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On the possibility for sea and ocean waves energy utilization by a turbine with fluctuating blades

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Abstract. *In the current work the operation principle of a new type of water turbine constructed by the authors is presented. This turbine which may utilize the energy of the sea and ocean waves is with fluctuating blades. The kinematic scheme of the turbine is presented and on its basis the main turbine parameters - revs and linear velocity, are defined. In addition to this a test rig for investigation of the turbine parameters is presented.*
Key words: *turbine, fluctuating blades, energy from sea and ocean waves*

1. Introduction

Depletion of reserves of conventional energy sources increased the energy prices, environmental pollution from burning of fossil fuels, global warming and climate changes worldwide. This more and more pressing issue leads to two logical starting points:

- Reduction of fossil fuels as an energy source
- Utilization of energy from local renewable energy sources (RES).

Renewable energy is attractive because it is generated with no or only a little pollutants of the environment, available resources are renewed and, in fact, they will never be exhausted. [6, 7]

Basic renewable energy sources are:

- solar energy;
- tidal energy;
- geothermal energy;
- wind energy;
- energy of sea and ocean waves;
- biomass ;

Covering the energy demand of the humanity, and preserving the ecological balance of the earth, is possible only if the inexhaustible energy of the environment is used. Current work is dedicated to the utilization of the energy of the sea and ocean waves as a renewable energy source. [1,2,3,4,5]

Devices for converting the wave energy along with changes in the level and slope of the surface wave may utilize the changes of the kinetic and potential energy and pressure in the wave. Devices converting wave energy are diverse consistent with typical values that define their work. Some of the main inventions in this direction are listed below:

- Salter's duck (Fig.1) – This is a wave energy device invented by Stephen Salter at the University of Edinburgh during the oil crisis in the 1970s. The device is also known as nodding duck or Edinburg duck. Its shape provides the most efficient extraction of energy from the waves that enters from the left side on figure 1, and thus causing oscillation. The cylindrical opposite side ensures missing of no right wave fluctuations in duck currently stationed around the axis O. The power is taken away from the axis of the oscillating system under conditions of minimal impact. The reflection and transmission of energy and therefore the device has high efficiency in a wide range of wave frequencies.

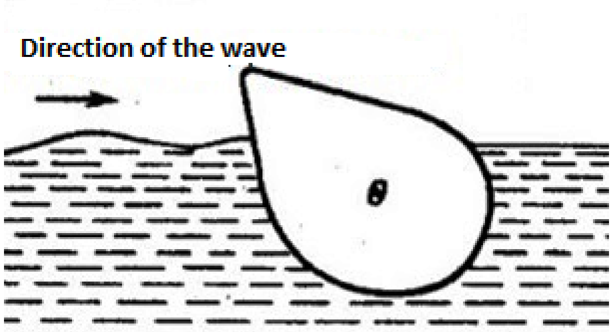

Fig.1 – Stephen Salter's duck (http://greenenergytechnology87.blogspot.bg)

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

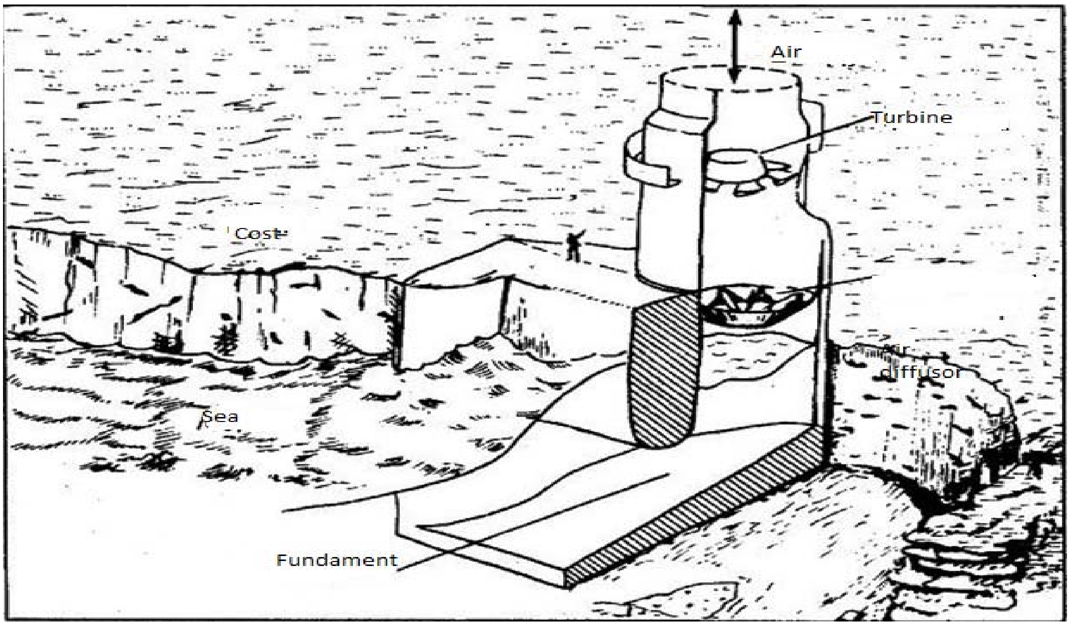

Fig.2 - Oscillating water column (http://greenenergytechnology87.blogspot.bg)

The aim of current paper is to present an idea and model of a test rig for investigation of turbines with oscillating blades that use the energy of the sea and ocean waves. This test rig will be used for experimental study under laboratory conditions.

2. Kinematic scheme

The operation principle of the turbine with oscillating blades is the following: the turbine wheel is mounted on a vertical shaft which is connected with a platform located on the free sea surface and moves up and down under the action of the waves. When this movement produces torque relative to the shaft, which is mounted on the wheel, which is transmitted to the platform, the energy (created torque) is utilized. Since the first experiments will be performed under laboratory conditions, it is clearly necessary to adopt the following scheme of movement for obtaining the desired effect: the turbine wheel is immersed in a tank of still water, and the platform to which is attached the shaft carrying the working wheel is forced to perform reciprocating movement up and down thus imitating sea waves.

Such a scheme of movement is achieved through the test rig shown in Figure 3, whose kinematic scheme is shown in Fig. 4. The kinematic scheme enables the necessary kinematic relations to be determined.

Figure 3 shows the construction of the test rig, which consists of the following elements.

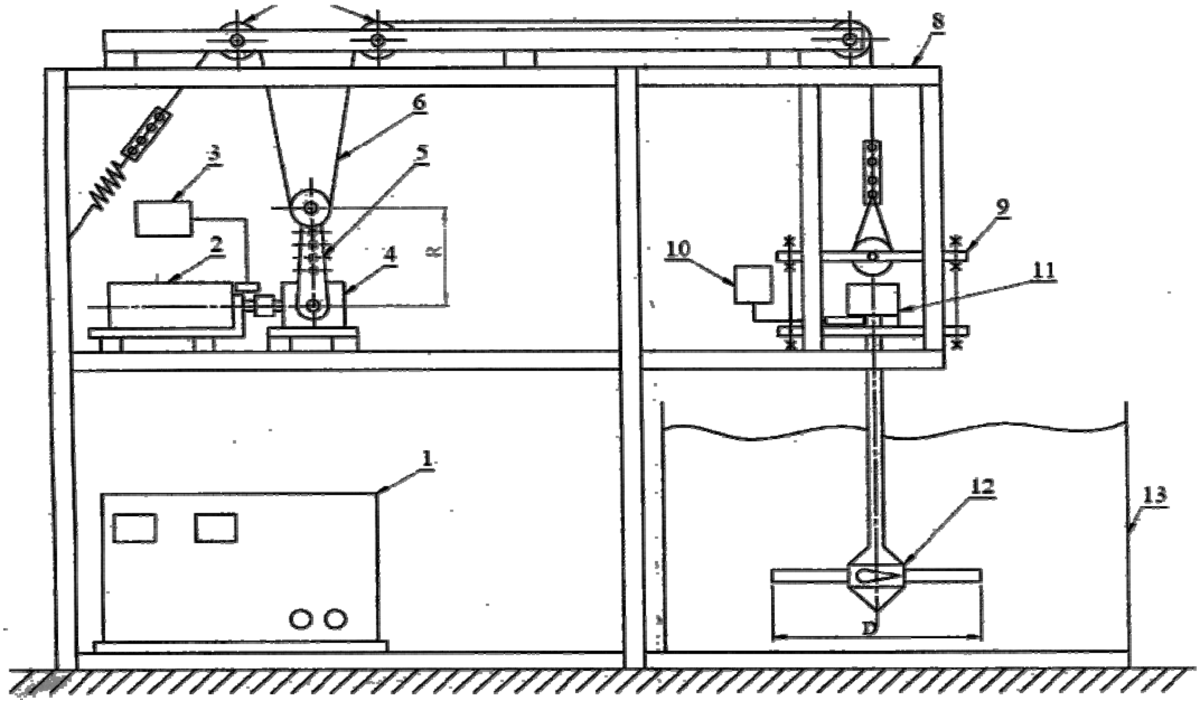

Fig.3 – Construction of the test rig

1 - Rectifier, 2 - DC electric motor, 3 - Tachometer, 4 – Speed Reducer, 5 - Crank, 6 - Lanyard, 7 - Guiding rollers, 8 –Framework, 9 - Mobile platform, 10 - Cyclometer, 11 – Generator, 12 – Impeller, 13 - Water tank

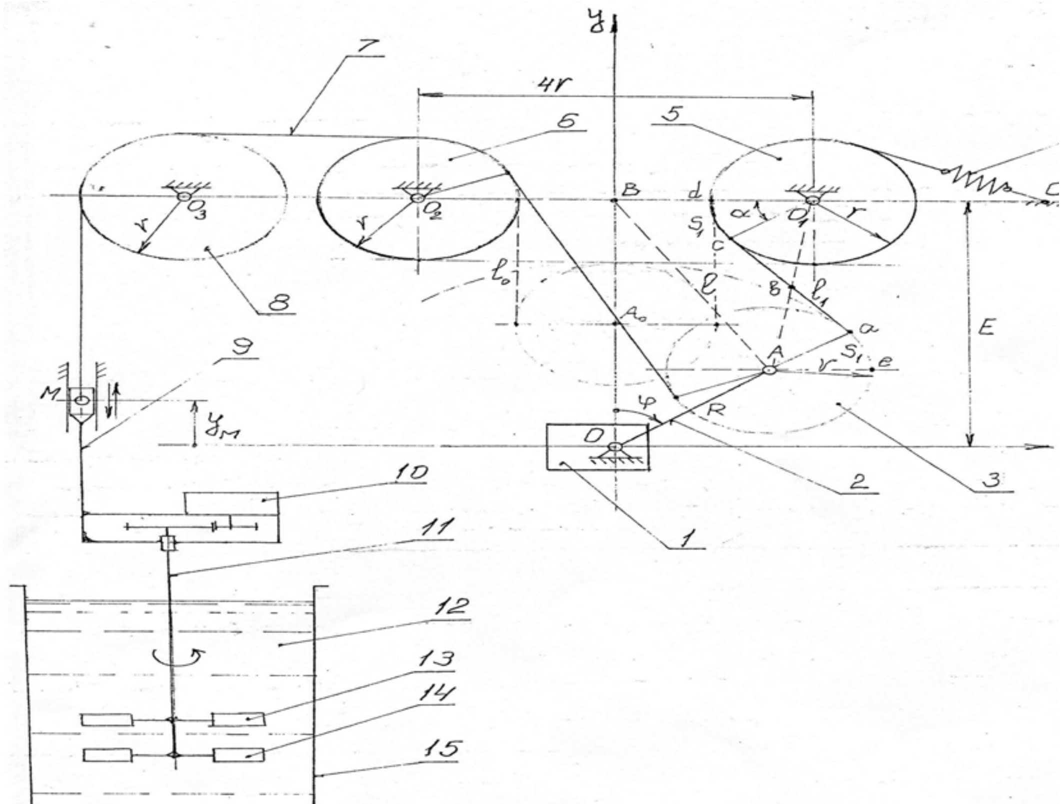

Fig.4 – Kinematic scheme

The operation of the test rig is performed in the following manner: the rectifier 1 supplies the DC motor 2 with electricity and by changing the rotational velocity of the electric motor 2, respectively of the crank 5, which via a system of rollers moves the platform 9 up and down, thereby mimics the behavior of the sea waves. Consequent of the movement of platform 9 the immersed turbine wheel starts to spin, consequently rotating and the shaft on which it is installed. This makes it possible to measure directly the resulting torque and the vertical speed of the impeller (turbine) by the cyclometer 10.

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. 4 formed according to the kinematic scheme, the length l is obtained as a function of the angle φ

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

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 4. 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. 4.

$$y_M(\varphi) = \frac{2R_{\kappa p}}{\lambda}\sqrt{1+\lambda^2 - 2\lambda\cos\varphi} + \lambda - 1 \qquad (2)$$

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:

$$G_{pl} \geq C_x \rho z F_{pl} \frac{v^2}{2} \qquad (3)$$

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

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

For the acceleration of the platform is obtained the following:

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

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

$$n_k \leq \frac{15}{\pi R_{\kappa p}}\sqrt{\frac{2G_{pl}}{C_x \rho z F_{pl}}} \qquad (6)$$

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 time M_T and the consequent crank revs.

According to Euler the timing M_T is determined by:

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

3. Construction of the test rig

Regardless of the direction of passage of the water through the turbine wheel it is designed so that the direction of rotation of the impeller is not changed. It is known as Wells turbine. These rotors operate continuously under variable speed and pressure of the fluid flow. In order high effectiveness to be achieved, the rotors have to be optimized as the wave energy is not transmitted directly to the turbine wheel. The constructed turbine with fluctuating blades has the advantage that the transmission of the wave power on the turbine wheel is direct, which leads to higher efficiency of the facility. This effect is achieved by constructing the turbine with fluctuating blades as shown in Fig. 5 and 6.

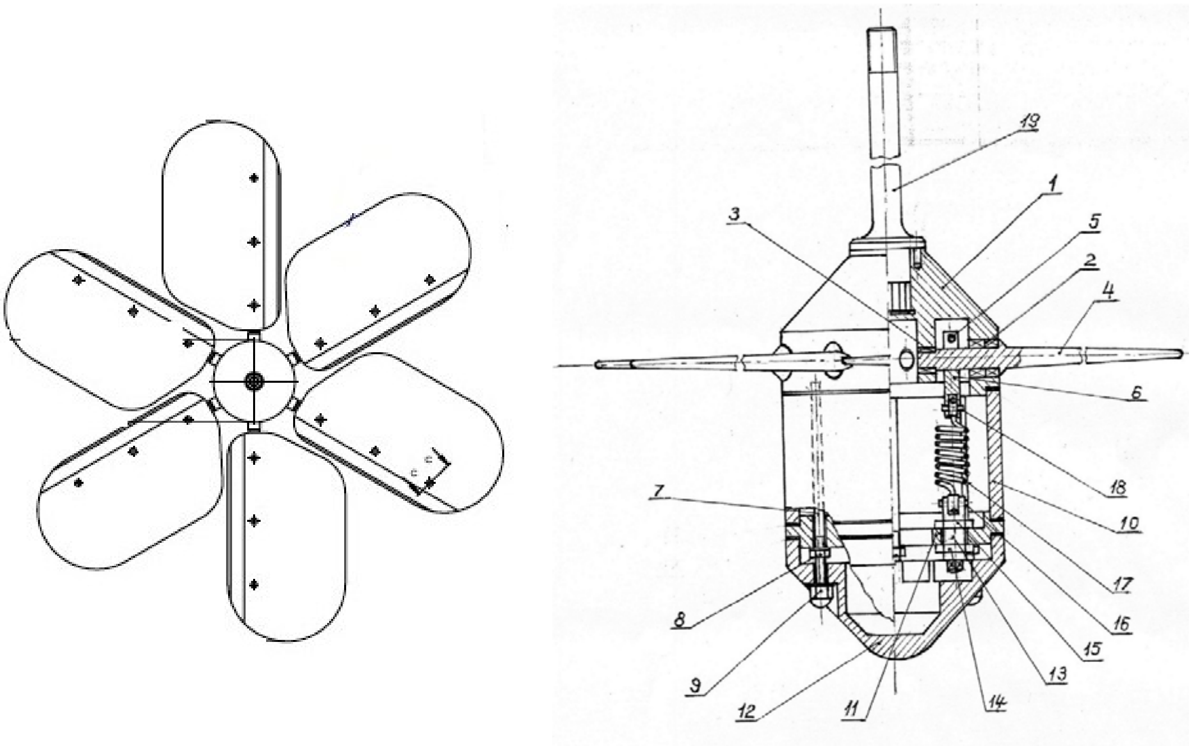

Fig.5 Sketch of the turbine wheel

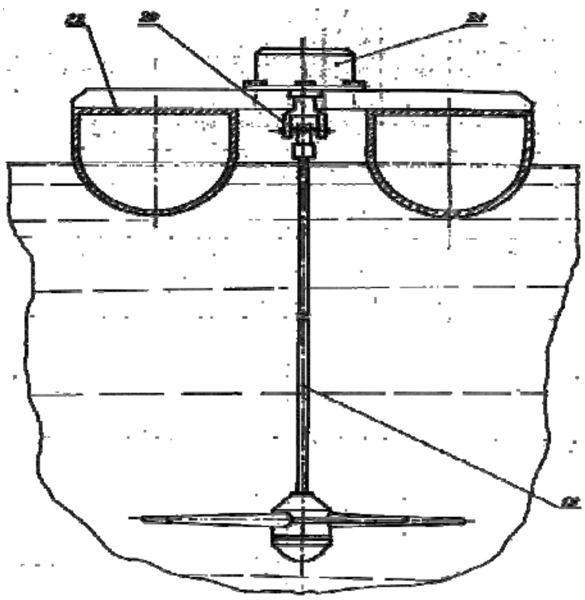

Fig.6 Sketch of the test rig

In the center of the hub of the turbine 1 through a rigid connection is mounted vertical shaft 19 which via a universal connector 20 is connected to an electrical generator 21 mounted on the movable platform 22 situated on the free water surface.

The reciprocation of the turbine wheel takes place in the following way - fig.5. The mobile platform 22 moves up and down with the behavior of a wave, as a result of this movement on the fluctuating blades 4, alternating moments are exerted according to hydraulic axle bearings 2 and 3. These moments are sign varying and are in equilibrium with the spring moments created from the main springs 17. The hydraulic force applied to the static centers of the fluctuating blades 4 have horizontal components which create torque to the vertical shaft in vertical direction.

The moment and the rotation of the hydraulic turbine with fluctuating blades determine the power of the turbine. This power through the vertical shaft 19 and PTO clutch 20 is transmitted to the electric generator 21 located on the platform 22 for utilizing of the received energy.

For a turbine with the following design parameters: $n_{cr} = 60\min^{-1}, z = 6$, $F_1 = 0,026m^2$, $r_w = 0,18m$, $\alpha = 30^0$, $r_d = 0,05m$ experimentally are determined its main parameters, moment, revs and power, by using the equation given above.

$$M_T = 0,494kg.m$$

$$n_T = 18,34\min^{-1}$$

$$N_T = M_T.n_T = 0,015kW$$

Conclusion

The utilization of the renewable energy sources is essential for the growing needs of the modern world. Capturing and converting the energy from sea and ocean waves is just one of the possibilities but with large potential.

The presented hydraulic turbine with fluctuating blades utilizes the kinetic energy of moving water into water courses, either sea or ocean. The movement of large water masses is carried out periodically in the form of tides or lifting and lowering (wave motion of the water), which brings tremendous energy. The hydraulic turbine with fluctuating blades constructed by the authors has the advantage that converts directly the reciprocation of the platform into rotation of the turbine shaft and thus a high efficiency of the hydro-generator would be achieved.

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