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On the investigation of parameters of turbine with fluctuating blades

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***Abstract**: Current paper presents basic ideas and goals of the research program for experimental and numerical investigation of a turbine with fluctuating blades.*

***Key words:** experimental and numerical investigation, fluctuating blades, turbine*

INTRODUCTION

The last few decades are characterized by very serious energy problems. During the oil crisis oil prices suffered sharp changes and in addition to this in the same period mankind witnessed irreversible natural disasters and incidents with nuclear power plants. On the other hand constantly is raising the production costs for electrification needs of third world countries. Eventually the world has realized major environmental risks of contemporary energy generation technologies. In this sense, renewable energy sources (RES) offer a reasonable way out of the situation and the prospects are to replace as much as possible conventional energy sources. One of the possible ways is to utilize the energy of sea and ocean waves. For this purpose there are already developed different types of devices

Devices based around the profile of the wave.

The device, developed by Stefan Saltaire from Edinburgh University, was called "duck" (Figure 1). Its shape provides maximum efficient extraction of energy from the wave that enters from the left side and causing oscillation. The cylindrical opposite side ensures that no right wave fluctuations around duck axis O are possible. The power is taken away from the axis of the oscillating system under conditions of minimal impact. The reflection and transmission of energy are negligible (5%) and therefore the device has a high efficiency in a wide range of the frequency of the waves. The development of this construction is towards increasing the shock resistance and create anchored garland of converters as a flexible line. The estimated size of the actual device is 0,1.λ, which corresponds to 10 m and for Atlantic waves than 100 m. Chain of "ducks" of several kilometres in a suitable area can provide a total capacity of 100 MW.

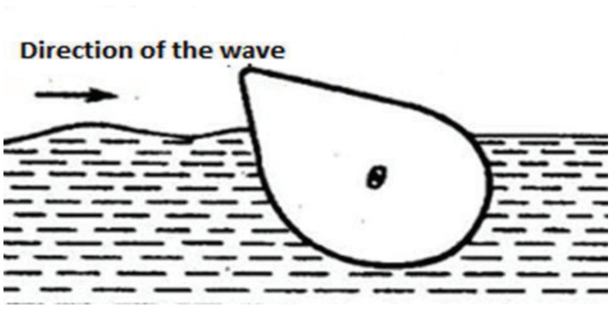


Fig.1 – Stephen Salter’s duck (http://greenenergytechnology87.blogspot.bg)

Oscillating water column.

When the wave is went on partially submerged hollow tower (Fig. 2), which is open under the water, the pillar fluid in the hollow is faltered and this exerts pressure of the air above the liquid. The hollow can be connected with the atmosphere through a turbine. The periodic flow of air in upward and downward direction can be organized so that it will passes through the turbine in the same direction or to use suitable turbine (eg Wells turbine).

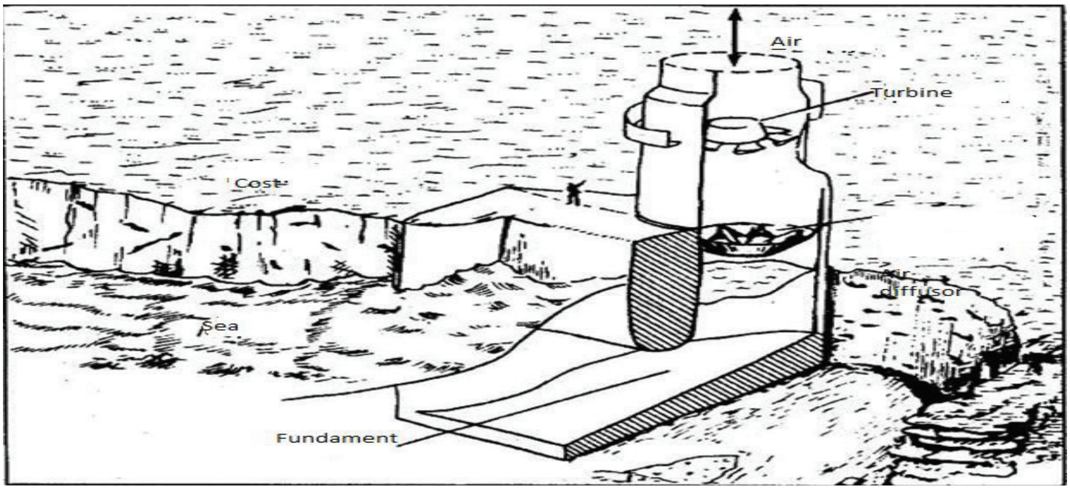


Fig.2 - Oscillating water column (http://greenenergytechnology87.blogspot.bg)

In current paper a new type of turbines is presented that combines the ideas of these two types devices, i.e. turbine with fluctuating blades of the runner. A special feature on these turbines is that they are subjected to alternating axial wrap. This causes the blades to fluctuate around its longitudinal axis. The hydraulic pressure as a force is applied in the static centre of the blade. This force creates alternating point to the longitudinal axis of the blade. This moment is balanced by the moment created by the spring force applied to fluctuating shovel.

METHODOLOGY OF THE STUDY

The aim of the paper is to provide guidelines for future experimental laboratory studies by a test rig. Firstly it is important to relate the variation of the considered parameters $(M_T, V_{cp}, N_T, \eta, \omega_T)$ with the variation of the angle α. This will be made by using kinematic characteristics shown in Figure 3.

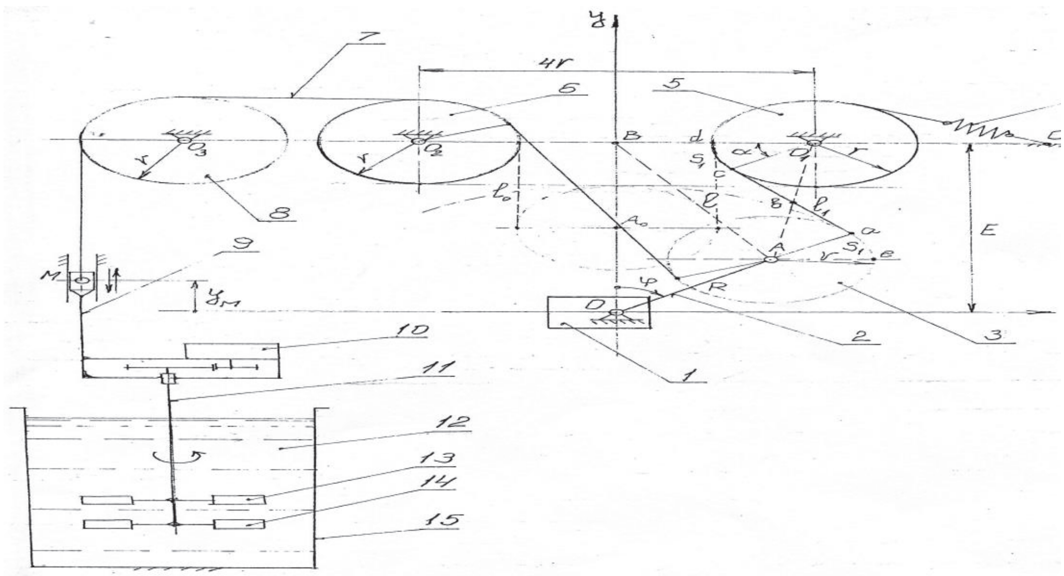


Figure 3- Kinematic scheme of a fluctuating blade

For the proper functioning of the test rig it is necessary to know what is the relationship between the speed of rotation of the crank and the vertical linear speed of the platform.

Referring to the triangle AOB on Fig. 3 formed according to the kinematic scheme, the length l is obtained as a function of the angle φ

$$l(\varphi)=\frac{R}{\lambda}\sqrt{1+\lambda^2-2\lambda\cos\varphi} \tag{1}$$

Knowing the kinematic characteristics of the test rig is necessary in order to determine the law of motion of the platform as a function of the speed of the crank. This makes it possible to determine the maximum speed of the crank using these geometric dimensions resulting from the kinematic diagram according to Figure 3. In a consequent analysis and processing it is obtained the law of motion of the platform, expressing the movement of the M point in Fig. 3.

$$y_M(\varphi)=\frac{2R_{кр}}{\lambda}\sqrt{1+\lambda^2-2\lambda\cos\varphi}+\lambda-1 \tag{2}$$

If the known dependence of drag of streamlined body attached to a freely falling under its own weight wheel and the platform is used, the following relationship can be written:

$$G_{pl}\geq C_x\rho zF_{pl}\frac{v^2}{2} \tag{3}$$

Once the law of the movement of the platform is known its speed is calculated by:

$$V_M(\varphi)=2R_{cr}\omega_{cr}\frac{\sin\varphi}{\sqrt{1+\lambda^2-2\lambda\cos\varphi}},m/s \tag{4}$$

For the acceleration of the platform is obtained the following:

$$a_M(\varphi)=2R_{cr}\omega_{cr}^2\frac{\left(1+\lambda^2-\lambda\cos\varphi\right).\cos\varphi-\lambda}{\left(1+\lambda^2-2\cos\varphi\right)^{1,5}},m/s^2 \tag{5}$$

Given that the weight of the platform is known along with the speed of movement, the critical speed of the crank, which must not be exceeded, can be determined

$$n_k\leq\frac{15}{\pi R_{кр}}\sqrt{\frac{2G_{pl}}{C_x\rho zF_{pl}}} \tag{6}$$

Once the main kinematic parameters of the platform motion are known another milestone in the experimental study is to measure the value of the resulting torque M_T and the consequent crank revs.

For this purpose is using the known method for measuring the moment shown in Fig.4.

According to Euler the timing M_T is determined by:

$$M_T=\left(P_2-P_1\right)r_c,N.m \tag{7}$$

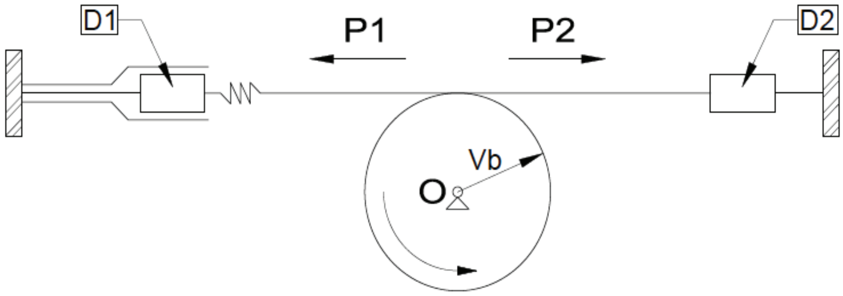
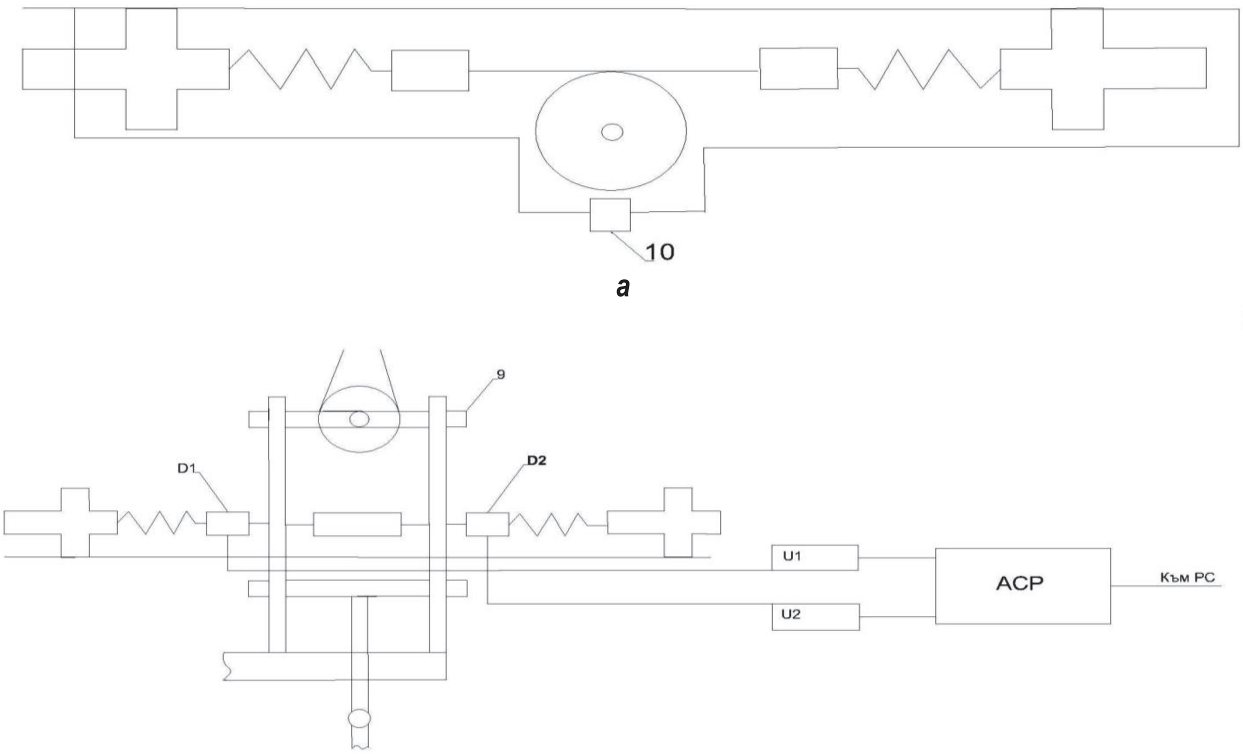


Fig. 4- Method of Euler



a

b

Fig. 5-Scheme of the measurement

The measurement is done by two dynamometers working on strength. It is use foil dynamometers which are connected in Scheme of -Wheatstone bridge with supply voltage 5V, resistivity of the shoulders of the bridge $R = 350\Omega$ and the sensitivity of the bridge $2\frac{mV}{V}$.

Structural scheme is shown in figure 6.

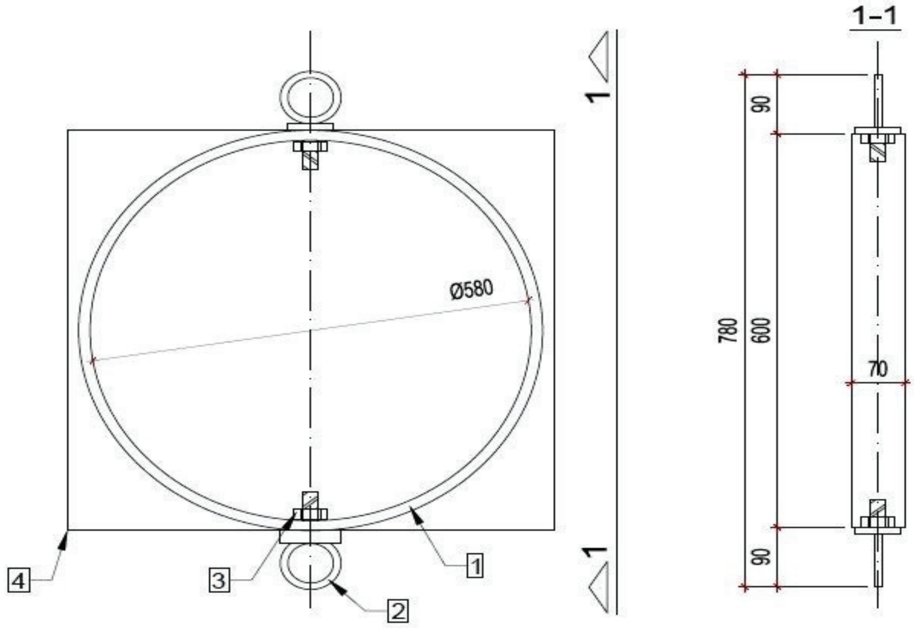


Fig. 6 - Structural scheme

The entire facility is placed in a box in the front and back of the box has a ring to which is attached cord work, and on top laboratory version is displayed for output to strain amplifier with digital recording. Previously is performed calibration of dynamometers. It is used thin cord for realizing shut (friction) moment on the turbine shaft. Since according to equation (6) the measurement concerns only the difference between the forces and is not necessary to know what the value of the coefficient of friction of the cord used.

As the information from strain gauges in the form of an electrical signal can be switched ADC and the signal is fed to a computer for processing.

DESCRIPTION OF NUMERICAL EXPERIMENT

Based on the described parameters for turbine with fluctuating blades a numerical study will be conducted of different types of the turbine and its blades using a commercial software package FLUENT 6.3.12.

The procedure for conduction of the numerical simulations is as follows:

Buliding the geometry. The geometry of the turbine will be built on the FLUENT pre-processor - GAMBIT, the dimensions of numerical area will be consistent with existing experimental research in order to optimize and shorten the design time.

Meshing the model. Developing a good numerical grid is essential for the numerical study as it is preconditions the adequacy of the results. In this case study the behavior of turbine with different diameters network quality is essential for true and detailed presentation of the efficiency of the test – rig. The two main parameters that determine the accuracy of the numerical results and need to be controlled are:

- Number and type of the control volumes;
- Mesh quality.

Mathematical model: To close the system nonlinear partial differential equations three turbulence models will be applied: a standard k-ε model, k-ω model and Reynolds stress model.

Processing and visualization of results: the results obtained by the simulations will be visualized and analyzed with Fluent post processing panels as well as with Tecplot software package.

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This paper has been reviewed.