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EXPERIMENTAL STAND FOR TESTS ON LOW HEAD CROSS FLOW TURBINES

BY

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Abstract. The production of energy from small hydraulic potential sources is an important target of energy policies. Innovative solutions in order to extend the energy efficient working domain of hydraulic turbines to the very low power rates field are needed nowadays.

The paper proposes an experimental stand to be used for tests on picoturbines and presents a case study that analyzes how the dimension of the stand influences the geometrical parameters and the expected energy efficiency of the turbines to be tested.

Key words: cross flow turbine; experimental stand; picoturbine; renewable energy.

1. Introduction

One of the most important objectives of the Directive 2009/28/EC (H.G. 1069, 2007) is the use of local renewable resources, no matter what the importance of the producer/consumer is. Since large hydraulic turbines already have very good energy performance, nowadays the challenge is to study, improve and construct micro & pico water turbines (Paish, 2002; Nasir, 2013).

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The present paper focuses on research concerning new types of cross flow picoturbines. The cross-flow turbine is also known as the Banki-Ossberger turbine. Donat Banki, a famous Hungarian scientist designed a simple and cheap turbine, presented in a manuscript in 1917 and obtained a patent in 1922 (Banki, 1922). Fritz Ossberger in collaboration with the Australian engineer Anthony Michell obtained an improved version (Ossberger & Michell, 1933) and started production of this machine in his own enterprise.

One important step in the design of a new type of turbine is the experimental study. Mockmore and Merryfield (1949), Desai and Aziz (1944) and Khosrowpanah *et al*. (1988) have found the optimal configuration of their cross flow turbine by experimental analysis.

Experimental analysis requires the setup of an adequate stand. This is the first objective of this paper. The second objective is to find out which should be the geometrical characteristics of a picoturbine to be tested on this stand and which the expected energy performance is.

The classic methodology to design hydraulic turbines is to identify the construction characteristics that can offer the best performance at a given nominal head and nominal flow rate. Most cross flow turbines have a nominal head in the field H = 2.5…200 m (Ossberger, 1986). Sometimes the disposable head load might be very low, even less than 3 m and new types of turbines for low heads are recommended.

The trend of energy policies worldwide is to utilize all the hydro energetic potential of a region. Unlike large and medium hydropower, small hydropower is part of renewable resources domain. Research on the extension of the operation domain in the area of very low heads brought more and more solutions (Sadrul *et al*., 2002). This paper proposes an experimental stand to be used for tests on picoturbines and presents a case study that analyzes how the dimensions of stand influences the diameter of the rotor and the energy efficiency of the cross flow turbine.

2. Stand for Experimental Analysis of Cross Flow Turbines

For ecological and environmental protection reasons, part of the hydraulic potential of hydroelectric power plants is lost, because a servitude flow must be assured. A solution to extract the energy from the lost hydraulic potential is to use a low head cross flow turbine. Moreover, the flow from an irrigation canal has energy potential that is wasted and implementing a picoturbine at the end of it can be a continuous source of cheap electricity. The advantage in using already built canals or hydro-mechanical constructions is that few investments are necessary.

There are already on the market, several construction types of cross flow turbines, which work at small and medium heads. When tests for research purposes are needed, the variation of the head is usually done by the variation of the pressure in the adduction pipe in order to simulate medium heads. Such methods can not be used for a low head turbine and the variation of the head has to be done by changing the position of the turbine towards the upstream flow.

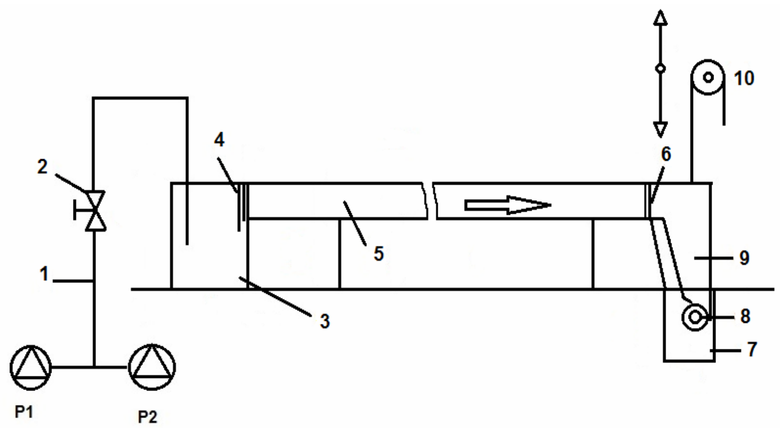

Fig. 1 − Stand for experimental tests on cross flow picoturbines. Side view.

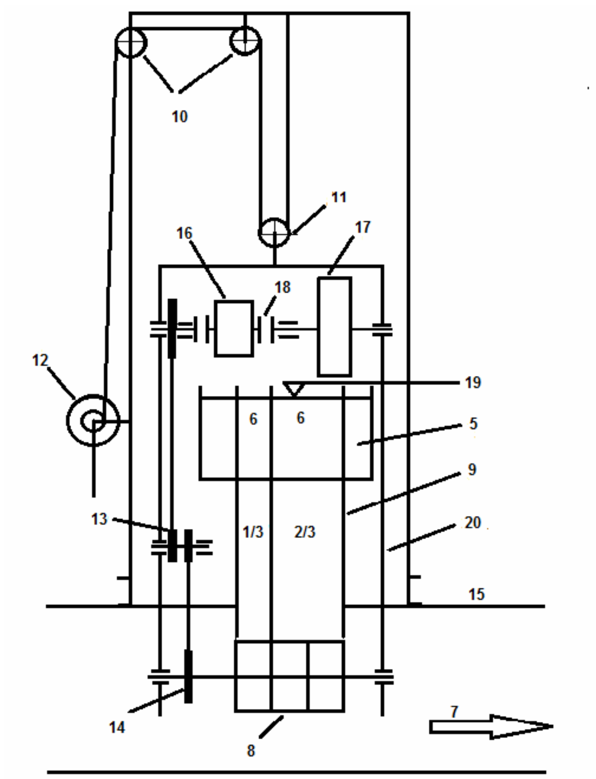

Fig. 2 − Stand for experimental test on cross flow turbines. Front view.

A proposed experimental stand for cross flow turbines is described in Figs. 1 and 2. It contains an open channel and the additional equipment needed to perform tests on a cross flow turbines that has to work at very low heads.

The open channel 5 is fed with water from two centrifugal pumps P1 and P2 coupled in parallel. The pumps deliver the water to pipeline 1 that is connected by the valve 2 to the open channel. First, the water has to pass through a smoothing reservoir 3. In order to reduce the turbulence a rack denoted 4 is located at the exit of the smoothing reservoir.

To guide the flow to the injector 9 of the turbine a contraction area 6 is installed at the end of the channel. Downstream the rotor of the cross flow turbine 8, there is the tail race 7, situated under the floor of the laboratory, denoted 15.

The main problem is how to make possible the modification of the position of the rotor towards the main flow. This paper proposes a lifter-descending system connected to the rotor. During experiments for drawing the characteristics of the turbine, the system can be used to variate the head that is measured from the free surface level 19 to the axle of the rotor 8. Since the weight of the rotor is quite high, the system contains fix load pulleys 10, one mobile load pulley 11 and a cable real 12. A metal frame 20 situated under the level of the channel supports the assembly injector-turbine and guides the lifting/descending movements.

An undesirable phenomena can occur during tests, the acceleration of the rotor. A mecano-hydraulic brake 17 can prevent and stop it.

The mecano-hydraulic brake and the torque transducer 16 are installed on an axle that has the same rotational speed as the rotor 8, by means of a transmission stage in two steps. The transmission steps 13 and 14 use Gall chains. The rotary type torque transducer 16 is placed on the upper shaft by using two flexible couplings 18.

3. Case Study

A stand to be constructed at the Fluid Mechanics and Fluid Machines – ERENED laboratory, “Gheorghe Asachi” Technical University of Iaşi will be analyzed.

The case study is about the experimental possibilities offered by the open channel with 0.76 m width and 0.57 m high. The fluid flow velocity can vary up to 0.5 m/s in this channel, which means that the fluid flow rate is $Q = 0.2\ m^3/s$.

The distance between the free surface of the water and the axle of the rotor is in the field $H = 0.5$-2 m. As a consequence, the maximum hydraulic power of a pico cross flow turbine that has to be tested is 3.96 kW.

In the given conditions, the question should be in this case, which is the recommended diameter of the rotor and the number of blades. One other important problem concerns the expected energy efficiency rate.

Previous studies (INE, 1986; Perez, 2007) recommend selection of the diameter and of the number of blades as it is presented in Table 1. On the graph presented in Fig. 3 it can be noticed that the maximum diameter of cross flow turbines to be tested on the proposed stand is 500 mm.

Table 1
Recommendations for the Design of a Banki Turbine

$Q/\sqrt{H}$	*Diameter* mm	*Number of blades*
0.02236-0.04743	200	22
0.04743-0.07906	300	24
0.07906-0.11068	400	26
0.11068-0.15812	500	28

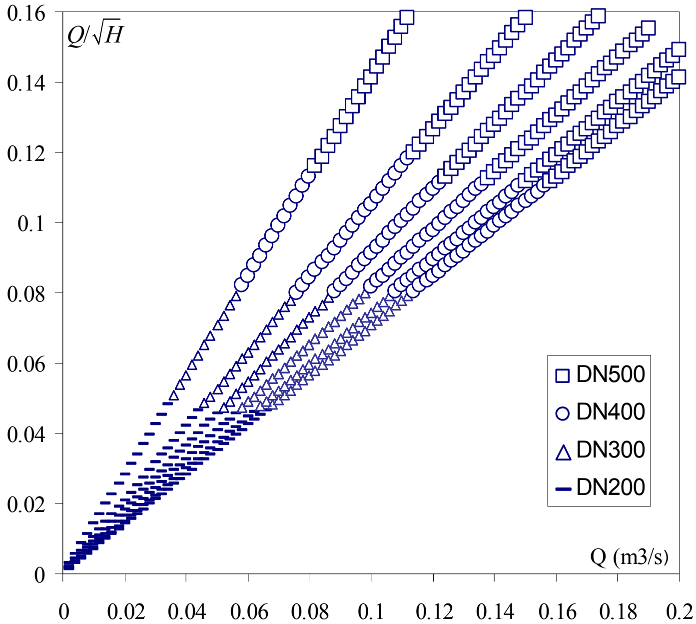

Fig. 3 − Working domain of cross flow turbines to be tested on the stand.

Banki proposed an equation to calculate the maximum hydraulic energy efficiency,

$$\eta_{\max} = 0.771 - 0.334 \cdot \frac{D}{H} \tag{1}$$

The expected energy efficiency rates for the turbines to be tested on the stand described above are presented in the Table 2.

Table 2
The Maximum Energy Efficiency Possible to be Obtained for Cross Flow Turbines

H m	*Diameter* 200 mm	*Diameter* 300 mm	*Diameter* 400 mm	*Diameter* 500 mm
0.5	63.74%	57.06%	50.38%	43.70%
0.9	69.68%	65.97%	62.26%	58.54%
1.2	71.53%	68.75%	65.97%	63.18%
1.5	72.65%	70.42%	68.19%	65.97%
2	73.76%	72.09%	70.42%	68.75%

4. Conclusions

The paper proposes an experimental stand to be used for tests of new types of cross flow turbines. The description of the stand includes details on the devices that are part of it.

A case study is presented in order to illustrate how the dimension of the stand influences the geometrical parameters of the turbines to be tested and the expected energy efficiency.

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STAND EXPERIMENTAL DESTINAT TESTĂRII PICOTURBINELOR TRANSVERSALE DE CĂDERE MICĂ

(Rezumat)

Ultimele tendințe de dezvoltare a cercetărilor în domeniul turbinelor hidraulice indică un interes deosebit pentru zona puterilor mici. În hidroenergetică, turbinele de putere mică sunt considerate ca făcând parte din clasa echipamentelor ce produc energie din resurse regenerabile, deoarece impactul asupra mediului este minim. Un pas esențial în identificarea de soluții inovatoare este testarea pe standuri adecvate.

Lucrarea propune un stand de încercare conceput pentru turbine transversale de cădere mică. Standul este compus dintr-un canal cu nivel liber şi instalațiile conexe turbinei. Pentru un caz particular de stand, ținând seama de dimensiunile constructive ale acestuia sunt analizate limitele instalației propuse. Se determină randamentul maxim posibil a fi obținut pentru turbinele transversale, adecvate condițiilor experimentale oferite de stand. Valorile maxime ale randamentelor hidraulice posibil a fi obținute variază in intervalul 44%-74%.