Design of Low Drag-to-Power Ratio Hydrokinetic Turbine

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ABSTRACT

A special type of horizontal axis hydrokinetic turbine is designed for Minesto's tidal kite with the goal of minimizing the drag-to-power ratio. The tidal kite is capable of sweeping through low velocity tidal stream (1.2–2.4 m/s) with the speed several times higher than current due to hydrodynamic lift forces acting on the wings. The turbine is located in front of the kite and extracts kinetic energy from the motion of kite in the tidal stream.

In conventional stationary hydrokinetic turbine, the structural support counteracts the drag forces on the turbine. Since the produced power is proportional to the cube of water velocity into the turbine, a lower drag is desirable to increase the kite speed. Excessive drag caused by higher loading of the turbine blades prohibits the kite to reach design speed. Therefore, conventional turbine design approach was not suitable for this project.

To reduce the overall weight of the kite, the turbine design was limited to open blade version (without duct). A matrix of design space was developed with diameter (D), rotational speed (RPM), number of blades (N) and tip speed ratio (TSR) as variable parameters. Using lifting line solver OpenProp[1], we selected a series of designs with highest drag to power coefficient ratio and desired output power of range.

For those selections, we performed CFD simulations using OpenFOAM viscous solver to determine blade section properties and type of hydrofoil with highest performance without risk of cavitation inception. The blade geometry was optimized using CAESES software coupled with CFD calculation. In the next step, the structural analysis and the total weight of the blades were the criteria to consider for the final design.

Model test was carried out in SSPA cavitation tunnel in different cavitation numbers and tip speed ratios. The model test resulted in minor improvement of the blade shape and the final new design was used to build a quarter of scale prototype for open sea test.

The quarter-scale sea trial is currently underway in Minesto's test site in Strangford Lough, UK, using a 3-meter wing prototype of tidal kite.

The paper compare CFD analysis with cavitation tunnel model-scale tests and quarter-scale sea trials. The performance of the new design is also compared to an existing reference design. In terms of drag to power coefficient ratio, the performance was improved by 20 %.

REFERENCES

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