Stand for Testing of Hydrokinetic Turbines

Valentin Obretenov, Tsvetan Tsalov, Stanislav Mateev

Abstract: *The work is considered the scheme and the characteristics of a test rig of hydrokinetic turbines. It was installed in the laboratory of hydropower and hydraulic turbomachinery of the Technical University of Sofia. Described are the characteristics of the facilities of the stand as the main attention is given to modeling supply: model turbine, bearing shaft, loading systems. Analyzed are the possibilities for testing various types of hydrokinetic turbines, as well as their modes of operation. Special attention is paid to the measurement system of the stand: methods and tools for measuring of the parameters needed to determine the internal and external characteristics of turbines.*

Keywords: *hydrokinetic turbines, test stand, sensor, measurement.*

Introduction

The depletion of the organic fuel deposits of the planet puts forward sharply the necessity to search for new technologies for the production of electric energy. One of the approaches to solve this problem is the elaboration of efficient systems for utilizing the energy of free water currents (in the rivers, the seas and the oceans) applying the so called hydrokinetic (continuous flow) turbines. At this stage it is mostly pilot installations of this type that find practical application. The basic reason for this fact is the requirement of considerable capital investments, put forward by this kind of technologies, as well as the relatively low degree of restoring back the invested financial resources.

The elaboration of efficient turbine blade systems and the construction of hydrokinetic turbines requires first of all to carry out extensive experimental research work under laboratory conditions. This imposes the design and construction of experimental setup, which would allow modeling of the processes of energy transformation in this type of water turbines.

The present work considers a scheme and the specific features of a stand for testing of hydrokinetic turbines. The research work is part of the research program envisaged within the framework of the project DUNK-01/3.

Scheme of the Stand

Fig.1 represents the principal scheme of the stand.

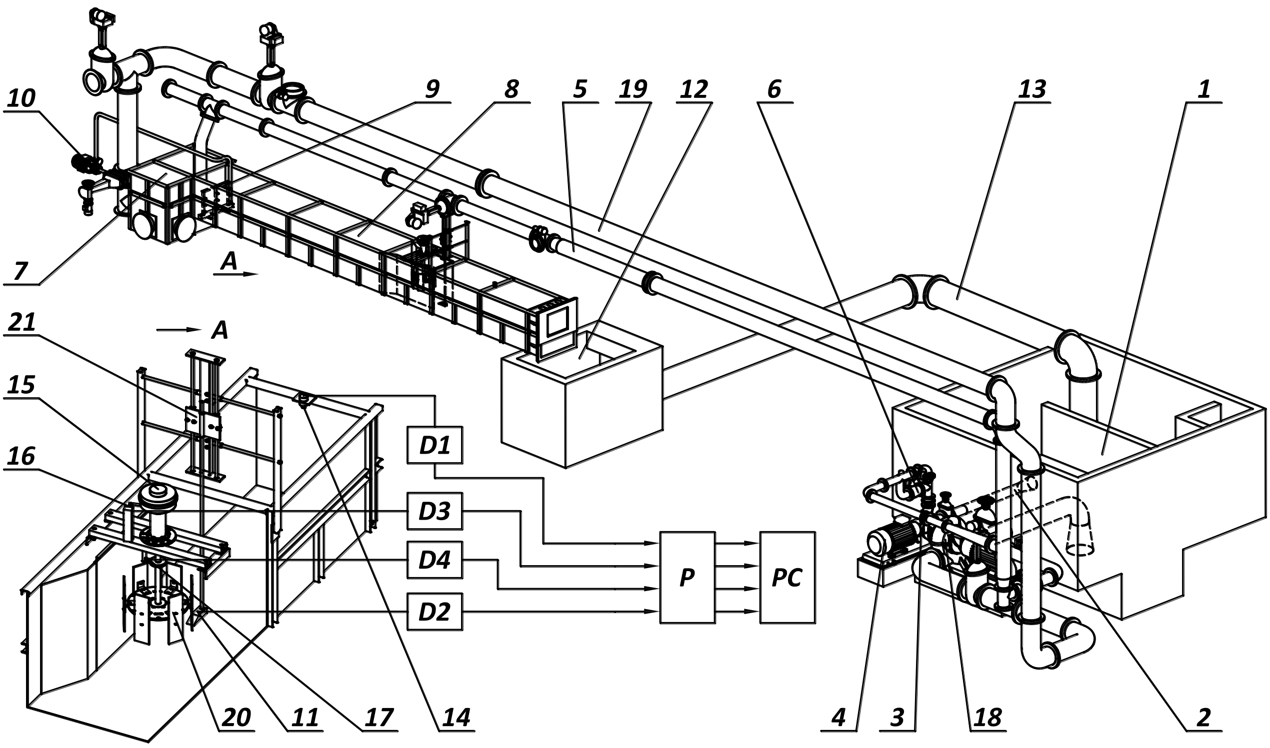

Fig.1. Scheme of the stand.

The velocity of the free current at the inlet of the turbine is controlled by a centrifugal pump 3, model META 150-NHD-400-38-YC-20-09, manufactured by the company Sigma Olomouc (Czech Republic). It is driven by the asynchronous electrical engine 4. The pump sucks in water from the main reservoir 1 through sucking pipeline 2 of diameter 200 mm and it pressurizes the water flow inside the feeding pipeline 5 of diameter 300/250 mm. A needle valve 6 is mounted at the outlet of the pump, which enables adjusting the parameters of the flow.

The water is fed into the settler shaft 7, and thereafter it passes over into the channel 8, which has a rectangular cross-section (1×1 m) and a length of 10 m. An accelerator of the flow 9 is installed at the entrance of the channel 9, which is driven by a single-step centrifugal pump 10 model 6E50, manufactured by VIPOM (town of Vidin). The device is equipped with 11 injection nozzles, whose number and locations can undergo changes. The alteration of the flow rate inside the channel is accomplished by means of regulating the parameters of the pump 10 or by changing the number of the included nozzles. The distribution of the nozzles enables achieving better uniformity of the flow rate distribution before reaching the turbine being tested.

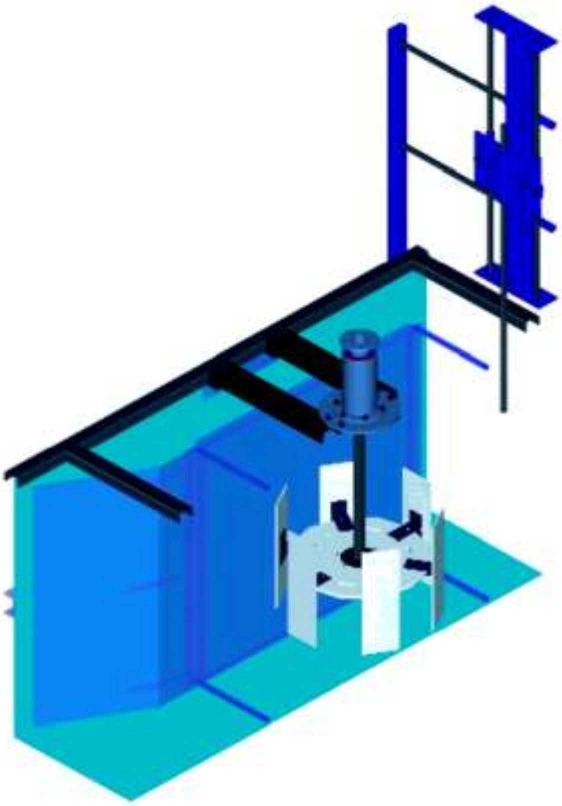

Fig.2. Calibrated channel

In order to create one and the same set of conditions during the testing process of various hydrokinetic turbines and to accelerate the velocity of the stream within the zone of the turbine a calibration section is designed having a constant width and sufficient length (with a view to ensure stable conditions in the course of the testing process) – Fig.2. The device is mounted inside the channel, whereupon its width can be altered depending on the value of the basic diameter of the working wheel of the tested turbine.

The measuring system 21 is mounted in a section, located immediately after the model turbine. It is designed to measure the flow rate distribution within the section, where the turbine is located (during the measurement the turbine is outside the channel). The system allows displacing the anemometer 11and fixing it in any point. The stand is equipped with two anemometers: hydrometric propeller and ultrasonic system of the VP002/10 type delivered by "Mainstream" Company (UK).

A spillover wall is located at the end of the channel 8, over which the water flows falling into the shaft 12 and then along the pipeline 13 it is returning into the main reservoir 1. The level of the water inside the channel is measured by means of ultrasonic level gauge 14.

Model block

In principle it is possible to test different constructions of hydrokinetic turbines on the stand having a horizontal or vertical shaft. In this specific case the turbine has vertical shaft, i.e. the classical design construction of Darrieus (H-type). A characteristic feature of this type of construction is the option to mount working blades of various number and shape, whereupon the angle between their positions in the in the grid of the working wheel can be changed within wide limits.

Fig.3. Model block

The bearing body of the turbine is constructed in such a way that enables the isolation and separate measurement of the momentum of friction in the bearings, which answers the requirements for conventional testing of water turbines, in accordance with the Standard 60193 of IEC [1, 2]. This is an essential point in the specific case having in mind the comparatively low values of the effective output.

The loading of the shaft is realized by means of an electromagnetic brake 15, which has already proved its effectiveness upon its application in the stand №7C (wind-driven engines with a vertical axis) in the HEHT Laboratory [4].

The turbine is mounted on a frame. Its position can be changed with respect to the axis of the channel along the width or along the height. An option is foreseen to change the position of the axis of the shaft of the turbine in regard to vertical line.

Fig.3 illustrates the model block of the stand.

Methods and tools for the measurements on the stand

The choice of the measuring appliance is in conformity with the requirements of the training process and the program for the scientific research work in the laboratory. At this stage the following methods are applied and the following measuring gauges are used in the stand:

1. Flow rate

The velocity of the stream in front of the working wheel of the tested turbines is measured using digital anemometers. The stand is equipped with two anemometers:

- Hydrometric propeller №3343 ("Gidrometpribor" company, Georgia);
- Ultrasonic anemometer D1 (fig.1) of the type VP002/10 manufactured by "Mainstream" company (UK).

Due to the non-uniformity in the flow rate distribution it is necessary to take the average value in regard to the flow rate:

$$c_s.S = \int_0^b \int_0^h c dh db \quad (1)$$

One obtains for the average flow rate c_s in the measurement section the following expression:

$$c_s. = \frac{\int_S c(s) dS}{S} = \frac{\int_0^b \int_0^h c dh db}{BH} \quad (2)$$

where b and h are the current width and height, while B and H are the maximal width and height of the measurement section. The height h is measured by means of an ultrasonic level gauge (D1) of the type 947-F4V/Y-2D/2F-1C/D0-180E/300E of the company Honeywell. There exists an option to measure it applying the calibrated piezo-metric tube.

2. Frequency of rotation

In order to measure the frequency of rotation of the working wheels of the tested turbines an inductive transducer (D4 – fig.1) is used for the frequency and a process indicator model DP manufactured by Delta Instruments. A disk is mounted on the shaft of the turbine having several slits along the periphery, while in the intermediate vicinity a sensor is mounted, model E2E delivered by OMRON Co. The signal is passed over to the process-indicator, model 4003 of the "Delta Instruments" company.

3. Capacity

The capacity of the shaft of the tested hydrokinetic turbine (effective output) is determined by the rotational momentum M_b and by the angular velocity ω:

$$P = M_b \omega = \frac{\pi}{30} M_b n \quad (3)$$

The rotational momentum is determined on the basis of the force F, which the bearing stator of the brake is exerting through the lever on the measuring gauge 16 and the shoulder l:

$$M_b = Fl \quad (4)$$

A transducer DP3 of the type BCM 1660/50N (Belgium) is used to measure the force and the process-indicator of Delta Instruments.

A second option is envisaged to measure the rotational momentum using the sensor type DFM22 2.5S, produced by MEGATRON Elektronik AG & Co (Germany) – Fig.4.

Fig.4. Sensor for the rotational momentum

The intensity (power) of the water stream is determined by the expression [4]:

$$P_w = \rho S \frac{c_{w,s}^3}{2} \quad (5)$$

where ρ is the density of water; $S = DH/2$ is the effective surface area of the working wheel (half of its cross-sectional area: H is the height of the wheel); $c_{w,s}$ is the average flow rate.

4. Coefficient of efficiency of the turbine (power coefficient)

$$c_p = \frac{P}{P_w} \quad (6)$$

The signals from the primary transducers (D1, D2,D3,D4) are transferred to the analog-digital converter *P*, while the quantities converted into digital code are input in the laboratory computer *PC*. The control of the process of measurement is accomplished by means of specialized software.

Conclusion

The results from the research work carried out give us the reason to draw the following important conclusions:

1. A laboratory stand has been elaborated to carry out model investigations on hydrokinetic turbines. The stand opens possibilities to carry out a wide spectrum of studies on this type of turbines with vertical or horizontal shaft, which will find application both in training of students, as well as in scientific research work. An important advantage of the stand is the option to model various conditions of operation of the turbine, which is very difficult to realize during the operation of full-scale industrial equipment.

2. The design of the scheme of the stand has been done with a view to utilize to a maximal extent the equipment, available in the laboratory, as well as from the viewpoint of providing standard conditions, required in order to compare results.

3. A construction of model hydrokinetic turbine has been developed belonging to the Darrieus type (H-type). This construction enables carrying our research work on operating wheels of different number and varying form of the blades, allowing the variation of the angle between the positions of the blades in the frame of the operating wheel.

4. The selection of the methods and devices for measuring the parameters of operation of the stand has been done taking into account the specific character of the basic tasks to solve the problem at this scale and in accordance with the precision required by the standard regulations.

References

[1] International Standard 60193. Hydraulic turbines, storage pumps and pump-turbines – Model acceptance tests. Geneve, 1999.

[2] Grozev G., V. Obretenov. "Manual for laboratory exercises on water turbines pumps and ventilators" (in Bulgarian), Sofia, Publishing House "Technika", 1985.

[3] Obretenov V., Water Turbines (in Bulgarian), Publisher "Ecoprogress", Sofia, 2008.

[4] www.hydrolab.tu-sofia.bg

Biographies

Valentin Obretenov was born in Dryanovo, Bulgaria, on July 2, 1950. He studied at the Technical University of Sofia-Bulgaria and received Dr. degree from the same university in 1982. Since 1976 he worked in the Faculty of Power Engineering and Power Machines of the Technical University of Sofia as a Assistant and Associate Professor in the field of hydropower and hydraulic turbomachinery .

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