Experimental investigation of water turbine with oscillating blades

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Abstract. Energy from renewable sources reduces greenhouse gas emissions and lowers our dependence on imported fossil fuels. In the presented work, a new way of harnessing the energy of sea waves is given, namely a turbine with oscillating blades. The experimental stand on which the experimental tests were carried out at different revolutions of the hydromotor of the turbine and at four different angles of the blade is presented.

1 Introduction

Electricity is the main driving factor for the development of all branches of industry, transport, utilities and agriculture. It plays an ever-increasing role in the acceleration of technical progress, ensures high rates of labor productivity, improves working conditions, living conditions, exerts an enormous influence on the distribution of productive forces and, more than any other factor, determines the level of the economic development of the national economy and the national income of society.[1-2]

Forecasting the development of global electricity production for several decades is complicated by many factors. It is assumed that by the end of the century, the production of electrical energy will reach 20-25 trillion kWh worldwide, and according to other data, 30-35 trillion kWh [2]. The issues of effectively meeting energy needs and overcoming the global energy crisis are particularly relevant today. Proceeding from the real objectivity - reduction of energy-raw resources (oil, coal, natural gas and others), the tendency to solve the energy problem is imposed, at the expense of the rational use of one's own resources - taking into account the geographical, natural-economic specifics and the scientific and technical potential of each country [1].

Waves have the highest energy density of renewable energy sources, compared to others like wind, solar, biomass and geothermal. This means waves have the greatest potential to be an important contributor to the world's "energy mix resilience" [3,4].

In the works, an experimental study of a new hybrid system for the utilization of wave energy is made. This experiment is based on already done analytical studies in [5-6].

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2 Experimental test-rig

The turbines are driven by a hydraulic station, which drives a hydraulic motor, which in turn transmits the movement to the turbines. In the first case, by means of a steel rope coupled to the hydraulic motor and the eccentric roller, it simulates the movement of waves in the seas and oceans, thus the turbine with the oscillating blades rotates and generates its power. When the turbine with oscillating blades Figure 1 lowers and raises its blades, they change their angle of attack and thus utilize the energy of the wave. [7].
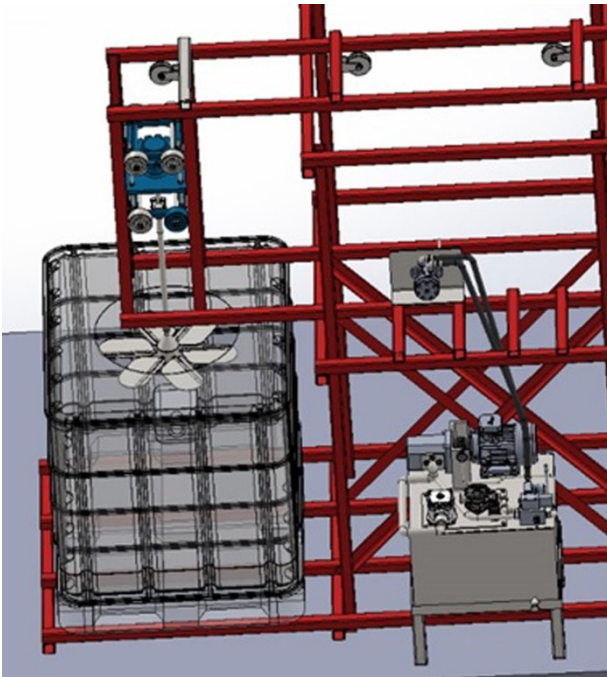
Fig. 1. Experimental test-rig.

2.1 Description of the experiment performed

The oscillating blade turbine experiment is to limit the working blades of the turbine to different angles.

The blades, being of the oscillating type, follow the amplitude of the wave and change their angle of attack. The operating range at the different wave levels that follow vary from (- 90° to 90°). The limitations of the angle of the blades of the turbine is presented in Figure 2.

In order to confirm the angle of attack of the blade through which the turbine has the highest revolutions respectively and torque of the developed bench, the following elements are adjusted.

Fig.2 Turbine with oscillating blades.

The oscillating vane turbine performs the wave amplitude using a hydraulic system to which a "crankshaft" is attached, which serves to change the wave amplitude in its experimental test. The rotation frequency of the crank is set by the hydraulic motor connected to the hydraulic system. In order to carry out the experiment, it is necessary to attach the following measuring devices to the stand, which will measure the quantities and parameters requested by us. A shaft speed or so-called wave frequency or amplitude sensor is mounted on the drive shaft of the hydromotor. A digital tachometer is attached to the shaft of the turbine with oscillating blades for measuring the revolutions of the turbine, a torque meter measures the torque realized by the turbine, as well as an additional brake to load the shaft of the turbine to measure the torque. In Figure 3 shows the system for measuring the parameters of the turbine shaft, where: 1 – Hydraulic motor;2 – Crank (Through it we determine the amplitude of the wave (It has the different sizes 50, 70, 90, 110, 150 mm));3 – Construction (or supporting frame of the elements);4 – Scale for load settings on the turbine; 5 – Flywheel;6 – RPM sensor; 7 – Coupler (between the turbine load and the torque sensor);8 – Torque meter ;9 – Coupler (between the torque sensor and the turbine shaft);10 – Cardan coupling (used so that the turbine shaft can be moved smoothly along the three axes);11 – Turbine shaft; 12 – Supporting frame of the test-rig;

Fig.3 Scheme of the measurement.

Each test shall be carried out according to the following procedure:

1. The hydraulic system is turned on;

2. The revolutions of the hydraulic motor are set to a certain value that we need (in this case, we have selected the following revolutions of the output shaft of the hydraulic motor of 10, 19 and 23.5 min-1);

3. After the adjustment, the measurement of the revolutions of the turbine shaft begins;

4. The torque measurement is visualized on the torque meter monitor;

5. The load (brake) of the turbine can be changed, and in the case of the test it is set to a certain load desired by us;

6. If necessary, the amplitude of the wave can be changed using the Crank.

3 Results

The initial data of the experiment are given at Table 1:

Table 1. Initial data of the experiment

r_{cr}	D_{1tur}	D_{2tur}	z	F_l	$r_в$	ρ	δ	$R_{кр}$
m	m	m	num	m^2	m	kg/m^3	mm	m
0.18	0.5	0.08	6	0.026	0.05	1000	12	0.09

The blade angle is $55^0, 60^0, 65^0, 70^0$. We choose this value due to our results at [7].
The average velocity of the turbine is determined by:

$$V_a = \frac{2R.n}{15} \tag{1}$$

The power of turbine is determined by:

$$N_T = 0,00145 z \rho F_1 \sin\alpha \left(V_a \sin 2\alpha\right)^3, kW \tag{2}$$

The torque of the turbine is determined by:

$$M_T = 0,4437 a z \rho F_1 \sin\alpha \left(V_a \sin 2\alpha\right)^2, \tag{3}$$

where R - radius of the crank, m, n - revolutions,min $^{-1}$ z- number of blades, F_1 - face of blades, m^2, α -angle of the blades.

At Table 2, 4, 3 and 5 are given the results which is obtain from the experiments.

Table 2. Data at angle of the 55.

-	$n_{hм}$, min^{-1}	n_t, min^{-1}	Mt,N.m
1	10	7	1,01
2	19	35.1	1,08
3	23.5	44	1.146

Table 3. Data at angle of the 60

-	$n_{hм}$, min^{-1}	n_t, min^{-1}	Mt,N.m
1	10	8	1.1
2	19	35,6	1,18
3	23.5	48.5	1.285

Table 4. Data at angle of the 65

-	$n_{hм}$, min^{-1}	n_t, min^{-1}	Mt,N.m
1	10	9	1.23
2	19	39.1	1.4
3	23.5	51.2	1.41

Table 5. Data at angle of the 70

| -	n_{hM},min^{-1}	n_t, min^{-1}	MtN.m
1	10	11	1.26
2	19	40	1.42
3	23.5	52	1.52

where n_{hm}-revolutions of hydro motor and n_t-revolutions of turbine.

Based on equation 1-3 is made calculation using the initial date given in Table 1 to 5.

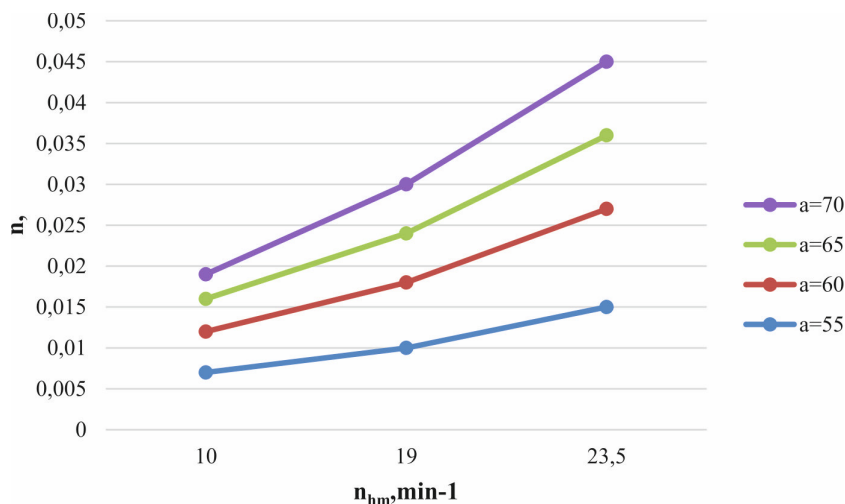t Figure 4 is given the distribution of torque at different angel of the blades.
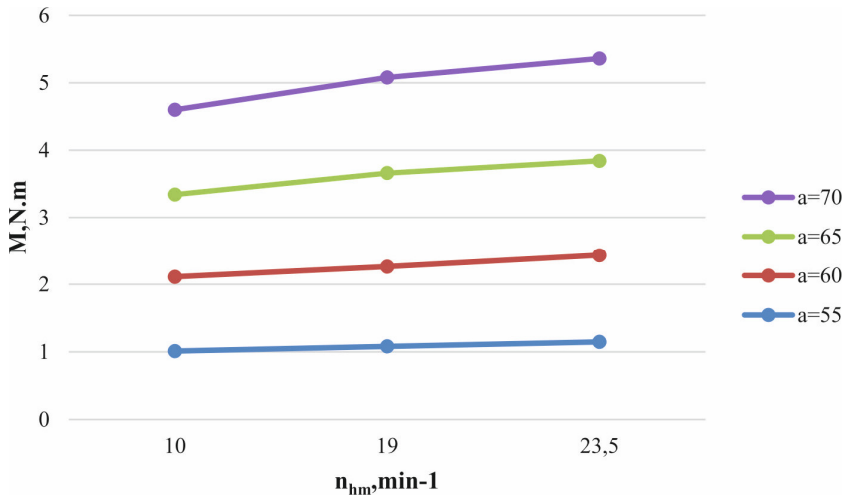
Fig. 4. Distribution of the torque.

At Figure 5 is given the distribution of the power of the turbine at different angle of the blades.
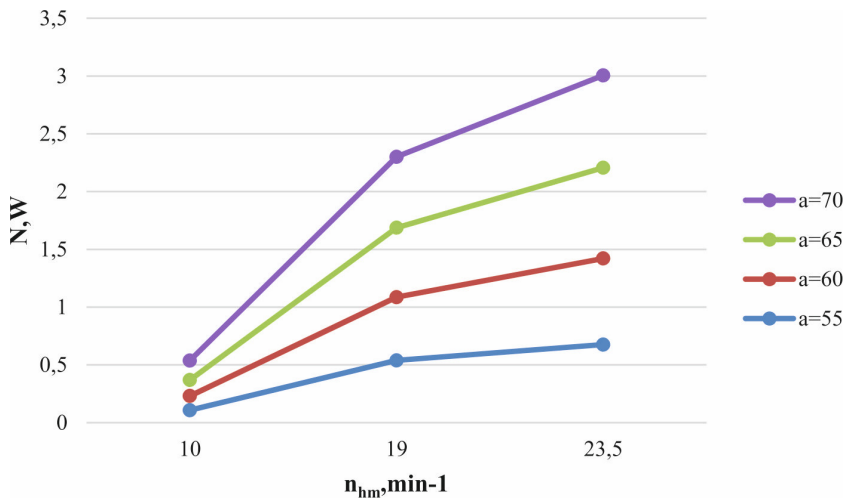
Fig. 5. Distribution of the power of turbine.

At Figure 6 is shown the efficiency at different angel of the blades.

Fig. 6. Distribution of the efficiency.

From the obtained results, it can be seen that as the blade angle increases, both the torque and power of the turbine increase. In contrast, as the vane angle increases, the efficiency decreases. It can be seen that at angles 65^0 and 70^0 we have a much higher efficiency.

4 Conclusion

The presented paper presents experimental results of an oscillating blade turbine that harnesses the energy of sea and ocean waves. Several vane angles were investigated and these results are graphically presented. From the obtained results, it can be seen that the use of this type of turbine is quite effective and can help reduce the carbon footprint in nature. The results obtained from the analytical study [7] completely coincide with the data obtained from the experiment, which leads to the conclusion that the methodology used is effective and can be applied in practice.

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