Implementing varying blade profile and Reynolds Number in BEMT code

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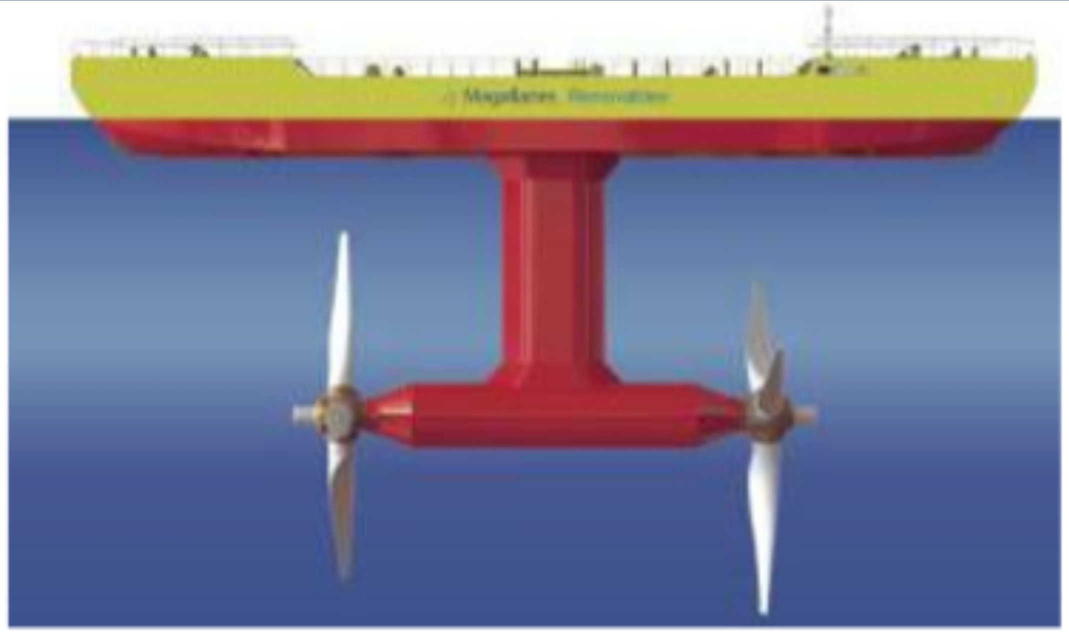

Figure 1. Schematic side view of the Magallanes ATIR rotor.

Tidal energy converters (TECs) have the potential to become significant contributors in the generation of low carbon energy.

The most significant barrier limiting widespread adoption of TECs is cost, which is significantly increased by planned and unplanned maintenance.

Accurate numerical models can be used to predict the structural loads on TECs to help improve the reliability of their design, reducing costs.

Blade element momentum theory (BEMT) offers an efficient method for predicting the performance of TECs. A robust BEMT model has been developed at Swansea University[1],[2], which will be the basis of this work. Classic BEMT models only allow for inputs of constant blade profiles and Reynolds Numbers which contributes to inaccuracies in predicting the performance of TECs.

A comparison between the BEMT model with and without the inputs of varying blade profiles and Reynolds Numbers has been made against laboratory results to quantify any improvements in the accuracy of the BEMT model.

The rotor used for comparison is Magallanes ATIR[3]. A schematic of this rotor is shown in Fig.1 whilst Fig.2 shows the blade profile along the radius of the rotor blade.

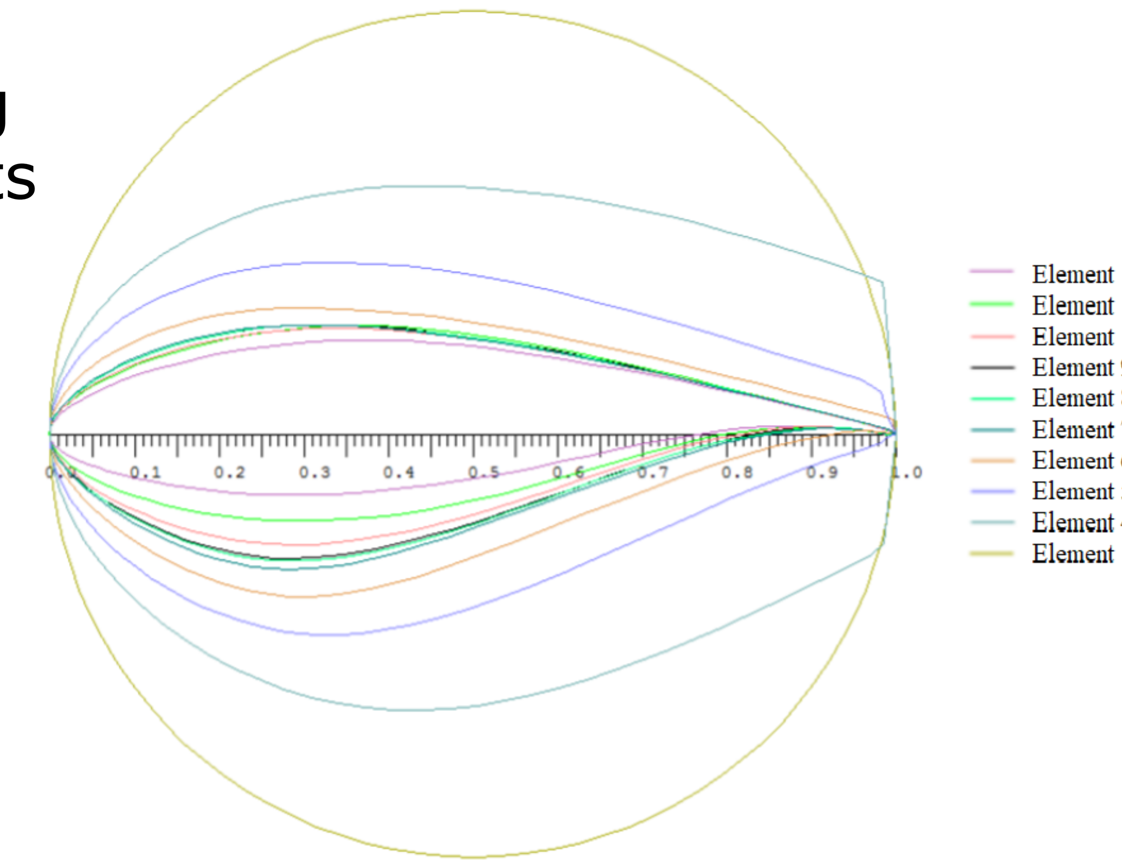

Figure 2. Blade profile along the radius of the Magallanes ATIR rotor.

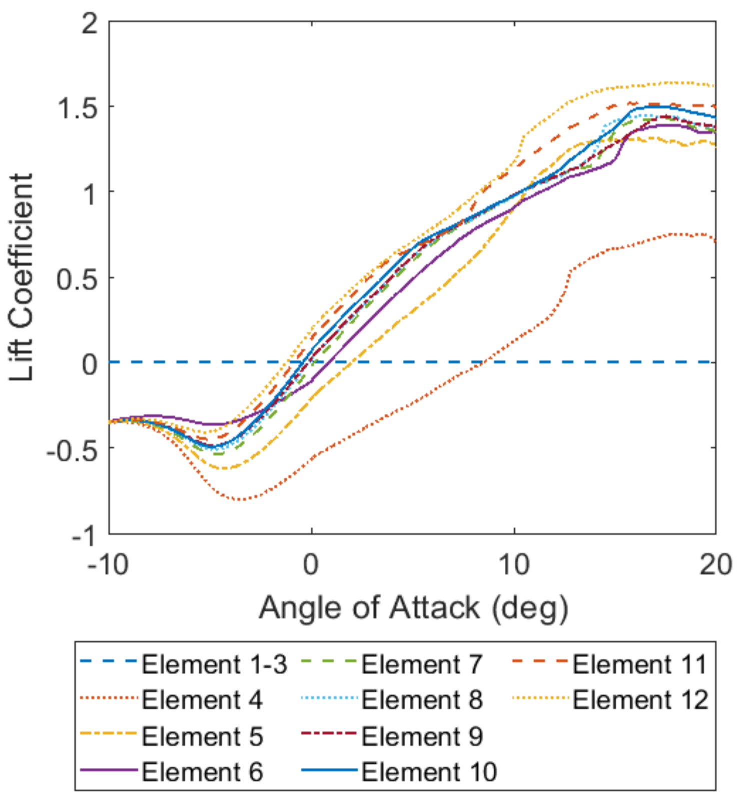

Figure 3. Lift coefficients for different elements along the radius of the rotor

BEMT calculates the performance of the rotor from the lift and drag characteristics. As seen in Fig.2 there is a big difference in blade profile, and hence lift and drag characteristics, from the rotor hub to tip.

Fig.3 shows the lift coefficient for each element between angle of attack of -10deg and 20deg. Assuming constant lift and drag coefficients across the whole rotor is clearly inaccurate and must contribute to inaccuracies in the BEMT model.

Fig.4 is a plot of power coefficient (Cp) against tip speed ratio (TSR) for results from the BEMT with and without varying blade profiles and Reynolds Numbers, and laboratory tests. For reasons of commercial sensitivity, all Cp values have been anonymised by scaling with the maximum value of Cp.

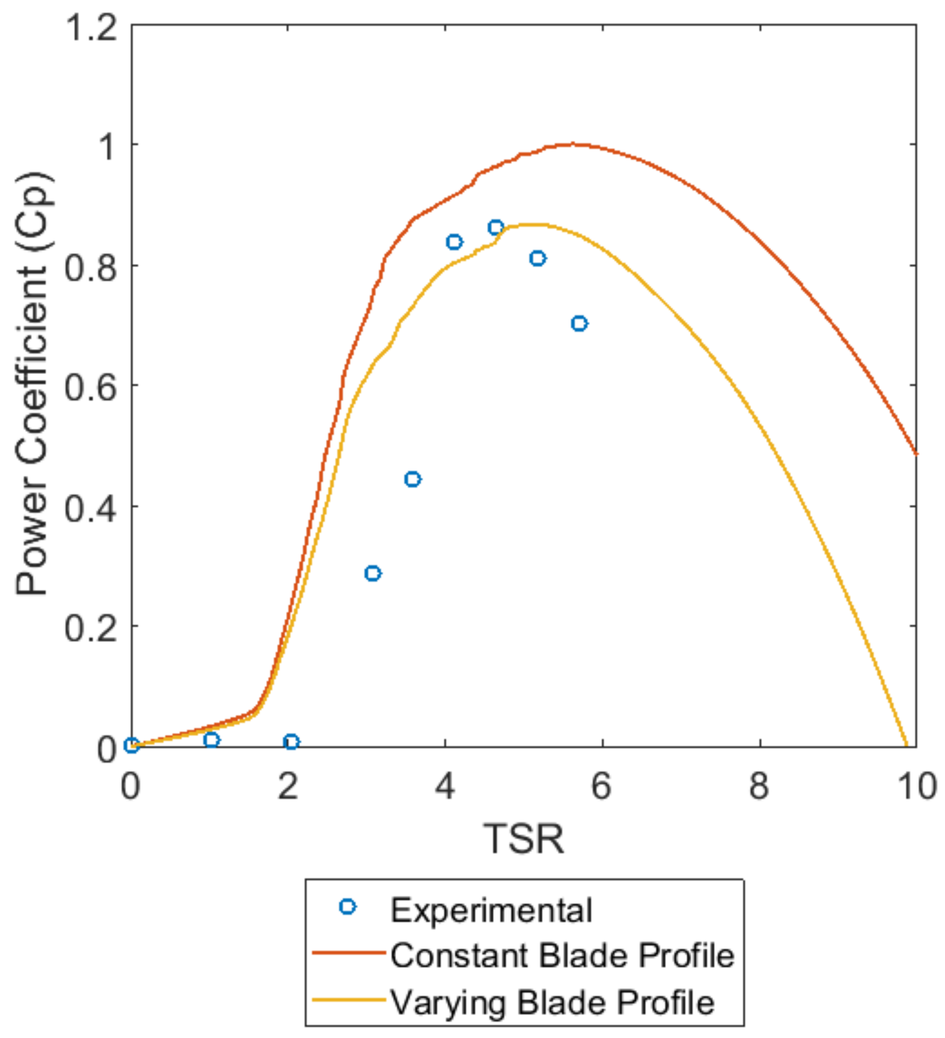

Figure 4. Comparison of coefficient of power against tip speed ratio for experimental and BEMT results.

The inclusion of varying blade profiles and Reynolds Numbers in the BEMT model reduced the maximum Cp value by 13% to exactly match the maximum Cp of the laboratory tests. It also reduced the TSR at maximum Cp value to better replicate the laboratory results.

Significant improvement in BEMT rotor performance prediction is seen with the inclusion of varying blade profiles and Reynolds Numbers. This will result in better design of TECs, reducing their cost, and increasing their adoption as generators of low carbon energy.

[1] I.Masters, J.C.Chapman, M.R.Willis, & J.A.Orme. A robust blade element momentum theory model for tidal stream turbines including tip and hub loss corrections. Journal of marine Engineering and Technology 10(1), 25-35. (2011).
[2] J.C.Chapman, I.Masters, M.Togneri, & J.Orme. The Buhl correction factor applied to high induction conditions for tidal stream turbines. Renewable Energy 60, 472-480. (2013).
[3] P.Mycek, B.Gaurier, G.Germain, G.Pinion, & E.Rivoalen. Experimental study of the turbulence intensity effects on marine current turbines behaviour. Part 1: One single turbine. Journal of Renewable Energy 66, 729-746. (2014).

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