

# Novel Design of Vertical Axis Current Turbine for Low Current Speed via Finite Volume Method

Fatemeh Behrouzi<sup>a</sup>, Adi Maimun<sup>b</sup>, Yasser M. Ahmed<sup>a,c\*</sup>, Mehdi Nakisa<sup>a</sup>

<sup>a</sup>Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia

<sup>b</sup>Marine Technology Centre, Universiti Teknologi Malaysia, 81310 UTM, Johor, Malaysia

<sup>c</sup>Faculty of Engineering, Alexandria University, Alexandria, Egypt

\*Corresponding author: yasser@mail.fkm.utm.my

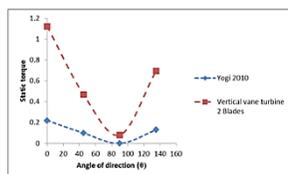
## Article history

Received :25 December 2014

Received in revised form :  
25 March 2015

Accepted :15 May 2015

## Graphical abstract



## Abstract

Now a day, increasing energy demand and environmental effect of fossil fuel cause to replacing fossil fuel with renewable energy. This paper presented novel design of turbine to generate more torque to capture more energy of water and hence cause to high output power. In this work Computational Fluid Dynamics (CFD) using realize k-e turbulence model, have been used to analyses the effect of arm on the static torque and the contours of pressure in different angle of direction for vertical vane turbine. Investigation of arm effect on static torque of vertical vane turbine and comparison between turbine with arm and without arm showed the average torque in vertical vane turbine is higher than without arm. The model settings of validation study was accomplished by comparing simulation of performance of turbine  $C_p$  and  $C_m$  with the experimental data taken from Hayashi and Hara (2005), that showed realize k-e has good agreement with experimental data.

**Keywords:** Arm; turbine; renewable energy

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## 1.0 INTRODUCTION

Nowadays, majority of remote area are very poor, with low living condition and limited access to media and information.

It is proof that utilization of electricity energy is key of economic growth and improvement of people's living standards (Fatemeh *et al.*, 2014) so to improve and development living level of remote area residents, providing of electricity is essential, world energy (especially in developing country) still heavily relies on the fossil fuel resources.

Growth of population, increasing energy demand, rising fossil fuels price, depleting fossil resources, global warming and their environmentally harmful effect Encouraged to reduction of using fossil fuels and replacing them with green energy and renewable technologies.

Among of different renewable energy, hydro is continuously available against of other sources, so hydro power generation (large and small scale) is the prime choice in term of contribution to the world's electricity generation (Paish, 2002; Williams *et al.*, 2011).

Also, as for geographical location, equatorial climate, more access to ocean, river, irrigation channel and surface water after rainfall in Malaysia, it is the best choice to use hydro energy to generate electricity for islands and remote area are poor in electricity.

Recent developments have focused on kinetic energy devices to generate electricity due to straightforward and easy understood since they use principle operation similar to wind turbine as opposed to environmental effect of storage solution using dam and reservoirs and costly (Junior, 2011).

There are 2 main type of kinetic energy conversation rotor, horizontal and vertical axis turbines (Duvoy *et al.*, 2012; Gorlov 2004). Output power is main factor to quantify performance of turbines shown by dimensionless coefficient,  $C_p$ , power coefficient that it depends on the velocity of current can be different.

It is important to consider the challenges associated with increasing the efficiency and electrical power generation using better design of turbine.

Malaysian current has small depth and low current speed (Royal, 2005) gives some limitation to the energy to be extracted. It is essential to use a mechanism which relies primarily on generating high torque and hence high output power from low speed current.

Despite the effort to development on renewable energy, but up to now they are not used to their maximum potential in Malaysia. Consequently, some modification should be done on the current speed or the turbine, or both of them to allow turbines to work in low current speed.

This paper presents a new design of Vertical axis Current Turbine (VACT) applicable in low speed current which increase

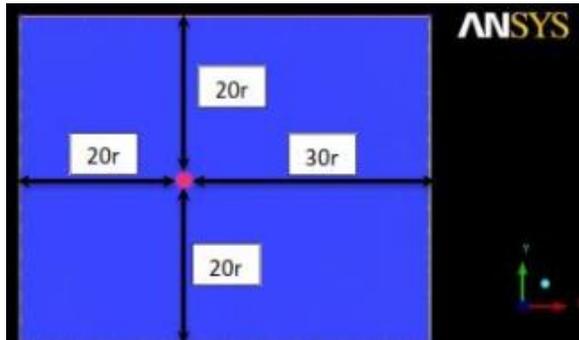
torque leading high output power and hence generate more electricity while is being increasingly used to harness kinetic energy of water and convert it into other useful forms of energy as a clean and renewable energy.

**2.0 VALIDATION STUDY USING CFD**

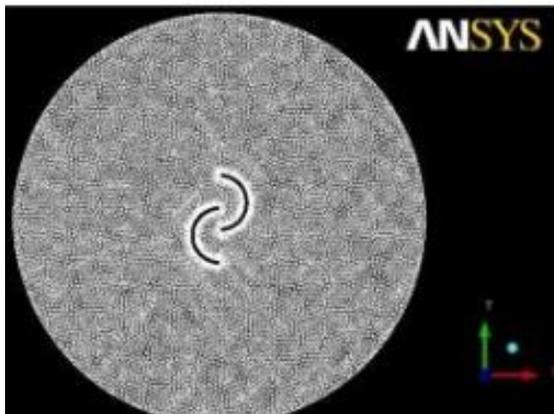
By comparing the simulation results with the available experimental and numerical, further analyses is accepted and can be rely on, so ,at first step the validation study should be done.

In validation step, 2D simulation were carried out for one stage conventional Savonius rotor to find Cp and Cm and compared with the experimental data taken from Hayashi and Hara (2005) and numerical result of Yaakob et al (2012), using several two equation turbulence models in ANSYS-FLUENT 14, the semi implicit method for pressure-linked equations (SIMPLE) algorithm for pressure velocity coupling, second order upwind scheme was recommended for all convection terms and SMM approach used for motion of solid body in fluid.

Three complete revolutions with suitable and constant time step value are always computed, that the first revelation is for initializing the flow and two revelation used to compute main target Cp and Cm. Mesh structure, computational domain and result shown in Figure 1 and 2. The results showed using realize k-e caused to excellent agreement between numerical and experimental data. As a consequence, the CFD procedure can be used as a reliable evaluation tool for further process.

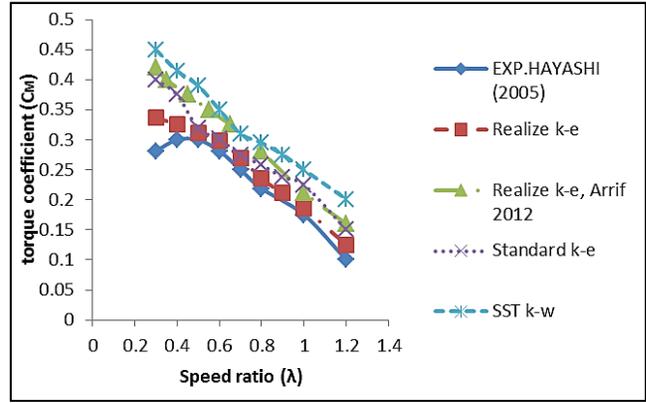


(a) Computational domain

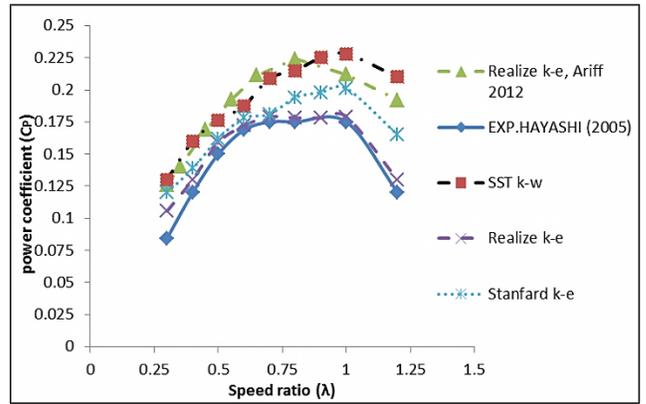


(b) Geometry and mesh of Savonius turbine

**Figure 1** (a) Computational domain, (b) Geometry and mesh of Savonius turbine



(a) Torque coefficient of Savonius turbine



(b) Power coefficient of Savonius turbine

**Figure 2** Torque and Power coefficient of Savonius turbine

**3.0 VERTICAL VANE NUMERICAL SIMULATION**

According to validation study, realize k-e can be applied for present study to simulate Savonius turbine a=4 and optimized it using arm. The main dimension of vertical vane turbine extract from Savonius turbine in yougi (2010), as mentioned in Table 1.

**Table 1** The main dimensions of the model of the VACT

NO	Spe cifications	Model VACT
1	Height of Rotor, H	1.5 m
2	Diameter of Rotor, D	0.375 m
3	Nominal Speed, V	0.17 m/s
4	Arm length, r	0.23 m
5	Blade Area, A	0.28125 m <sup>2</sup>

The mesh grid of vertical vane turbine is shown in Figure 3. It is considerable that to find accurate result the fine mesh is essential.

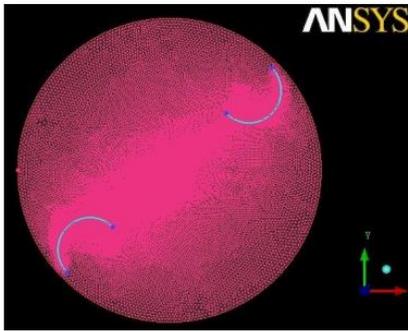


Figure 3 Mesh grid of vertical vane turbine

**4.0 TORQUES IN DIFFERENT ROTATIONAL ANGLES OF THE TURBINE**

The simulation was run in different angles of direction (0°, 45°, 90° and 135°) as shown in Figure 4, using realize k-e. The results of simulation give static torque of 2 blades vertical vane turbine in each angle of direction and compared with Savonius turbine as shown in Figure 5.

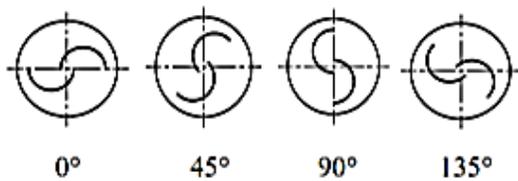


Figure 4 Different angles of rotation

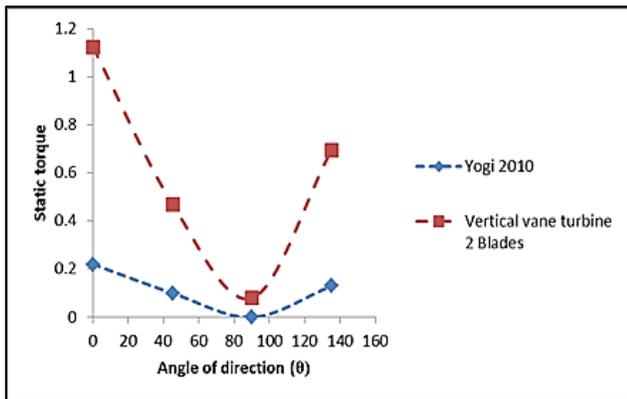


Figure 5 Static torque at different angles of rotation for 2 blades of vertical vane turbine

As Figure 5 shown the average torque in vertical vane turbine is higher than Savonius due to using arm but in 90° angle the torque is around zero and has fluctuation that by using at least four blades can solve this problem to achieve smooth torque graph.

**5.0 PRESSURE DISTRIBUTION AT DIFFERENT ROTATIONAL ANGLES OF THE TURBINE**

Figures 6 and 7 show the contours of pressure for VACT at different angles of rotation. The results showed the maximum pressure (red color) accrued in zero angle at the concave blade that lead to give positive torque to rotate the turbine.

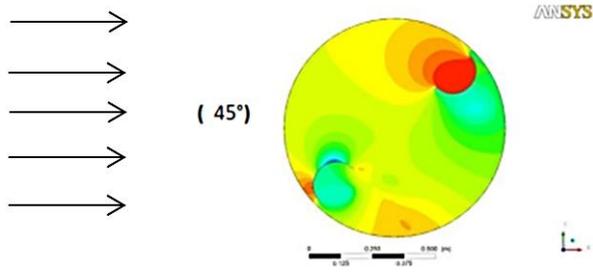
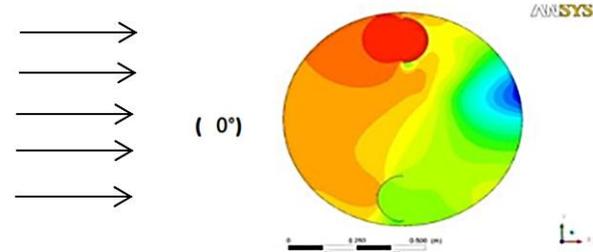


Figure 6 Pressure contours at angle of 0° and 45°

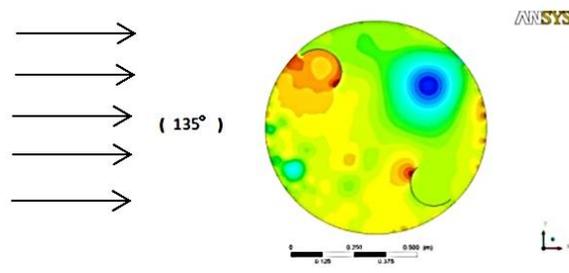
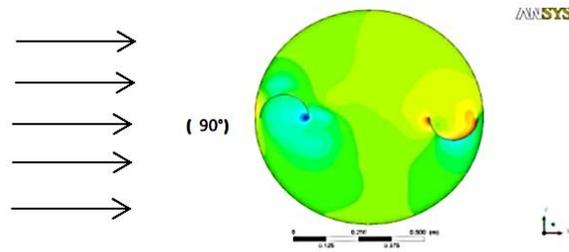


Figure 7 Pressure contours at angle of 90° and 135°

**6.0 CONCLUSION**

Researchers focus on renewable sources as a solution to solve the problem associate with environmental impact of fossil sources and demand of electrical energy using different method to improvement the hydro turbine system to harness more energy of water.

This paper presented a new idea to generate more torque using arms in Savonius turbine. CFD simulations of vertical vane turbine and comparisons it with the ordinary Savonius turbine showed that the average torque of vertical vane is higher than Savonius turbine, which will lead to generating more power. The rotor of the vertical vane turbine provided with two blades, where some fluctuation has been seen at 90° and the use of at least four blades seams will solve this problem and will achieve smooth torque graph. Finally, the contours of pressure indicates that more pressure occurred at 0° and in all positions average torque is positive.

#### Acknowledgement

The authors would like to thank the Faculty of Mechanical Engineering in Universiti Teknologi Malaysia (UTM) for financial support under MOHE-UTM-Vote No. Q.J130000.262410J49.

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