Anisotropic blockage for tidal turbines (AnisoTide)

The aim of this project was to demonstrate how anisotropic blockage, for example arising from large width to depth ratios, influences tidal turbine loads. This is not considered in engineering design tools, despite being present and varied across the tidal energy industry (Figure 1).

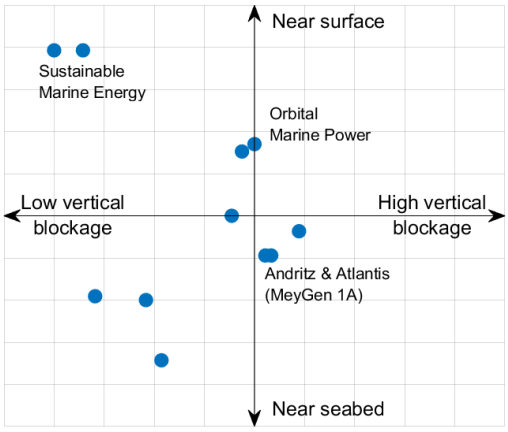

Figure 1. Vertical blockage ratios and installation depths for a range of tidal energy projects..

Experiments were conducted at the University of Oxford's flume (width, w=1.1 m, maximum depth, h=1 m) using porous disks. Disk diameter (d) and water depth were varied to control vertical (B_v) and global (B_g) blockage. Disk porosity was also controlled by plugging the disk holes. Disks were mounted on a single axis force sensor and positioned in the channel using a custom frame (Figure 2). Flow measurements were made with a Nortek ADV to obtain a disk averaged flow speed without disks present, U_0, and through the disk, U_d (by averaging points just up and downstream of the disk). The following parameters are defined (with ρ=1000 kg/m^3):

$$\underbrace{A_d = \frac{\pi d^2}{4}}_{\text{Disk area}}, \quad \underbrace{B_g = \frac{A_d}{wh}}_{\text{Global blockage}}, \quad \underbrace{B_v = \frac{d}{h}}_{\text{Vertical blockage}}, \quad \underbrace{C_T = \frac{F_x}{0.5\rho U_0^2 A_d}}_{\text{Thrust coefficient}}, \quad \underbrace{C_P = \frac{C_T U_d}{U_0}}_{\text{Power coefficient}}$$

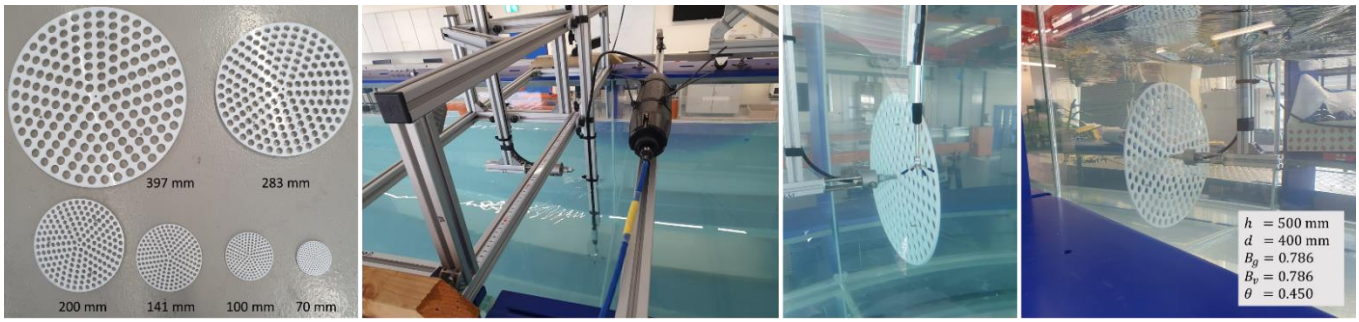

Figure 2. From Left to Right: Disks used in tests; Mounting rig (no disk); ADV measuring flow just behind disk; Disk with high vertical blockage

Figure 3 shows the preliminary results. Thrust increases with vertical blockage as does the inferred power. Global blockage values considered are relatively low and have much less effect on results than vertical blockage. Porosity also influences the loading, although relative differences are much smaller than the vertical blockage effect for the parameter ranges considered here.

This project demonstrates that loads increase as tidal turbines fill an increasing proportion of the water column. These effects are not considered by standard blade-element design tools nor blockage corrections. This is important as turbine developers are currently designing such rotors as a route to cost reduction and industrialization, and therefore under-predicting loads.

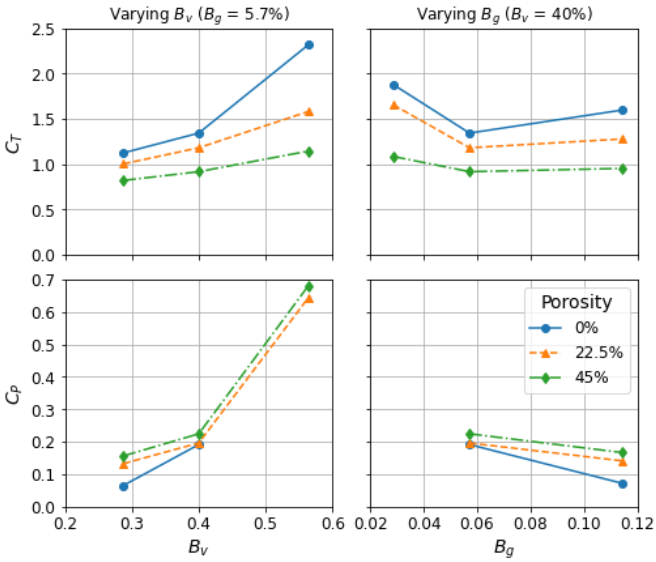

Figure 3. Selected results showing effect of vertical blockage (left column) and global blockage (right column) on disk thrust (top row) and power (bottom row).

I would like to acknowledge the financial support of SuperGen ORE and Department of Engineering Science (University of Oxford). Additionally Andritz Hydro Hammerfest provided useful discussions and the experiments were performed during my postdoc funded by Richard Willden's EPSRC fellowship.

To discuss results or collaborate on the topic, please feel free to send me an e-mail at MARIN where I now work.

James McNaughton – j.mcnaughton@marin.nl 24/03/2023