Experimental Investigation of Thrust and Power on a Tidal Turbine Fence Array

Susannah Cooke, Supervisors: Richard Willden and Byron Byrne

SUMMARY
Experiments using porous disc arrays in a flume to simulate fences of tidal turbines in a confined tidal channel
- Comparing experimentally observed thrust and extracted power of disc arrays to that predicted by analytical theory
- Investigating multiple porosities of discs at multiple spacings

THEORY
- Analytical 'partial fence theory' [1] based on actuator disc theory
- Predicts higher thrust and power available to correctly spaced arrays
- Includes simplifying assumptions regarding separation of wake mixing between device and array scales
- Previously investigated in computational work [2] but only tested experimentally as regards thrust, not power [3]

EXPERIMENTAL SET UP
5m wide flume at the University of Manchester
- 8 porous discs, Ø27cm (B_G = 0.2)
- Multiple spacings/disc porosities
- Velocity measurements taken downstream in wake behind array

RESULTS
Not possible to measure \( U_{\text{disc}} \) using ADV to calculate power. Closest measurement possible at 0.3d downstream.

\[
\text{‘Inferred power’}: P_{\text{inferred}} = T_{\text{disc}} \times U_{\text{disc,0.3d}}
\]

As predicted by theory:
- Power increase as spacing reduced from homogenous fence
- Drop-off in thrust/power at highest disc resistance
However:
- Measured \( C_{PG} \) values much lower than predicted
- Shift in location of peak \( C_{PG} \) vs theory predictions

\begin{center}
\begin{tabular}{|c|c|c|c|c|}
\hline
\( \Theta \) & w_d & 0.25 & 0.3 & 0.35 & 0.4 \\
\hline
0.05 & 2.27m & ✓ & ✓ & ✓ & ✓ \\
0.1 & 2.59m & ✓ & ✓ & ✓ & ✓ \\
0.2 & 2.59m & ✓ & ✓ & ✓ & ✓ \\
0.3 & 2.81m & ✓ & ✓ & ✓ & ✓ \\
0.4 & 3.02m & ✓ & ✓ & ✓ & ✓ \\
\hline
\end{tabular}
\end{center}

\( \Theta \) (open area ratio) \( w_d \) (constant array width: \( \Theta = 0.3 \), all s/d)

- Likely to be largely due to significant drop-off in both thrust and power seen at edges of all arrays – i.e. end effects

CONCLUSIONS
Experimental findings generally in line with trends predicted by theory – increased power available to correctly spaced arrays

Significant differences from theory in magnitude of thrust and power – likely largely due to end effects on finite fence array

Experimental results will be used to develop an improved analytical model to include these effects

REFERENCES