Journal of Science & Technology 122 (2017) 048-051

The Effect of D/H Aspect Ratio Change on Energy Characteristics of H-type Darrieus Turbine

Nguyen Quoc Tuan[1*], Nguyen The Mich[2], Do Huy Cuong[2]

[1]Institute for Hydro power and Renewable energy – Vietnam Academy for Water Resources*

[2] Hanoi University of Science and Technology – No. 1, Dai Co Viet Str., Hai Ba Trung, Ha Noi, Viet Nam

Received: February 16, 2017; Accepted: November 03, 2017

Abstract

For the H-type Darrieus turbine runner, the geometry parameters such as runner diameter, blade height, number of blades, D/H ratio, blade profiles... have certain effects on working capacity and the efficiency of the turbine. Therefore in order to provide runner samples with high efficiency and working capability, it is needed to design, simulate and test many runner samples, and then select the most suitable one with real water flow condition. This paper simulates the circumstances on changing D/H aspect ratio of the runner samples, specifically in 03 cases including D/H = 0.9, D/H = 1 and D/H = 1.1 to evaluate the working capacity and efficiency of the turbine, and then to establish the curves on power characteristics of H-type Darrieus turbine. Based on that, we can select the runner sample working better than the remaining samples.

Keywords: Simulation, H-type Darrieus turbine, hydro power, renewable energy, Ansys-Fluent software

1. Introduction

Blade profiles affect much on the working efficiency of turbine. There are many kinds of high quality aerodynamic profiles studied at famous research institutions on aero-dynamic in the world. Currently, the most popular one is NACA profile of National Aeronautics and Space Administration (NASA, in the U.S) used for H-type Darrieus turbine. NACA profile has many suitable characteristics of aero-dynamics such as Reynolds number, angle of attack, chord length, coefficients of lift and thrust, sliding scale, largest and smallest pressure coefficient.

Currently, the theoretical basis of H-type Darrieus turbine used to exploit water flow energy is entirely based on the theoretical basis of straight-bladed vertical-axis Darrieus wind turbine. As such, research works about this turbine type are mainly used for exploiting wind power, and few research studies are carried out for exploiting the water flow energy. In addition to blade profiles, the geometry parameters of runner also affect the working characteristics of H-type Darrieus turbine. One of geometric parameters is D/H aspect ratio – the ratio between diameter and blade height of the runner. The change of the D/H aspect ratio will affect blade rotation, the turbine efficiency will change and reach the maximum value and then decrease gradually[1]

The article presents some research results on the effect of D/H aspect ratio change on turbine energy characteristics that used to exploit water flow energy by using simulation software ANSYS – Fluent.

2. Research Methodology

The article use Ansys-Fluent software to calculate, simulate energy exchange process between water flow and turbine runner by models of H-type Darrieus turbine runner in cases of changing the aspect ratio as D/H = 0.9; D/H = 1; and D/H = 1.1. The computational models studied with flow velocity on changes in the range of 1.5 m/s - 3.5 m/s[2], meanwhile, researches on straight-blade vertical-axis wind turbine usually has a wind speed up to 9 m/s and turbine efficiency of 32%[1]. Simulation calculations can evaluate the working characteristics of turbine, thus possibly select a turbine runner model of high-energy property.

3. Model Geometry

3.1. Selection of blade profile

There are many samples of NACA profiles, however the research results showed that NACA0018 profile is the most suitable one for H-type Darrieus vertical axis turbines[2].

The tip speed ratio is defined as follows:

---

[*] Corresponding author: Tel.: (+84) 989.588.892
Email: nguyentuan.afm@gmail.com

$$\lambda = \frac{R\omega}{v} \tag{1}$$

(where R: Runner radius; ω : Angular velocity: V: Water flow speed; A: Turbine swept area; P: Shaft power)

The power coefficient is defined as follows:

$$C_p = \frac{P}{P_{\max}} = \frac{P}{\frac{1}{2}.\rho.V_{\infty}^{3}.A} \tag{2}$$

3.2. Establishment of physical model

This paper simulates the dynamic relationship in cases of changing D/H aspect ratio of H-type Darrieus turbine runner with different velocities, specifically in 03 cases including D/H = 0.9; D/H = 1 and D/H = 1.1. From which, the physical model will be established for 03 cases with the parameters as shown in the below Table 1 and Figure 1:

Table 1. Runner parameters for 03 studied cases

Case / Items	D/H = 0.9	D/H = 1	D/H = 1.1
Diameter D (mm)	1000	1000	1000
Height of blade H (mm)	1110	1000	910
Blade No. Z	10	10	10
Profiles	NACA 0018	NACA 0018	NACA 0018
Chord length c (mm)	100	100	100

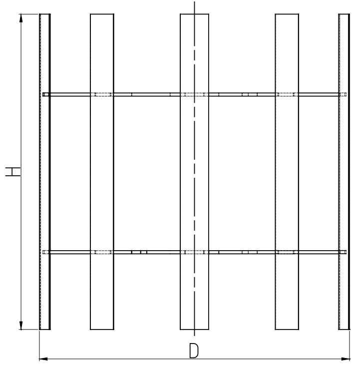

Fig. 1. The runner of H-type Darrieus turbine

3.3. Calculation and simulation methods

Fluid dynamic calculation with computer support (CFD) is a useful tool to analyze flow energy characteristics. The CFD can predict properties of torque, pressure on turbine runner, from which to predict energy characteristics of turbine. This paper uses Ansys - Fluent software for simulation.

3.3.1. Turbulence model

There are many models of turbulence flow, in which k- ω model and k- ω model are most commonly used ones. The k- ω model is used with the problem in boundary layer, near the wall while the more distant regions, need to use k- ω model. When using k- ω model, it is necessary to use a wall function to resolve the boundary layer. This means that the mesh density near the wall should be included in order to obtain all of viscous boundary layers.

In almost cases, k- ω model gives the same results as other models when using a coarser mesh density near the wall, which reduces the time to complete the calculations [3].

This paper uses k- ω turbulent flow model for calculation and simulation, shown by 02 equations on kinetic energy k and ω turbulent loss rate as follows [4]:

$$\frac{\partial(\rho\varepsilon)}{\partial t} + \frac{\partial(\rho\varepsilon u_t)}{\partial x_t} = \frac{\partial}{\partial x_t}\left[\left(\mu + \frac{\mu_t}{\sigma_\varepsilon}\right)\right]\frac{\partial\varepsilon}{\partial x_t} + C_1\frac{\varepsilon}{k}G_k - C_2\rho\frac{\varepsilon^2}{k} \tag{1}$$

$$\frac{\partial(\rho k)}{\partial t} + \frac{\partial(\rho k u_t)}{\partial x_t} = \frac{\partial}{\partial x_t}\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_t}\right] + G_k - \rho\varepsilon \tag{2}$$

Where: C1, C2, σ_k are empirical constants, Gk is the quantity expressing the formation of kinetic energy, it depends on the velocity gradients and turbulence viscosity.

$$G_k = \mu_t\left(\frac{\partial u_t}{\partial x_j} + \frac{\partial u_j}{\partial x_t}\right)\frac{\partial u_j}{\partial x_t} \tag{3}$$

Turbulent viscosity is derived from k and ε, including a constant is determined empirically by $C_\mu = 0.09$, we have:

$$\mu_t = \rho C_\mu \frac{k^2}{\varepsilon} \tag{4}$$

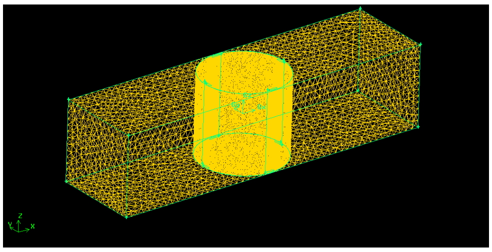

Fig 2. The turbine runner model after meshed

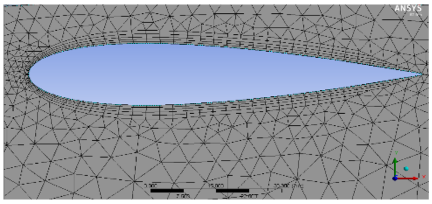

Fig 3. Structureless mesh model on blade profile

3.3.2. Meshing model

03 models with same type of triangle and structureless mesh are meshed before proceeding to run the simulation. After that the models are meshed as shown as the following Figure 2 and Figure 3:

The meshing is done on Gambit software, the thickest mesh density is at blade profile and blade tip locations, in these areas the mesh is thicker than the others such as inlet and outlet areas. The meshing parameters of models are shown in Table 2.

Table 2. Meshing parameters of 03 models

Case Items	D/H = 0.9	D/H = 1	D/H = 1.1
Mesh node No.	2184799	1934879	1706923
Mesh element No.	9323392	8125898	7232985

3.3.3. Solution method

The selection of solver, viscous model, material properties, boundary conditions are carried out as follows:

Solver:

Interpolation method: Implicit; Direction: 3D; Time: Steady; Turbulence model: k-□; Heat exchanger: None; Material: salt water with ρ=1000 kg/m3.

Seting up conditions for problem calculation: Velocity, ignoring the influence of gravitational acceleration

Boundary condition:

Inlet condition: inlet velocity change in the range 1.5 – 3.5 m/s

Blade condition: Wall

Symmetrical surfaces

Outlet condition: Residual pressure (variance between outlet and inlet pressures) Pres = 0

Figure 4 shows the 3D problem model with setting boundary conditions before proceeding to run and simulate models by Ansys-Fluent software.

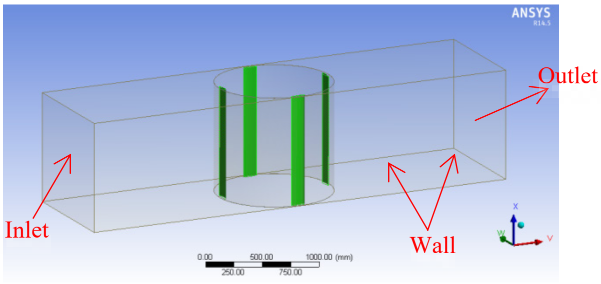

Fig 4. Problem model with Boundary condition

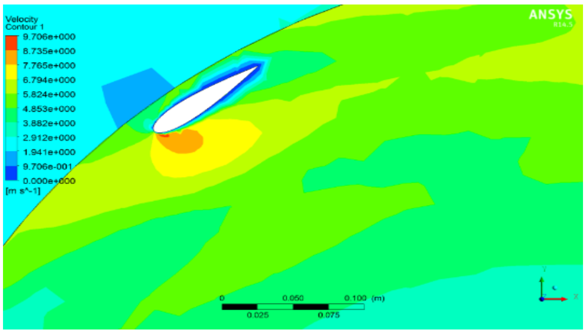

Fig 5. Velocity distribution around blade profile in the case of D/H = 0.9

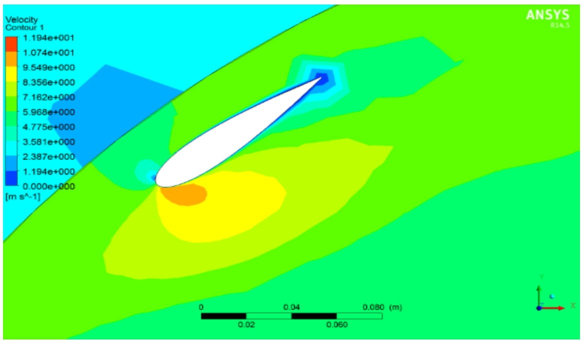

Fig 6. Velocity distribution around blade profile in the case of D/H = 1

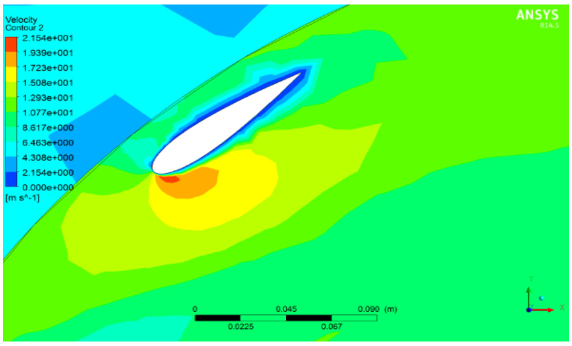

Fig 7. Velocity distribution around blade profile in the case of D/H = 1.1

4. Results and Discussion

The results of velocity distribution through the turbine runner were obtained after proceeding simulation the above research cases

As shown in Figures 5, 6 and 7, it is seen that the field of velocity distribution changes into several distinct regions when flowing through blade profiles. There is a phenomenon of turbulent flow at blade profile. After simulating, we obtain the calculated results for corresponding research cases and then we build the relationship curves Cp-λ to evaluate working characteristics of H-type Darrieus turbine

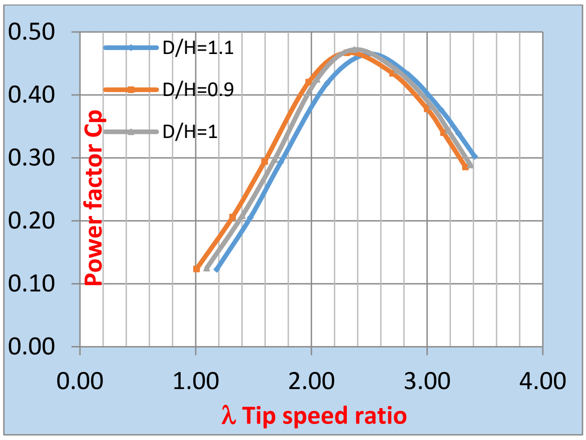

Fig 8. Relationship curves Cp-λ of research cases

As shown in Figure 8, it is found that when flow velocity or tip speed ratio increases, the power coefficient CP or turbine efficiency increases and reaches its maximum value and then decreases. When changing the D/H aspect ratio, the turbine's energy characteristics also change. Based on the simulation and calculation results, it is shown that in case of aspect ratio D/H = 1, the working efficiency is highest at the value CP = 0.472, λ = 2.37 compared to the two remaining cases where D/H = 0.9 and D/H = 1.1 under the same research condition of flow velocity.

5. Conclusion

This paper presents the research results on the effect of D/H aspect ratio on H-type Darrieus turbine efficiency by using Ansys-Fluent software. Based on the results of simulation and calculations on turbine runner models in cases of D/H = 0.9; D/H = 1 and D/H = 1.1 respectively, it is shown that:

- When the flow velocity increases, the turbine efficiency also increases and reaches to the maximum value and then decreases gradually. The greatest performance values of research cases corresponding as follows:

In the case of D/H = 0.9: CPmax = 0.467; λ = 2.31

In the case of D/H = 1: CPmax = 0.472; λ = 2.37

In the case of D/H = 1.1: CPmax = 0.465; λ = 2.50

- When changing D/H aspect ratio, turbine efficiency also changes. In the case of D/H = 1 the turbine efficiency reaches the maximum value compared to the remaining research cases.

With water flow speed ranging in 1.2 - 3.5 m/s, it is possible to fully choose H-type Darrieus turbine with aspect ratio D/H = 1 to exploit the water flow energy, ensuring that turbine has the highest performance. These research results can be fully applied in order to select the turbine runner geometric parameters that used to exploit water flow energy

References

[1]. [1]. Farhan A. Khammas, Mustaffa, M.T,Ryspek U (2015). “Investigate the effect of different design parameter o n performance evaluation of straight blade vertical axis wind turbine (SB-VAWT)”, International journal of engineering technologies and management research

[2]. [2]. Phung Hong Tuấn, Đo Anh Tuan (2013), “Report on tidal survey and water flow velocity measurement results in some locations of Cat Ba insland – Hai Phong province. Site selection for installation and experiment”, Institute for hydro power and renewable energy, project: KC.05.13/11-15

[3]. [3]. M.H. Mohamed, Performance investigation of H-rotor Darrieus turbine with new airfoil shapes, Renewable Energy Lab. of Mechanical Power Engineering Dept., Faculty of Engineering, Mattaria, Helwan University, P.O. 11718, Cairo, Egypt, (2012), pp.7

[4]. [4]. Rémi Gosselin, Guy Dumas, and Matthieu Boudreau, Parametric study of H-Darrieus vertical-axis turbines using uRANS simulations, Laboratoire de Mécanique des Fluides Numérique, Département de génie mécanique Université Laval, Québec, Québec, G1V 0A6, Canada, (2013), pp.3

[5]. [5]. Taher G. Abu-El-Yazied, Ahmad M. Ali, Mahdi S. Al-Ajmi, Islam M. Hassan, Effect of Number of Blades and Blade Chord Length on the Performance of Darrieus Wind Turbine, American Journal of Mechanical Engineering and Automation, (2015), pp.4