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# Experimental research on tidal current vertical axis turbine with variable-pitch blades

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ABSTRACT

Due to the limited storage and ever-increasing dependence on fossil fuel, the world is in the phase of shifting toward renewable energy. Tidal current energy is one of the most predictable forms of renewable energy, which is harnessed by utilizing a tidal current turbine. To study the performance of the tidal current turbine relating to the ability of energy absorption and exchanging, experimental tests play an important role which can not only validate the numerical results but also provide a reference for the prototype design. In this study, a series of experiments related to vertical-axis turbines (VAT) were carried out at Harbin Engineering University and a large quantity of experimental data to study the hydrodynamic performance of turbines was presented. Based on the different techniques used to control the pitch mechanism, the experiments can be classified as the cycloid type controllable-pitch, spring-control pitch and passive variable-pitch VAT experiment. The influences of the different parameters on the hydrodynamic performance of turbines were discussed. Finally, some control strategies for the blade for different turbines were given.

## 1. Introduction

Tidal energy is regarded as one of the most promising alternative energy resources because of its minimal environmental impact and high-energy density (Li and Cahsal, 2010). Tidal cycles are predictable with a time-varying flow velocity, which is beneficial for controlling the electrical grid because generation can be accurately forecast a head of time (Clarke et al., 2006). The device used to harness tidal current energy is the tidal current turbine, which shares a similar working principle with wind turbines. Based on this principle, tidal current turbines can be classified as horizontal-axis turbine and vertical-axis turbines. The latter may have some advantages (Salter and Taylor, 2007). Compared with Horizontal axis turbine (HAT), vertical axis turbine (VAT) can get higher torque in lower tip speed ratio and lower current velocity range so that VAT takes favorable in weak current conditions rather than HAT. In order to improve the performance of the turbine, the variable-pitch vertical axis turbine was investigated. To study on the hydrodynamic performance and the starting performance of vertical axis turbines, the controlling the angle of attack of blades was considered (Ikoma et al., 2010, 2011). The performance of the variable-pitch turbine was investigated (Matthew, 2007, Ikoma and Masuda, 2013), which are starting-driving, forced-rotation and hydraulic control mechanism design.

There are many parameters that affect the hydrodynamic performance of the turbine, including the flow velocity, number of blades, and the range of pitch, etc. The influences of the different parameters on the hydrodynamic performance of the turbine are summarized. Within the past 10 years, a series of experimental tests for the tidal current turbine have been carried out in towing tank and circulating flume at Harbin Engineering University (HEU) in China. Considering the different techniques used to control the pitch mechanism, the experiments can be classified as the cycloid type controllable-pitch, spring-control pitch and passive variable-pitch vertical axis turbine (VAT) experiments. In this study, the vertical axis turbine experiments and the experimental results were summarized. The experimental results were used to validate the numerical results and to provide a reference for the prototype design, which is significant for further research of tidal current turbines.

## 2. Experimental methods

### 2.1. Test facilities

All the experiments discussed were carried out at towing tank and circulating flume of HEU. The towing tank is shown in Fig. 1.

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**Nomenclature**

| | |
|---|---|
| $A$ | rotor area ($m^2$) |
| $P$ | rotor power (W) |
| $C$ | chord (mm) |
| $C_L$ | lift coefficient |
| $C_D$ | drag coefficient |
| $C_P$ | power coefficient$=P/(1/2\rho AU^3)$ |
| $Q$ | rotor torque (Nm) |
| $D$ | diameter of turbine (m) |
| $\lambda$ | tip speed ratio (TSR)$=\Omega R/U$ |
| $U$ | free stream speed (m/s) |
| $\rho$ | density of water ($kg/m^3$) |
| $\Omega$ | rotation speed of rotor (rad/s) |
| $Z$ | number of blades |

The length is 108 m, the width is 7 m and the depth is 3.5 m. The maximum towing speed is 6.5 m/s. And the towing tank was equipped with a wave making device that could generate regular and irregular waves. The circulating flume is shown in Fig. 2. The length of the circulating flume is 8 m, the width is 1.7 m and the depth is 1.25 m, the fluid velocity varied from 0.2 m/s to 2 m/s.

**Fig. 1.** Towing tank and towing carriage.