An Experimental Study on the Darrieus-Savonius Turbine for the Tidal Current Power Generation

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ABSTRACT

The Darrieus turbine is popular for tidal current power generation in Japan. It is simple in structure with straight wings rotating around a vertical axis, so that it has no directionality against the motion of tidal flow which changes its direction twice a day. However, there is one defect in the Darrieus turbine; its small starting torque. Once it stops, a Darrieus turbine is hard to re-start until a fairly fast current is exerted on it. To improve the starting torque of the Darrieus turbine used for tidal power generation, a hybrid turbine, composed of a Darrieus turbine and a Savonius rotor is proposed. Hydrodynamic characteristics of a semi-circular section used for the Savonius bucket were measured in a wind tunnel. The torque of a two bucket Savonius rotor was measured in a circulating water channel, where four different configurations of the bucket were compared. A combined Darrieus and Savonius turbine was tested in the circulating water channel, where the effect of the attaching angle between Darrieus wing and Savonius rotor was studied. Finally, power generation experiments using a 48 pole electric generator were conducted in a towing tank and the power coefficients were compared with the results of experiments obtained in the circulating water channel.

KEY WORDS: Tidal current power generation, Darrieus-Savonius turbine, Model test, Starting torque, Torque coefficient, Power coefficient, Single stream tube theory.

INTRODUCTION

Promotion of the utilization of natural energy is urgent as a countermeasure against global warming. There are several kinds of energy resources in the ocean but the utilization of ocean energy is far behind other natural energies such as wind, solar, ground thermal, small and medium hydraulic plants and biomass. Since the density of water is 800 times greater than air density and the power of the flow is proportional to the cube of the fluid velocity, the power of an ocean current of 2 knots is equal to a wind flow of 9m/s. There are some narrow channels in Japan such as the Naruto Channel, where the maximum current velocity is about 10 knots and the total power of the current is enormous. This is an appropriate location to propose this kind of project utilizing the ocean current to reduce carbon dioxide.

In this report, we propose a Darrieus-Savonius combined turbine to improve the small starting torque of a Darrieus turbine since a Savonius rotor generates large torque in the low speed range, whereas the Darrieus turbine generates large torque primarily in the high speed range. First, the hydrodynamic force of the semi-circular section which is used as the bucket of the Savonius rotor was measured in a wind tunnel. Then, the torque of the rotational axis of the Savonius rotor in four configurations of two buckets was measured in a circulating water channel. From the results of the tests, we adopted a configuration of the Savonius rotor to combine with the Darrieus turbine with two wings. We measured the torque of the combined turbine in the circulating water channel, altering the attaching angle between the Darrieus wing and the Savonius bucket. We confirmed the improvement of the starting torque of the combined turbine, but at the same time we found that the maximum torque at the high rotational velocity ratio was decreased by 30 % compared with the torque by the solo Darrieus turbine. To solve this problem, a ratchet mechanism or one way clutch mechanism between the Darrieus turbine and Savonius rotor was tested to avoid the negative torque which might be generated by the Savonius rotor.

Finally, electric generation experiments were conducted in the towing tank to confirm the starting torque characteristics of the Darrieus-Savonius turbine and the power coefficients were evaluated in comparison with the results obtained in the circulating water tank.