Flexible Blades for Tidal Turbines

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Long Abstract

Introduction

The predictability and high power densities of tidal flows have long been recognised. Yet tidal stream energy has not lived up to it's energy generating potential given the complexities of operating within the marine environment. The combination of wave-current interaction and a high level of turbulence in the tidal stream results in a highly complex and chaotic environment [1]. Any viable tidal stream device has to be capable of operating efficiently, reliably and economically within such an environment if tidal stream energy is to cement its place as a viable option for meeting the world's increasingly ambitious renewable energy targets.

Ocean waves result in wave-induced cyclic velocity fluctuations strong enough to propagate through the water column to typical turbine deployment depths. In addition as a turbine blade rotates, and passes through the depth-dependent wave induced flow field, the blade experiences cyclic load fluctuations with a period of the blade rotation (about 2 seconds). These cyclical loadings can decrease the life of a turbine blade to 30 months, when the expected lifetime is of the order of 30 years. Whilst oscillating flow has been extensively investigated in such fields as helicopter rotors and turbomachinery, the combined effect of flow and pressure fluctuations induced by ocean waves on blade loadings is poorly understood [3, 4].

This paper investigates the transient loading and flow phenomena with large angle of attack variations associated with wave-induced current on individual turbine blade sections in order to fully understand the processes involved. In addition a novel flexible blade design is presented which has been designed to reduce the amplitude of load fluctuations experienced through passively flexing the trailing edge section to decrease the effective angle of attack. Preliminary results show that this flexing has minimal effect on the lift generated, and so improves the durability and fatigue life of tidal turbines without a large loss in power efficiency.

1. Methods

A loosely coupled fluid structure interaction code is developed combining linear wave and cantilever beam theories to predict the loading behaviour of the rigid and flexible blades for a range of geometrical and flow conditions. The numerical results are complemented with experimental measurements performed in the University of Edinburgh's combined wave and current flume, where individual 1/30th scale tidal turbine blades of varying flexibility are exposed to wave-induced oscillating flow. High-resolution Particle Image Velocimetry (PIV) measurements are used to gain an in-depth understanding of the underlying flow field around both the rigid (Figure 1) and flexible blades (Figure 2). Images are taken at 15 Hz frequency and are phase averaged to provide a complete picture of the flow phenomena over an oscillation period. In synchrony with these PIV measurements, turbulence data is measured with Laser Doppler Velocimetry, wave elevation is measured with wave gauges and forces on the blades are measured via a dual strain gauge force balance. Similarities and differences between the numerical and experimental results are discussed in the full paper.

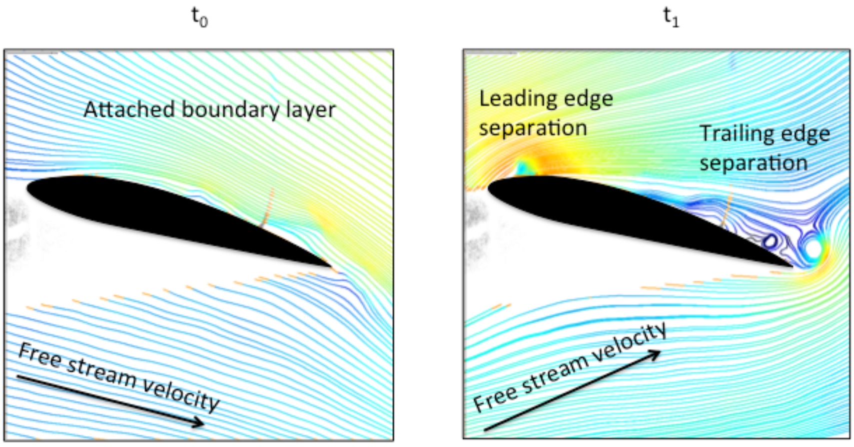

Figure 1: PIV measured streamlines coloured by flow speed (red is high speed, blue is low speed) around a rigid tidal turbine blade in wave-induced oscillating current.

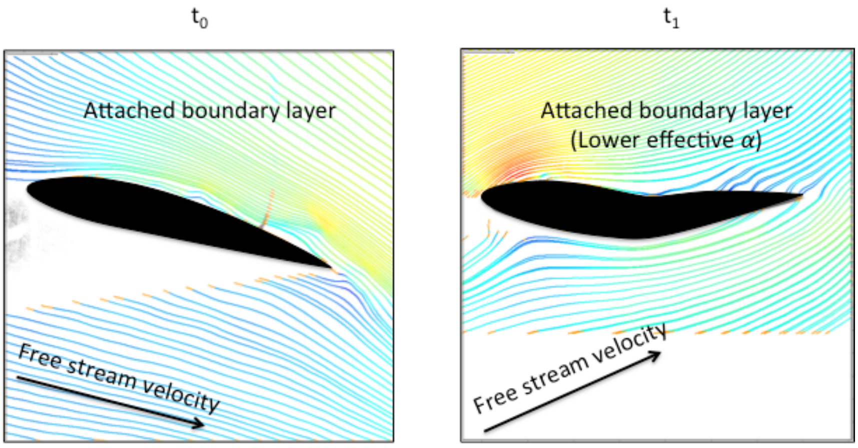

Figure 2: PIV measured streamlines coloured by flow speed (red is high speed, blue is low speed) around a flexible tidal turbine blade in wave-induced oscillating current.

This work provides valuable insight into the fluid dynamics of both flexible and rigid foils experiencing oscillating flow and pressure fields, and will contribute to the enhanced design of tidal turbine blades resulting in lighter and cheaper turbines with enhanced fatigue life. The high calibre experimental data collected also allows for the future validation of numerical models for predicting the stresses on blades with different flexibilities.

References

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