[1.]Tihomir MAČKIĆ, [2.]Goran JOTIĆ, [3.]Milan TICA, [4.]Jovica ILIĆ

MECHANICAL PROPERTIES OF MODIFIED FLIPWING HYDROKINETIC TURBINES

[1.]Mechanical Faculty of Banja Luka, Banja Luka, BOSNIA & HERZEGOVINA

Abstract: Energy demand from renewable sources imposes the need for the development of new types of water turbines in the field of hydrokinetic turbines. In this paper experimentally examined the mechanical properties of hydrokinetic turbine type Flipwing. Two shapes and sizes of blades were used, with some turbine design variations. Compared to the basic version of the Flipwing turbine, using modified design has yielded significant increases in turbine power.
Keywords: hydrokinetic turbine, Flipwing, design optimization, power measurement

INTRODUCTION

Hydrokinetic power is defined as the power derived from the kinetic energy of the water flow. Unlike a water-head turbine which convert potential energy of water to mechanical energy, hydrokinetic water turbines or water stream turbines uses kinetic energy from fast flowing water. The presence of water turbines that can use the kinetic energy of water is insignificant, because of the low efficiency and cost-effectiveness.

Flipwing turbine is horizontal axis hydrokinetic turbine, which was patented by the company Hydrovolts [1]. The rotor consists of 4 freely rotating blades (Figure 1), which stops at the central shaft. The efficiency of this turbine is 10% [2].

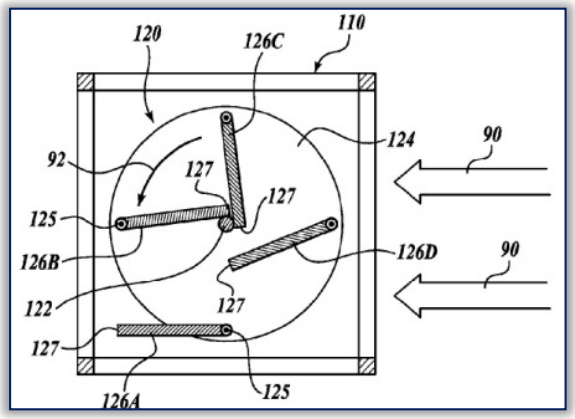
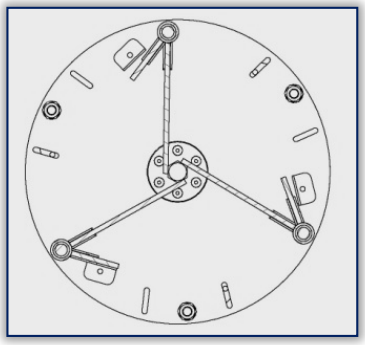


Figure 1. Flipwing turbine from Hydrovolts [1]

Company R+T Fliesenhandels GmbH has improved and simplified the design of the rotor of Flipwing turbines, reducing the number of blades on 3 and adding smaller blades (Figure 2a), which allowed a larger grip. This led to an increasing of efficiency to14%. This result is given in a report submitted by the Vienna Model Basin Ltd [3] (Figure 2b).

Some types of hydrokinetic turbines, which have a more complicated rotor design, achieve significantly higher efficiency than the Flipwing turbine [4, 5]. The aim of this work is to perform optimization, through modifying the design of housing and rotor blades of Flipwing turbines, to maximize efficiency.



(a)

ANALYSE

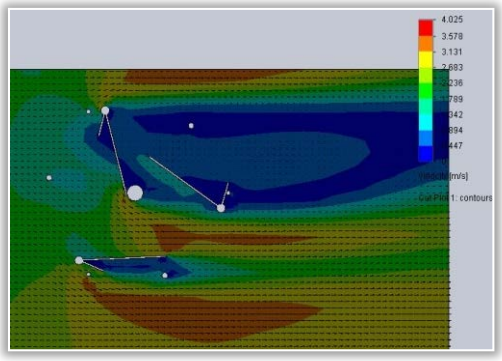
V_w [m/s]	Q_s [Nm]	n_s [rpm]	P_D [W]	η [-]	c_w [-]
2.0	126.7	32.2	426.7	0.147	1.481
2.5	198.7	38.5	800.3	0.141	1.318
3.0	268.8	45.3	1274.4	0.130	1.180
3.5	288.0	58.8	1772.3	0.114	1.254
4.0	283.1	75.8	2247.0	0.097	1.495

(b)

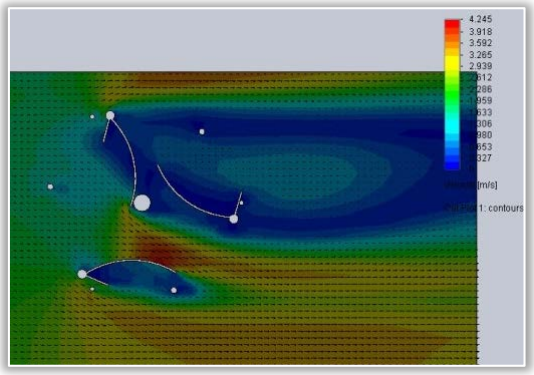
Figure 2. Modified Flipwing turbine with 3 blades and the efficiency results

DESCRIPTION AND TECHNICAL CHARACTERISTICS

At the beginning, a simple CFD analysis was performed (Figure 3) to determine the optimum shape and radius of the blades. It has also been found that increasing the number of blades effects in increasing the efficiency.



a)



b)

Figure 3. Simple CFD analysis with flat and curved blades

Accordingly, the rotor of the modified Flipwing turbine was made in two different construction solutions, in terms of rotating blades:

- Solution 1 - double wooden flat blades (Figure 4a),
- Solution 2 - single metal curved blades (Figure 4b).

a)

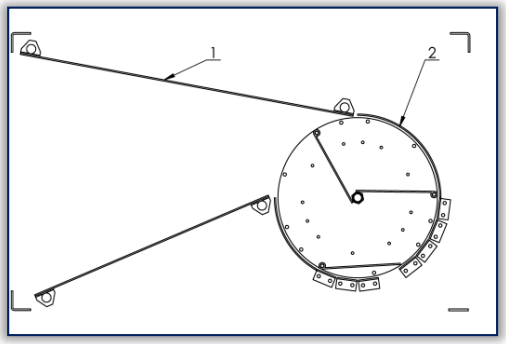
b)

Figure 4. Two different construction solutions of blades

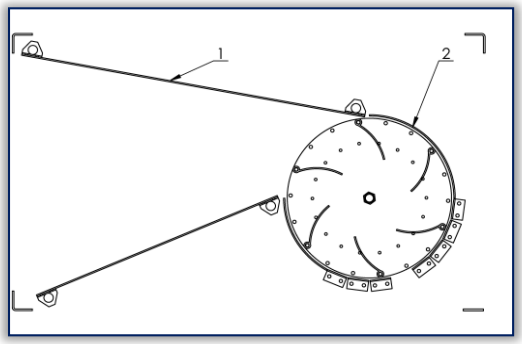
The rotor parameters for the proposed two construction solutions are as follows:

Parameters	Solution 1	Solution 1
number of sections	4	4
rotor length	2180	2180
rotor diameter	700	700
number of blades	12	24
dimension of blades	500 x 340	500 x 170
blades radius	0	160 mm
working angle of blade (˚)	75	30, 75, -

In addition, turbine rotors are placed in a special housing (Figure 5). On the front side of the housing there is an element for directing the water flow (1) or inlet part, while on the rear side are secured arc segments that can be disassembled. The aim is to examine the impact of individual housing segments on the overall power of the turbine.



(a)



(b)

Figure 5. Special housing of turbine rotors

POWER MEASUREMENT AND RESULTS

In the process of measuring the power of the turbine, the direct (in-line) method of the torque measure was used. The method implies that the sensor is mounted directly in the transmission. The power generated by the turbine rotor is obtained by the indirect measurement method using the following form:

$$P = M \cdot \frac{\pi \cdot n}{30} \ [W] \qquad (1)$$

where is: M – the value of the measured torque on the transducer,

n – angular speed of output shaft.

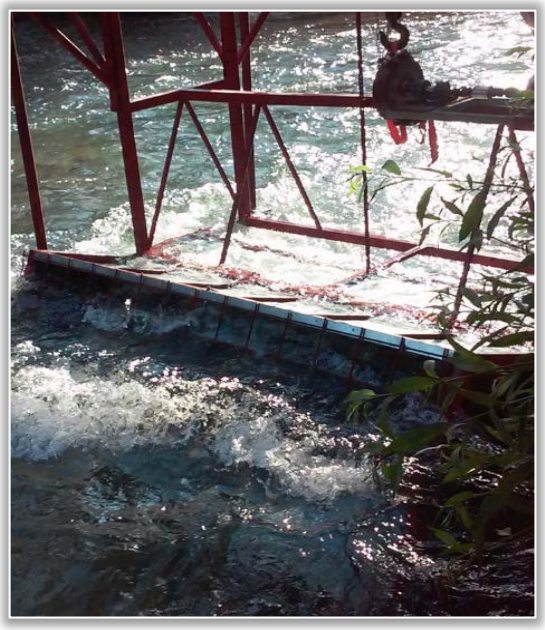
The calculated power is increased by the value of power losses in the transmission elements. The following measuring equipment was used in the

process of measuring torque and angular speed (Figure 6a):

- torque transducer 2 kNm,
- preamplifier MD 18,
- universal measuring amplifier HBM Darmstadt Germany,
- friction brake and
- angular speed encoder L-TACHO.

During measurements, the turbine with inlet part is immersed in the water to the level of complete turbine maintenance (Figure 6b).

(a)



(b)

Figure 6. Measurement of the power of modified Flipwing turbines

Torque and angular speed measurements were performed by multiple sampling with the same and different operating modes of the turbine.

The results of the measurements for the first construction solution are shown in Table 1 and for second construction solution are shown in Table 2.

Table 1. Measurement results – 1st construction solution of rotor

Water speed [m/s]	Torque [Nm]	Angular speed [min^{-1}]	Power [W]	Note
1.4	19	85	169	2.1.
1.4	18.5	76	147	2.2.
1.4	26.4	71	196	2.3.
1.6	17.8	115	214	2.1.
1.6	17.7	117	217	2.1.
1.6	15.3	137	219	2.1.
1.6	26	92	250	2.3.
1.6	19.8	123	255	2.3.
1.6	14.2	113	168	2.4.

Note:
2.1. Measurement without housing and inlet part.
2.2. Measurement with housing and without inlet part, partially immersed.
2.3. Measurement with housing and inlet part, fully immersed.
2.4. Measurement without the rear side.

Table 2. Measurement results – 2nd construction solution of rotor

Water speed [m/s]	Torque [Nm]	Angular speed [min^{-1}]	Power [W]	Note
1.4	15.8	51	84.3	3.1.
1.4	18.3	45	86.2	3.2.
1.4	22	38	87.5	3.3.
1.4	32	71	238	3.4.
1.4	30.6	79	253	3.5.

Note:
3.1. Measurement without housing and inlet part. Short working angle of blades.
3.2. Measurement without housing and with inlet part. Short working angle of blades.
3.3. Measurement with housing and inlet part. Short working angle of blades.
3.4. Measurement without housing and with inlet part. Long working angle of blades.
3.5. Measurement with housing and inlet part. Long working angle of blades.

SUMMARY

Experimental results have shown that the power of the Flipwing turbine increases if the rotor is made with a larger number of curved blades. The best result was design with 6 curved blades. allowing long working stroke of blades (for a working angle of 75°). Compared to the original design with three flat blades. an increase in power was achieved up to 40%.

The turbine housing has a different effect on the increase in power at the proposed structural solutions. In the case of curved blade construction. the increase is only 6%. while in the case of flat blades it is 16%.

However. with the first design solution. removing the rear side of the housing reduces turbine power by 50%. Since housing significantly increase the cost

price of production. it is proposed (for the second constructive solution) making Flipwing turbine without housing.

Note:

This paper is based on the paper presented at DEMI 2019 – The 14th International Conference on Accomplishments in Mechanical and Industrial Engineering. organized by Faculty of Mechanical Engineering. University of Banja Luka. BOSNIA & HERZEGOVINA. co–organized by Faculty of Mechanical Engineering. University of Niš. SERBIA. Faculty of Mechanical Engeneering Podgorica. University of Montenegro. MONTENEGRO and Faculty of Engineering Hunedoara. Unversity Politehnica Timisoara. ROMANIA. in Banja Luka. BOSNIA & HERZEGOVINA. 24–25 May 2019.

References

[1] William B. Hamner. Hinged-blade cross-axis turbine for hydro-electric power generation. Pub. No.: US 2010/0237626 A1. Pub. Date: Sep. 23. 2010.
[2] Evan Mangold (2012). An analysis of its performance and potential in the roza and kittitas canals. Master Thessis. The Evergreen State College. November 2012.
[3] Dr. Clemens Strasser (2015). Hydrodynamische Modellversuche - Tiefschlächtiges Wasserrad. BERICHT Nr. 2666/01. Vienna Model Basin Ltd.
[4] In Seong Hwang. Yun Han Lee and Seung Jo Kim. Optimization of cycloidal water turbine and the performance improvement by individual blade control. Applied Energy 86 (2009) .pp:1532–1540.
[5] A. Kumar. R.P. Saini. Performance parameters of Savonius type hydrokinetic turbine – A Review. Renewable and Sustainable Energy Reviews 2016. 64: 289-310.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

Faculty of Engineering Hunedoara.
5. Revolutiei. 331128. Hunedoara. ROMANIA
http://acta.fih.upt.ro