Performance Investigation of a Counter-rotating Tidal Current Turbine by Front and Rear Blade Angle by CFD and Model Experimentation

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ABSTRACT

Global warming is one of the issues in the world mainly due to the burning of fossil fuels and so alternative energy is now paramount in the 21st century. In Korea, the tidal currents in the South western sea has a large range of currents that are available for tidal current power generation. Single rotor turbines can obtain a theoretical maximum power coefficient of 59.3%, whereas dual rotor can obtain a maximum of 64%. In this study, we investigated the performance and efficiency of a Counter-rotating current turbine by different front and rear blade angle by water velocity using CFD and experimental methods.

KEY WORDS: Performance, Counter-rotating, current turbine, CFD, Experiment

INTRODUCTION

Global warming is one of the several issues in the world because the link between emissions of the burning of fossil fuels to the gradual rise in sea levels. With this effect of this issue in mind, many countries have increased the importance of alternative energy in the 21st century. One of the sources of energy is the ocean where the sun’s energy is converted into various natural phenomenon. Among the various marine energy resources in Korea, the tidal currents in the South western sea has a large range of currents that are available for tidal current power generation. The biggest advantage of tidal power and the difference from most renewable energy sources is that it is independent of seasons or weather and is always constant. This makes power generation predictable and makes tidal power a reliable energy source. Marine current turbines convert the kinetic energy in the marine current into a more usable form of energy such as electricity. The water velocity is used for power production and the sea water is still able to flow naturally through the tidal current turbines which makes this technology more environmentally friendly to the marine ecosystems around these systems. The horizontal-axis marine current turbine is one of the machines used to harness marine current energy. This type of turbine appears to be the most technologically and economically viable one at this stage. Single rotor turbines can obtain a theoretical maximum efficiency of 59.3%, whereas a dual rotor turbine can obtain a maximum of 64%. Therefore by optimizing the counter rotating turbines, more power can be obtained than the single rotor turbines.

A 40W horizontal axis type marine current turbine with 3 blades was designed according the Blade Element Momentum Theory. The purpose of this turbine is to conduct small scale experimental tests to analyze it’s performance characteristics. The turbine will be then scaled up to a size capable of producing 10kW in an submerged floating structure.

In a previous study, the 40W dual rotor turbine was fabricated and tested in a re-circulating water channel. The study looked at the performance characteristics, such as power and efficiency, of the turbine blade under varying water velocities. Then, the blade gap distance between the dual rotors was varied and the performance of the turbine was analyzed. After establishing the efficiency of this turbine when the blades were at 0 degrees, it was thought that changing either front/rear angles would increase the efficiency of the turbine.

Therefore in this study, we studied the performance and efficiency of a Counter-rotating marine current turbine by varying water velocities and front/rear blade angles using experiments and CFD methods.

NUMERICAL PROCEDURE

For this study, a 40W horizontal axis three bladed tidal current turbine was designed using BEMT. Fig.1 shows the single airfoil of NACA-63-421 with various twist angles and chord length. (left) and 3D modeling of a blade (right). Table. 1 summarizes the specifications and design of blade.

The diameter (D) of the turbine was 500mm and rated water speed was 1m/s. The design rotational speed is 190rpm. Fig.2 shows the three-dimensional model of the counter-rotating turbines and the experimental setup. Only a single blade was modeled with the other blades accounted for by specifying a periodic condition. The non-dimensional distance of the first node from the wall or the y-plus value was less than 5 in this calculation with approximately 6.2 million nodes in the hexa-grid. Fig.3 shows the computational domain. The distance from the blade to the inlet, top and outlet was 3, 5 and 7 times respectively the diameter of blade. The turbulence model used was k-ω SST. All the calculations were conducted under steady state condition using a commercial finite volume method solver, ANSYS CFX ver.13. The water velocity was varied from 0.8-2.0m/s.