ORIGINAL PAPER

NUMERICAL AND ANALYTICAL INVESTIGATION OF AN OSCILLATING WING HYDROKINETIC TURBINE AND HORIZONTAL AXIS MARINE CURRENT TURBINES

Y. FARAH[1], D. SAIFAOUI[1], A. BOULEZHAR[1]

Manuscript received: 11.05.2017; Accepted paper: 16.08.2017;

Abstract. *Morocco has vast resources in marine renewable energy to be used to offset the energy requirements because marine energy is one of many kinds of interesting emerging renewable energy. In this research a numerical and analytical investigation we will use with two types of technologies, which is based on the recovery of the kinetic energy of the marine current to generate electricity. The aim is to demonstrate the energy extraction potential of a hydrogenerator with oscillating wing compared to the tidal turbine to the horizontal axis and to validate some numerical predictions.*

Keywords: *Numerical and Analytical Investigation, Oscillating Wing Hydrokinetic Turbine, Horizontal Axis Marine Current Turbines.*

1. INTRODUCTION

The development and advancement of sustainable energy technology are of increasing importance, the kinetic energy potential inside tidal currents is a source of renewable energy [1]. Wherever an efficient means of achieving this energy can be improved, tidal currents could be provided to further satisfy the world's increasing energy needs, many studies have confirmed that marine currents have a great potential as a predictable sustainable resource for industrial scale production of electrical power [2]. There has been a developing importance in the utility of marine current turbines for electrical power generation and horizontal axis marine current turbines are one hopeful system that is being developed for this purpose [3].

Many types of hydrokinetic were considered. A practice of composites in marine structures, particularly for offshore utilization, composite materials offer new prospects for the renewable marine energy. However, the variability of their behavior, especially under catastrophic environmental loading performs a major obstacle to further progress. Composite materials are the materials used for general hydrokinetic [4]. Their attractive properties such as light weight, high stiffness, and good corrosion resistance compared to metallic materials make them the best choice for hydrokinetic designers. Based on these features of composite [5] manufacturing using composite materials can achieve a structural design with a complicated geometric layout and an important weight reduction compared with steel. Glass fiber reinforced polymer and carbon fiber reinforced polymer are most commonly used in marine renewable energy [6].

Designing composite hydrokinetic include balancing between hydrodynamic performance and structural integrity. In global composite materials are applied in marine renewable energy because they provide the following properties:

---

[1] University Hassan II, Renewable Energy Laboratory and Dynamic Systems, Morocco.
E-mail: younesse.farah@gmail.com.

- Best corrosion resistance
- Significant economies in weight compared with equivalent metal systems.
- Very high strength to weight ratio
- Simple and effective jointing and lower installation prices
- Minimal maintenance price.
- Can be almost formed into complex shapes.

This paper seeks to study two types of hydrokinetic technologies to tackle the problem of the heat wave and intermittently renewable energy like solar and the wind. In this context, the study is to make a comparison in terms of production and rigid structures.

2. TYPE OF TIDAL TURBINE

A preliminary study is needed before any establishment of a new concept of tidal: the parameters to be considered when designing a tidal turbine are current velocity, the thrust forces, water depth, and the nature of the seabed, the distance from the coast and the specificity of the marine environment such as water salinity, plant population or the wave climate, weather-related. All these parameters can determine the choice of the carrier structure and the turbine type. Although hydrokinetic projects are not very many, there is a great diversity among manufacturers of both the visual appearance that the mode of action of the blades of the turbines.

Oscillating Wing Hydrokinetic Turbine

An oscillating wing is defined as a wing that simultaneously makes a heaving and pitching. The profile is then left α to positive impact and generates an aerodynamic force Y pointing in the same direction as the heave and consequently produces a positive work hence a positive power, as can be seen in Fig. 1, where X and Y instant respectively parallel and perpendicular to aerodynamic forces the upstream flow, L the lift generated by the wing, its drag D, R the resultant force Instant Vy and the speed vector resulting from the heave of the wing [7].

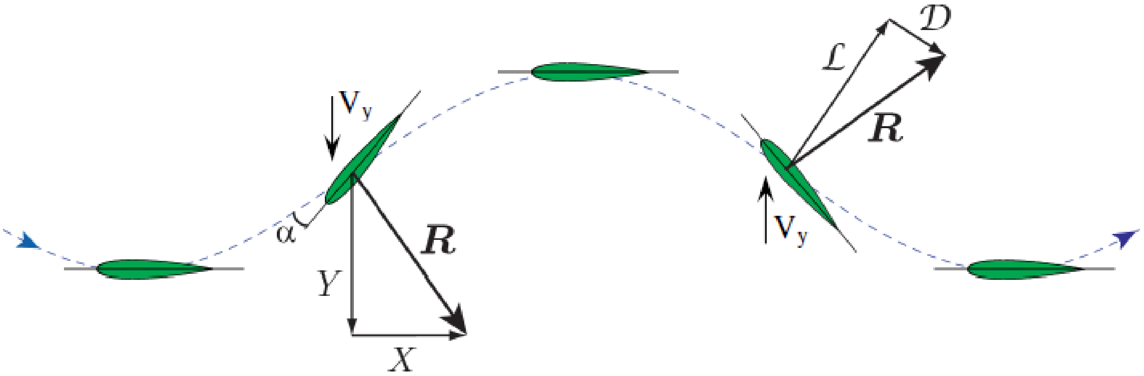


Figure 1. Energy extraction principle of a wing [8].

If the model oscillating wings is more interesting than the rotary blades is that for the same area occupied it produces more electricity. In addition, the vertical movement of the wings limits the turbulence of the stream in contrast to rotary motion. This reduces the space required between each camera in addition to limiting the mixing of the seabed.

Horizontal Axis Marine Current Turbines

One that looks like a wind, it is the most current tidal model (Fig. 2). These turbines consist of three blades with a horizontal axis with a diameter around 20 m and can produce a power of between 500 and 1000 kW. Their steel pile is fixed in the seabed. They include a conventional generator. A control system, placed in a cabin at 7 m above the sea, allows easier monitoring. Their energy efficiency is estimated at about 27% primary.

Advantage of this technology is the ability to perform maintenance out of the water .We also notes the possibility of installing the turbine rotor duplicate and therefore increases production for a particular pillar. Moreover, the adaptability of the supporting structure and the ability to rotate the arm around the pile are two other significant assets. Finally, this model let’s hope a long life (20 years) and it should be noted that few civil engineering is set up for its implementation.

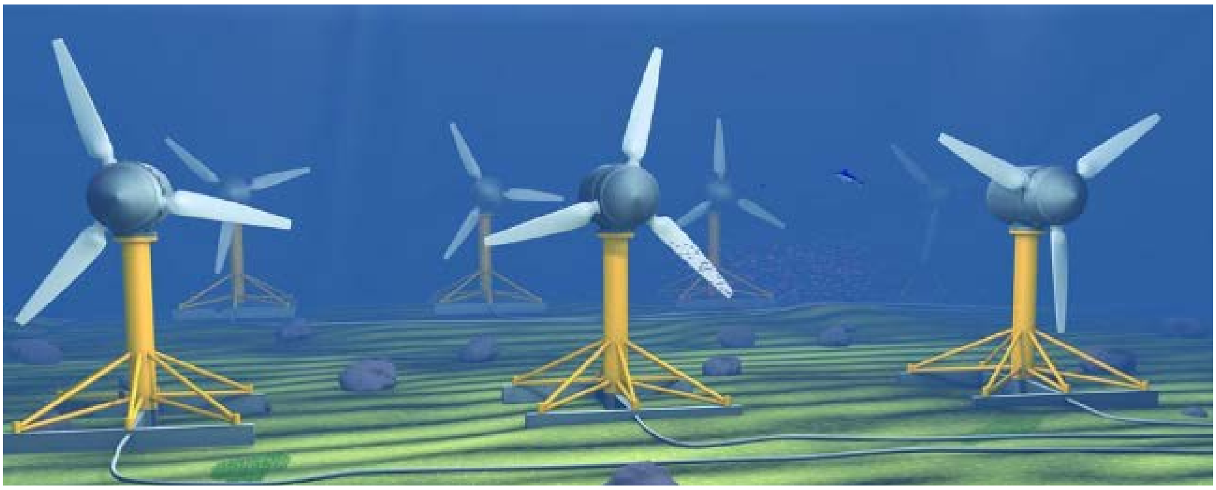


Figure 2. Horizontal Axis Marine Current Turbines

3. ANALYTICAL STUDY

In this part, we will do an analytical study on the principle of operation of turbines to generate electricity for two types the technologies.

In this research, we are led to estimate the power with an oscillating wing tidal using an analytical study with energetically approach.

We define the equivalent mass as the sum of the wing **(a)** and of the transmission system **(b)** including the energy losses. All forces are reduced to the center of pressure.

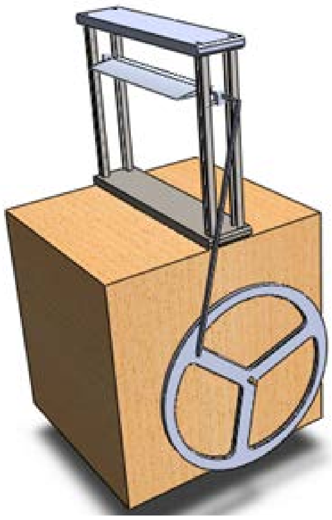
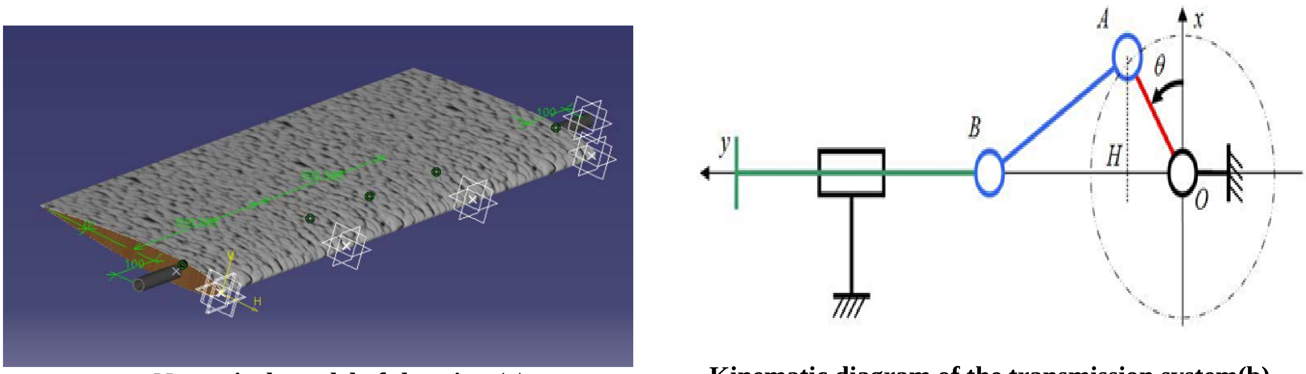


Figure 3. Prototype the system global.



Numerical model of the wing (a) **Kinematic diagram of the transmission system(b)**

Figure 4. Components of the system

According to the fundamental principle of dynamics:

$$m_t\vec{a} = m_t\vec{g} + \vec{F}$$

- **In the ascendant:**

Projecting on the axis $(0, \overrightarrow{e_z})$ is obtained:

$$\ddot{z} = -g + \frac{F}{m_t}$$

By integrating the term of velocity is obtained:

$$\dot{z} = v_{montée} = \left(-g + \frac{F}{m_t}\right)t$$

The rise time t_m is given by:

$$t_m = \sqrt{\frac{2H}{\left(-g + \frac{F}{m_t}\right)}}$$

- **In downswing**

$$\ddot{z} = g + \frac{F}{m_t} \quad \text{and} \quad \dot{z} = v_{descente} = \left(g + \frac{F}{m_t}\right)t$$

$$t_d = \sqrt{\frac{2H}{\left(g + \frac{F}{m_t}\right)}}$$

The instantaneous power is defined by:

$$\mathcal{P} = \overrightarrow{F_t}.\vec{v}$$

The average power over a period T by:

$$\bar{\mathcal{P}} = \frac{1}{T}\int_0^T \mathcal{P}(t)dt$$

- **In the ascendant:**

$$\mathcal{P}_m = \frac{1}{m_t}(F - m_t g)^2 t \ \ and \ \ \overline{\mathcal{P}_m} = \frac{1}{2m_t}(F - m_t g)^2 t_m$$

- **In downswing:**

$$\mathcal{P}_d = \frac{1}{m_t}(F + m_t g)^2 t \quad \text{and} \quad \overline{\mathcal{P}_d} = \frac{1}{2m_t}(F + m_t g)^2 t_d$$

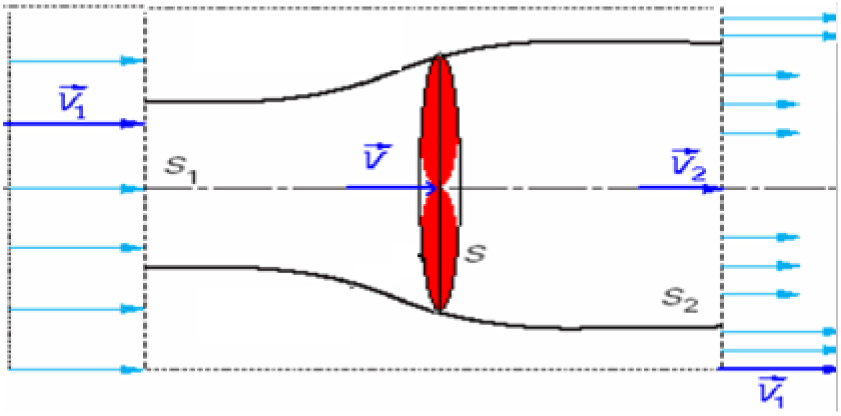
Thus the total average power is:

$$\overline{\mathcal{P}_{totale}} = \overline{\mathcal{P}_d} + \overline{\mathcal{P}_m} = \frac{1}{2m_t}(F + m_t g)^2 t_d + \frac{1}{2m_t}(F - m_t g)^2 t_m$$

Horizontal Axis Marine Current Turbines

The power recovered by tidal and wind, as we have just seen, roughly of the form $P=\frac{1}{2}\rho S V^3$ (ρ the density of the fluid in question, S the area swept by the rotor, and V is the velocity of the fluid incident). It may be noted that it is mainly the difference in density between water and air, which explains the differences in size between the two objects. One can in fact divide the length of the given wind turbine blades for producing a hydrokinetic and yet collect comparable power.

In this regard using Betz Law, one can determine the maximum yield of the turbines.



Making power balance between what happens to the rotor and making off again, an extracted power that is expressed:

$$P = \frac{1}{2}(\rho S V)(V_1^2 - V_2^2)$$

It is found that the force exerted on the rotor is:

$$\rho S V (V_1 - V_2).$$

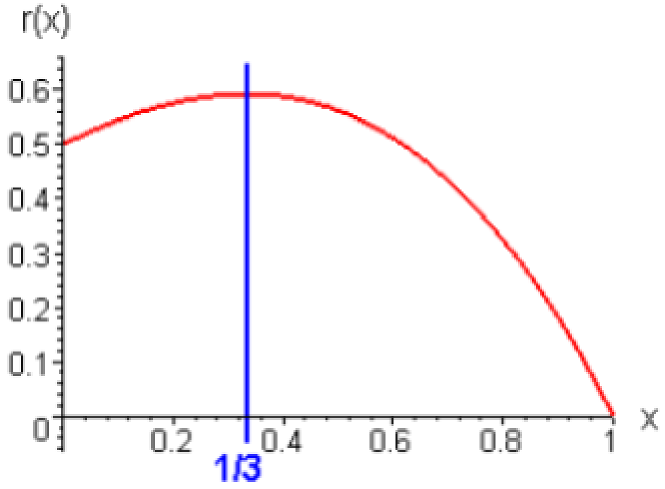
Then we show that:

$$V = \frac{1}{2}(V_1 + V_2).$$

Then search the maximum power that can be recovered. It is obtained for:

$$V_2 / V_1 = 1/3.$$

With this choice of the maximum rotor performance is obtained in which power is about 60%. It is the law of Betz. This result reveals that despite all the progress that we will achieve beautiful, we will never extract more than 60% of the energy currents.



4. NUMERICAL STUDY

In this part we will look into the side structure to assess the performance in our tidal against corrosion for the metal material and hydrodynamic and hydrostatic loads for composite and metallic structures. We used a catalog (Fig. 5) presenting us with different airfoils and aerodynamic characteristics [9].

Our choice was therefore focused on the NACA 0012: a symmetrical profile with aerodynamic characteristics is:

$$x_p = \frac{c}{4}$$

- The following aerodynamic coefficients:

$$C_L\ (\alpha = 10°) = 1{,}1\ ;\ C_D\ (\alpha = 10°) = 0{,}015;\ C_M\ (\alpha = 10°) = -0.1$$

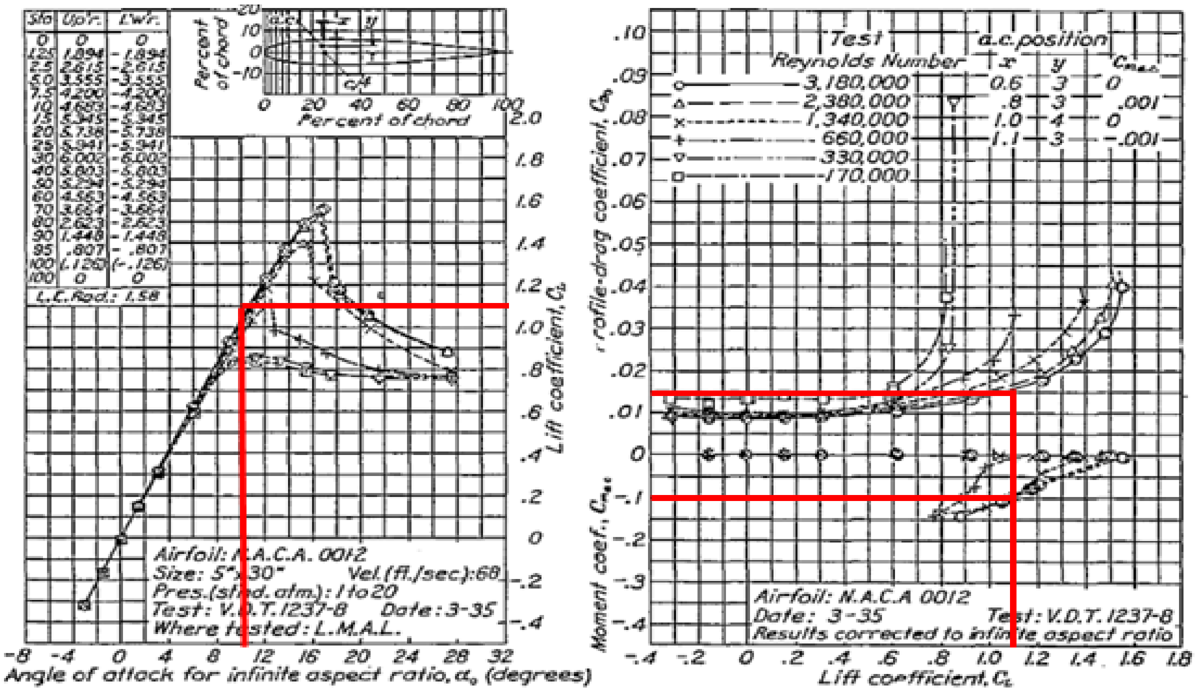
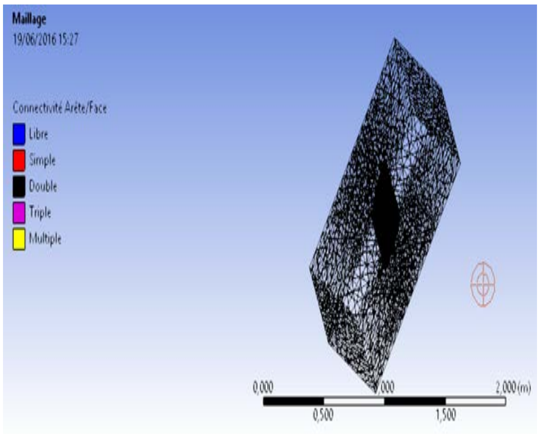
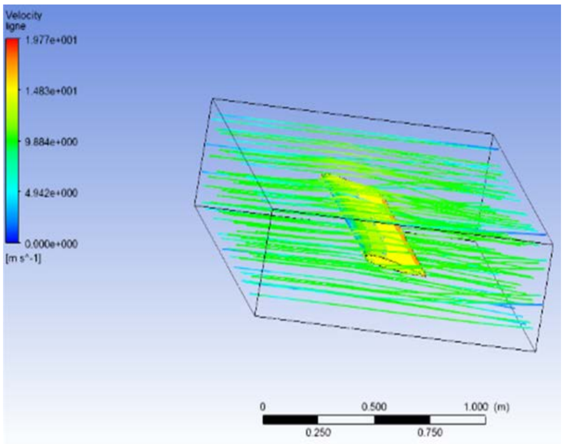


Figure 5. Charts aerodynamic characteristics of NACA-0012

We chose CATIA V5 to model the wing profile NACA 0012 by introducing an angle incidence 10°. After we saved the template as IGS exchange format for import into the fluid mechanics calculation software ANSYS fluent. Then we stuck to generate the mesh from the mesh included in the ANSYS software, ICEM CFD. We also verified that the trailing edge and attack are finely meshed.





5. CONCLUSIONS

At the end of our study, it appears that the use of turbines with oscillating wings is significant not only in terms of energy as it removes approximately 40% water but also environmentally, since they are not polluting.

Comparing the use of air as substituted water, the task proved more difficult. First, the ocean currents are more predictable than wind. This better have the HAO and take advantage of the maximum velocity of maritime. Second, given the difference in density of water compared with air (1000 times greater than air), the bearing capacities are less important for wind energy systems, something that affects the level technological solutions used and despite the mass minimization, the bearing capacities remain relatively low. Finally, given the conditions and the technology used, the price of these technologies remains inaccessible. Therefore, their use is seen as a luxury than anything else.

REFERENCE

[1] Laurens, J. M., Ait-Mohammed, M., Tarfaoui, M.,*Design of bare and ducted axial marine current turbines. Renewable Energy*, **89**, 181, 2016.

[2] Mohammed, M. A., Tarfaoui, M., Laurens, *Numerical investigation of bare and ducted horizontal axis marine current turbines*, 5th International Conference on Ocean Energy ICOE 2014.

[3] Ait-Mohammed, M., Tarfaoui, M., Laurens, J.M. *Renewable Energy and Power Quality Journal*, **1**(12), 386, 2014.

[4] Shah, O. R., Tarfaoui, *Composites Part B: Engineering*, **62**, 121, 2014.

[5] Shah, O. R., Tarfaoui, *Renewable Energy*, **87**, 168, 2016.

[6] Demers L.A.A., M.Sc. Thesis *Synthèse de mécanismes pour une génératrice hydrolienne à ailes oscillantes*, Université Laval, Québec, 2007.

[7] Lalande G., M.Sc. Thesis *Conception d’un prototype expérimental d’hydrolienne a ailes oscillantes*, Université Laval, Québec, 2010.

[8] Kinsey, T., Dumas, G., *AIAA Journal*, **46**(6), 1318, 2008.

[9] Eastman N.J., Albert, S., *Airfoil section characteristics as affected by variations of the Reynolds number*, Report 586, National Advisory Committee for Aeronautics, 1939.