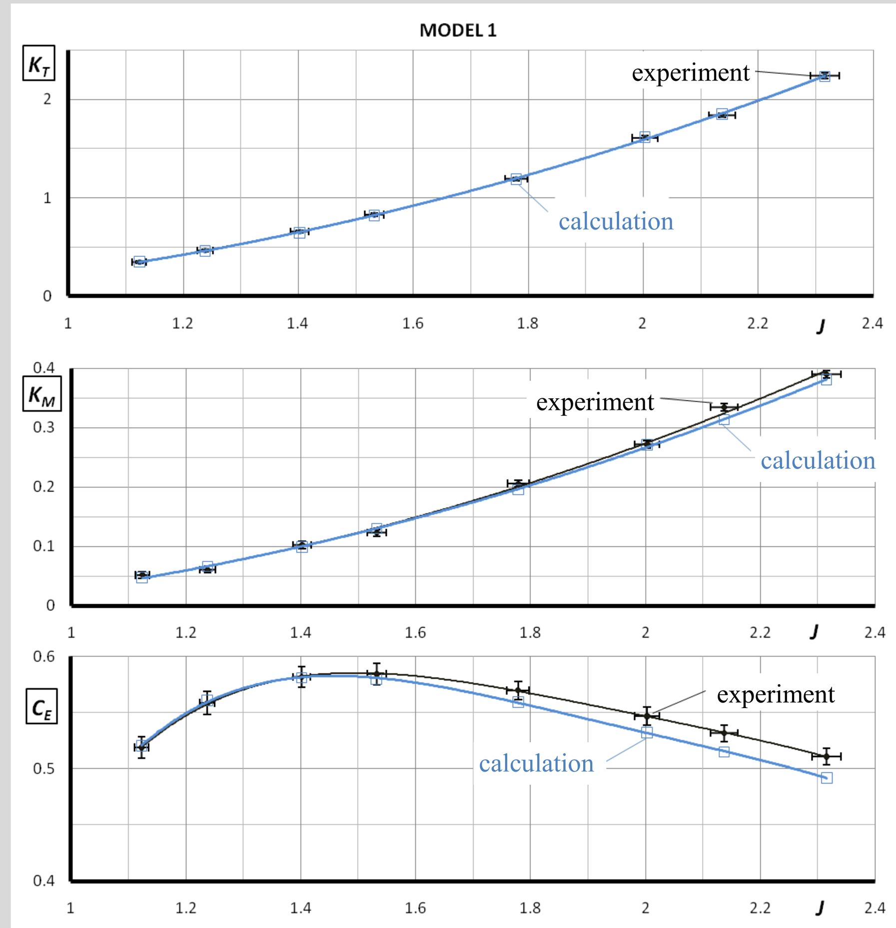

Fig. 4. The obtained results for model No. 1 (number of blades *Z* = 5 and blade pitch *h/D* = 1).

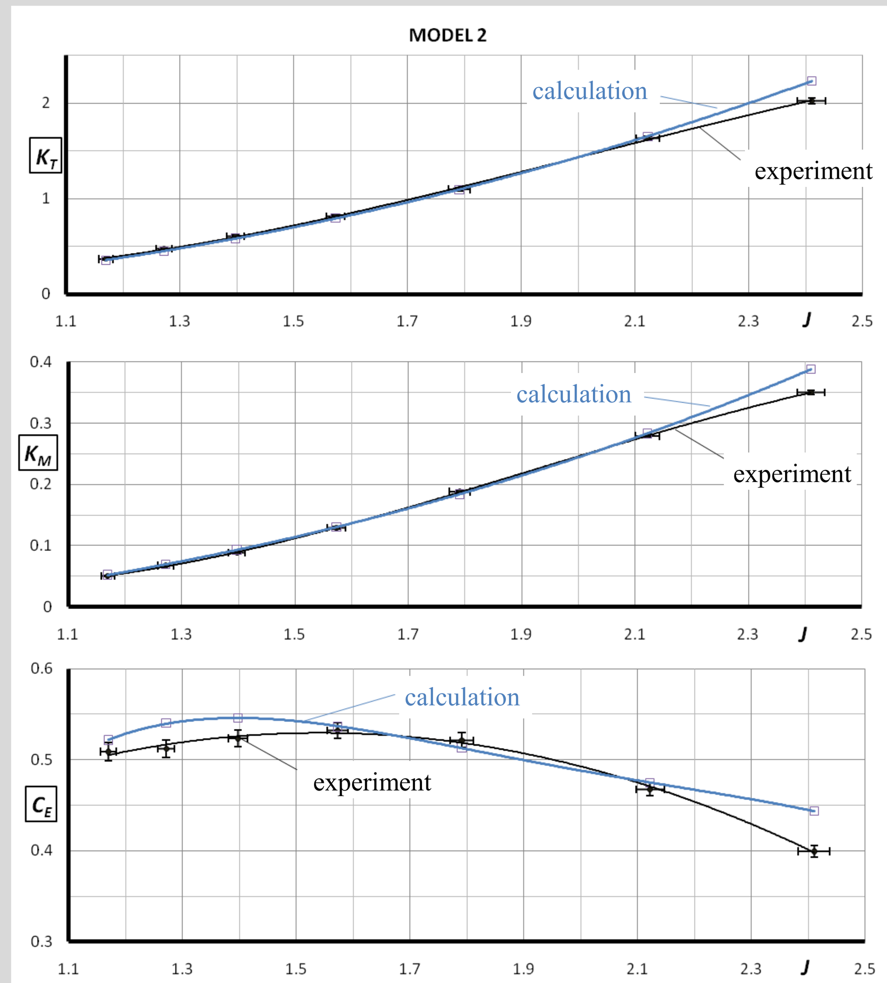

Fig. 5. The obtained results for model No. 2 (number of blades *Z* = 4 and blade pitch *h/D* = 1).

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