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The magnetic driver in rotating wave energy converters

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ABSTRACT

In rotating wave energy converters, the traditional contact seal cannot completely prevent water leakage problems. In this study, the magnetic driver was introduced to replace the traditional contact seal in rotating wave energy converters, aiming to achieve absolute waterproof sealing and long-term running of the equipment. The equivalent magnetic charge theory and the finite element method were adopted to analyze the influence of magnetic driver parameters on its transmitted torque. The correlations between transmitted torque and different parameters were deduced from theoretical calculations and simulation results. The magnetic driver serves to improve the performance of transmission mechanism and promote the development of rotating wave energy converters, and the outcome of this research will guide the design of magnetic drivers suitable for rotating wave energy converters.

1. Introduction

The demand for energy has been growing rapidly as a result of the fast development of society. Because of the depletion of fossil energy and pollution to the environment, the demand of high-quality, clean and renewable energy is particularly urgent (Zheng et al., 2013). It is foreseen that in the coming decades, renewable energy will become one of the most rapid-developing industries. Many countries have issued government-sanctioned recommendations calling for renewable energy (Zhang, 2014). Ocean energy has been explored for decades and shows a great potential. Although technical limitations and high costs may still present as bottlenecks of its application, exploiting ocean energy is one of the most effective ways to solve energy crisis in today's world. It is of great strategic and practical significance to exploit ocean energy (Astariz and Iglesias, 2015). Power generation is one of the best forms to utilize ocean energy. There are diverse manners to generate electricity from ocean energy such as tidal energy, wave energy, ocean thermal energy and salinity gradient energy (Zhao et al., 2015).

Wave energy is the collection of kinetic energy and potential energy of the ocean surface waves. It is the most abundant source of ocean energy and shows advantages of high energy density, wide scope and renewability. Its reserve is plentiful in the west coast of the United States, Europe and the east coast of China (Zhang, 2012). As a result of climate change, the wave energy flow density has been increasing over the last decade in the east coast of China (Zheng and Li, 2015; Wu et al., 2015; Liu et al., 2015), making it suitable to apply medium-and-small sized wave energy converters in these areas. For most wave energy converters, three stages are needed to convert wave energy into electricity. At the first stage, converts capture wave energy and change it into mechanical energy; at the second stage, they convert the mechanical energy into rotating mechanical energy; at the third stage, they convert the rotating mechanical energy into electricity (Wang et al., 2015). Power generation efficiency and reliability of wave energy converters have been improved greatly with many laboratory experiments and sea trials. However, some bottlenecks remain unsolved, such as low conversion efficiency, high maintenance cost, poor durability and survivability (Lv et al., 2015).

In this paper we present the rotating wave energy power generation device as an example (Fig. 1). Rotating wave energy converters usually adopt traditional contact seals which are difficult to prevent water leakage. The longer time the converters run, the more severe the leakage becomes. The transmission mechanism has been optimized for the device shown in Fig. 1 to improve its reliability and practicality. However, during the sea trials the device showed problems of low generation efficiency, large starting torque and serious leakage in the generator bin (Fig. 2). Complete sealing and low resistance were difficult to achieve in the transmission part. To solve the problems, the concentric magnetic driver with isolation cover has been used, which improves the transmission mechanism (Krasilnikov and Krasilnikov, 2012; Wang, 2015). The magnetic driver is often used in devices such as magnetic pump but rarely used in rotating wave energy converters. In the study, we introduced the magnetic driver into

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Fig. 1. Rotating wave energy power generation device.

Fig. 2. Water leakage.

rotating wave energy converters to achieve complete sealing and further improve the reliability and practicality of the converters. The magnetic driver can achieve non-contact, flexible transmission without friction and mitigate wave ripple (Markov et al., 2000). Fig. 3 shows the torque transfer process of rotating wave energy converters with the magnetic driver.

2. Mathematical modeling

2.1. Working principle of magnetic driver

The magnetic driver consists of an driving rotor and a driven rotor. It can achieve isolation and complete sealing by the isolation cover between the driving rotor and the driven rotor (Krasilnikov and Krasilnikov, 2009), as shown in Fig. 4. In Fig. 5, the N-pole and the S-pole are crosswise arranged. When there is angular difference between the driving rotor and the driven rotor, the N-pole magnet on the driving rotor gives pushing force to the N-pole magnet and pulling force to the S-pole magnet on the driven rotor. The pushing force and the pulling force work together to drive the driven rotor (Mei et al., 2011). Fig. 6 shows the magnetic flux line distribution of a 4-pole-pair magnetic driver. Compared with flat type magnetic driver, the concentric magnetic driver induces no axial thrust and pressure to the supporting units, which improves the stability and prolongs the service life of rotating wave energy converters. Additionally, the concentric magnetic driver has more homogeneous magnetic field distribution, higher magnetic field utilizing efficiency, better spatial installation performance and transmits larger torque than the flat type magnetic driver (Ose et al., 2011).

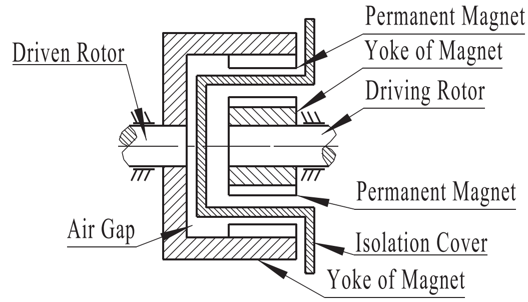

Fig. 4. Concentric magnetic driver.

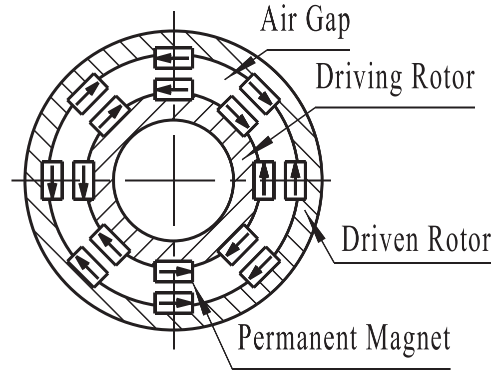

Fig. 5. Magnetic pole distribution.

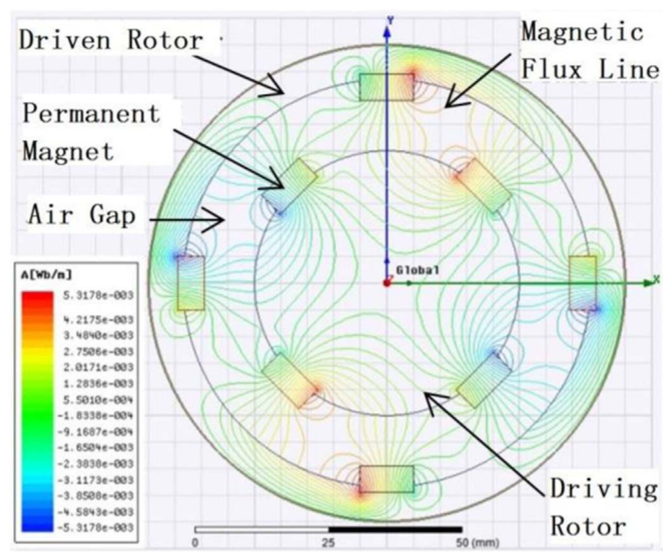

Fig. 6. Magnetic flux line.

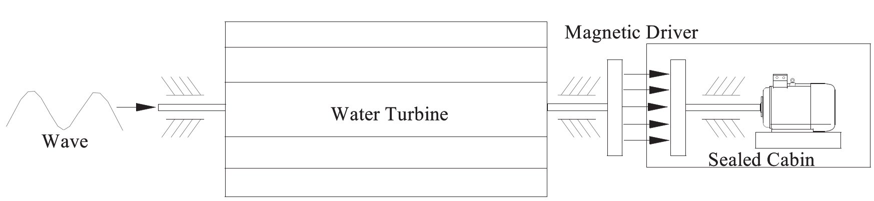

Fig. 3. Torque transfer process.