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Application of End Plates for Vertical Axis Hydro Turbine Performance Enhancement

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ABSTRACT

A three blade, fixed pitch, vertical axis tidal current turbine was designed, instrumented and tested in the UBC campus towing tank. Experimental tests measuring torque, angular position, and revolution speed were conducted. Disc-shaped end plates as well as rectangular end-plates cut from NACA 0012 extrusion were applied. Results for the case without end plates are also compared to those predicted by a free vortex model both with and without a 3D correction applied.

KEY WORDS: vertical axis; turbine; end plates; numerical simulation; tidal power.

INTRODUCTION

The vertical axis wind turbine has seen extensive research aimed at understanding the complex flow dynamics and interactions associated with the rotating foils (Blackwell, 1974; Paraschiviou, 1981; Strickland, 1975; Templin, 1974). Many of these same interactions are observed when adapting the technology to a water medium for energy extraction from river or tidal currents, as has been done during the past two decades; however, this application also presents a number of unique challenges and design opportunities requiring further investigation.

Below, the recent experimental and numerical modeling of a vertical axis hydro turbine at the Naval Architecture Laboratory at the University of British Columbia is discussed. This work has been conducted in collaboration with Blue Energy International, a private developer of tidal turbine technology. The effects of both disc-shaped and rectangular end plates with a NACA 0012 profile are examined, and are then compared to a 2D Free Vortex numerical code both with with and without Prandt's finite wing theory applied.

TESTING FACILITY

Testing was conducted in the 60m x 3.6m x 2.4m deep towing tank. A towing carriage, typically used for ship model testing, pushed a specifically-designed auxiliary carriage that spanned the tank, to which the turbine model was mounted (Figure 1).

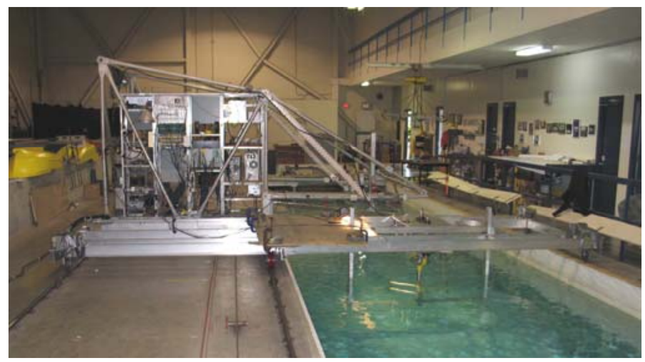
Figure 1: Experimental setup

EXPERIMENTAL INVESTIGATION

Model Design

The experimental model was a 0.91m diameter 3-bladed vertical axis turbine, with a central shaft of diameter 0.048m. The foil section used for the blades was a NACA 63_4-021 section with an ideal chord length of 0.0686m, of which the trailing edge was cropped to 0.065m to facilitate manufacturing. The NACA section was selected as per previous studies at the Canadian National Research Council (NRC) (Davis, Swan, and Kenneth 1981; 1982; 1984). The blades were mounted to the central shaft via two arms connected at the quarter-span locations. Arms were fixed to the blades using a pivot joint with a clamping mechanism such that the angle of attack could be adjusted using precision wedges. The lower shaft bearing was supported by a u-shaped frame, while the upper shaft bearing was on a plate above the free surface. Turbine revolution speed was regulated using an AC motor controller, and an optical encoder was used to measure rotational speed and angular position of the main shaft. A torque sensor was connected in-line between the gearbox and main turbine shaft to measure the torque produced by the turbine.

Riley (1951) demonstrated that end-plates with a foil-shaped cross-section were advantageous in reducing blade tip losses. Rectangular end plates with length equal to the chord and width of 0.58*chord with a NACA 0012 cross-section profile were applied. Given the circular path followed by the blade, a circular end plate (0.0064m thick) of diameter equal to blade chord was also tested. Figure 2 below displays the NACA 0012 (with flattened edge to sit flush on the foil) end plate and the circular end plate mounted to the blade.