Experimental Study of Wake Flow around a Twin-rotor Tidal Stream Turbine

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ABSTRACT

Investigating the wake structure and its recovery of a twin-rotor tidal turbine is of great significance to the development of such a kind of tidal turbines. Experiments were carried out in the circulating flume by using the Acoustic Doppler Velocimetry to study the wake characteristics of a twin-rotor tidal turbine, considering impacts of rotor spacing and rotors rotation direction. The experimental results show that the near wake behind the rotor is independent of each other, while the wakes start mixing into one at certain distance downstream. With an increase of rotor spacing, the mixing position gradually approaches the turbine. The turbulence intensity on the central axis of the two rotors is obviously larger, which is caused by the mutual interference between the twin rotors and the blockage effect of pile. Different rotors rotation directions affect the recovery of flow velocity behind these two rotors.

KEY WORDS: Tidal energy; Twin-rotor tidal turbine; Wake characteristic; Turbulence intensity.

INTRODUCTION

With the increasingly serious problem of energy shortage in the world, countries around the world have paid more and more attention to the development and utilization of renewable energy in recent years. The ocean occupies more than two thirds of the earth’s surface area, and is rich in marine energy. Tidal stream energy is a kind of marine energy with good development value, which has the advantages of large reserves, high energy density and strong predictability (Zheng et al., 2015). At present, the most effective device to extract tidal energy is tidal stream turbine. In order to most effectively exploit the tidal stream resource, tidal turbines are expected to be deployed in arrays. Whether the array arrangement of tidal stream turbines in sea area is reasonable is the key to the development of tidal energy, and the core work of turbine array arrangement is to study the wake characteristics of turbines. A bunch of researches have been conducted in investigating the wake of a single turbine in different conditions in the past decade. By physical experiments and computational fluid dynamics (CFD) simulations, Ebdon et al. (2021) demonstrated that turbulence intensity has a significant impact on the wake development for both recovery and width. Through physical experiments, Zhang et al. (2019) found that the existence of waves is beneficial to the speed recovery of the water flow behind the supporting structure, but it will make the speed recovery of the far wake slower. Lin et al. (2019) studied the turbine and its wake-field characteristics on the base type horizontal-axis tidal turbines and proposed that the single pile turbine will significantly change the surrounding water movement. Zhang et al. (2017) found that varying the turbine proximity to the water surface introduces differential mass flow rate around the rotor that could make the wake persist differently. In addition to a large number of studies on the wake of a single turbine wake, there are a lot of researches were conducted on multiple turbines in array. The close proximity of turbines to one-another in these arrays has the potential to lead to interactions between them. Nuernberg et al. (2018) improved that lateral and longitudinal spacing variations of four turbines in array affect the wake downstream. Li et al. (2013) studied the wake recovery of five turbines in the array with different spacing and different rotors rotation directions. Oppong et al. (2020) proposed a theoretical model to investigate wake and central mixing region of double horizontal axis tidal turbine.

Unlike previous studies, the present work investigates the wake characteristics of a twin-rotor tidal turbine, considering impacts from rotor spacing and rotors rotation direction. Understanding the wake characteristics of twin-rotor turbines by physical experiments, can be used as a reference for the application of twin-rotor turbines in the array.

EXPERIMENTAL SETUP

All experiments in this study were carried out in a circulating flow flume in Hohai University. The schematic diagram of measuring section is shown in Fig. 1. X in the coordinate system indicates the flow direction (longitudinal), while Y denotes the horizontal across the width (transverse axis) and Z represents the depth (vertical axis). The flume is 50 m long, 5m wide and 0.7 m high. The flow velocity in the test section was set as 0.33m/s. The water depth of the flume was 0.5 m, and the turbine hub was located at the middle height of the water depth. Seen from X direction, 9 sections are measured in each case, from 1D behind the rotor rotation plane to 15D downstream (D means the rotor diameter). The Acoustic Doppler Velocimetry (ADV) was used to measure the flow field. The circulating flume and ADV are...