WATER INFORMATICS SCIENCE & ENGINEERING
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Developing a Hydro Turbine for Shallow Water River Systems

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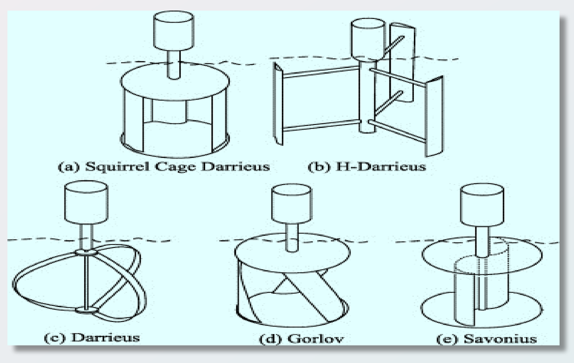
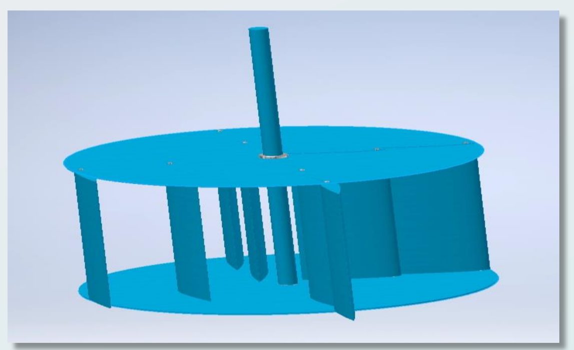
Why care about shallow water River systems for hydropower?

- Huge global potential of hydropower from in-land waters and built-in environment
- UK: >7,500 km of navigable waterways [1] with many possible sites for hydro development
- US: Small & Micro hydro from natural streams to increase 50% of hydroelectricity generation [2]
- India: >15,000 km navigable waterways [3] mainly for irrigation. >9% of the country's suicide accounted for farmers mainly due to farming related debts in 2014 [4]. Can the cost of farming be reduced by harnessing electricity?


Conventional Axial Flow Lift based Turbine for Tidal Current (Left) and an Estream ® miniature Turbine in a River (Right)





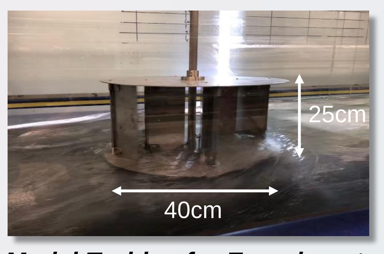
Common types of Vertical Axis Turbine [5] (Left) and the Model turbine considered for research (Right)

- Most of the research and development on hydro-kinetic turbines focused on tidal currents
- Efficient turbines for the tidal stream are emerging with axial flow and lift based providing promising results on efficiency [6]
- But what about shallow depth river systems and built-in environment?
- Lack of research on low cost, environmentally friendly turbine to adapt the shallow depth River and River-alike hydro-dynamics

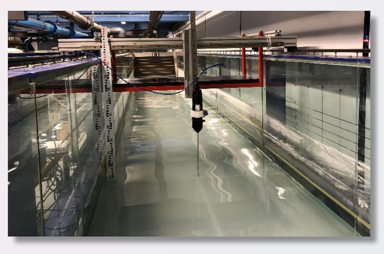
Methodology for Turbine Development

Experimental Testing

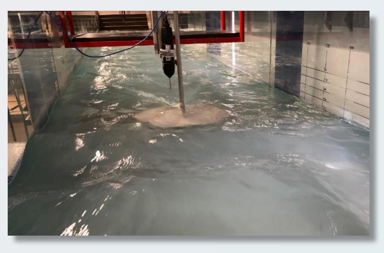
✓ Free Stream Velocity measurement of flume by Acquistic Doppler Velocimeter (ADV)



Model Turbine for Experiment

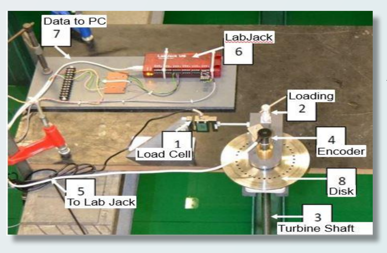


Nortek® ADV Profiler at Cardiff University flume to measure flow velocity



Model Turbine Generating Power in Test Flume

✓ Estimate theoretical power output of model Turbines



Instrumentation for Power Take-off Mechanism (PTOM) for test Turbine [7]

✓ Test the model turbine with changes in number and shapes of turbine blades at various Reynolds Number (R_e ⟶ 2~ 5 x10^5)

✓ Change the flume side walls to funnel the flow to the turbine

✓ Record and calculate measured power output of model turbines

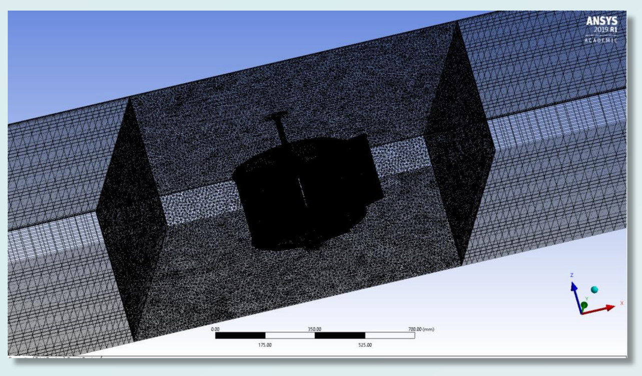
✓ Calculate turbine power coefficient (C_p)

✓ Assess results between two PTOM Approaches: Mechanical Disk Brake System & Electrical Servo-Motor System

CFD Modelling

✓ Develop and compare Computational Fluid Dynamics (CFD) models with ANSYS CFX ® for multiple rotating blade turbine

- 2D Model Approach
- Pseudo-Transient 3D Model Approach
- Dynamic 3D Meshing Approach

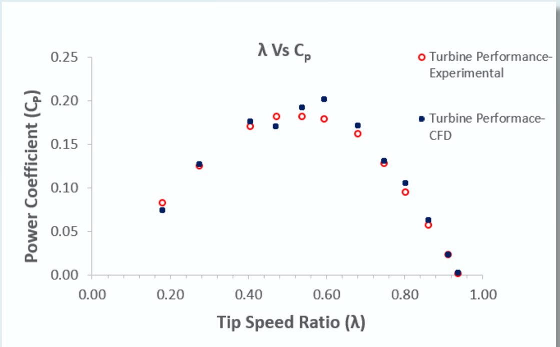


3D Mesh of Flume and Turbine developed using ANSYS CFX®

✓ Compute power coefficient (C_p) for all the options considered in the Experimental work

Validation

✓ Assess how accurately the ANSYS CFX ® results from different modelling approaches compare with the experimental outcomes from the turbine flume test



A Typical comparison of Experimental outcomes with the CFD results

✓ Quantify error and uncertainty estimates for both the CFD and experimental results

Optimum Turbine

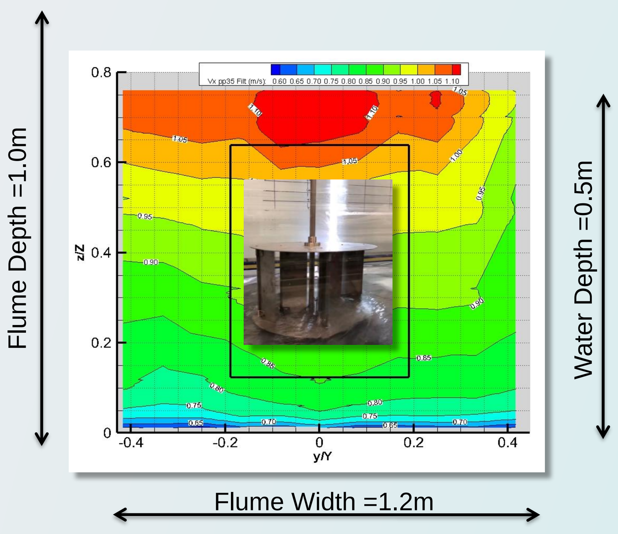
✓ Establish an optimum turbine configuration

✓ Recommend a computationally cost effective CFD Model Approach for an early stage Design Optimisation

✓ Understand the impact of channel shapes on turbine performance

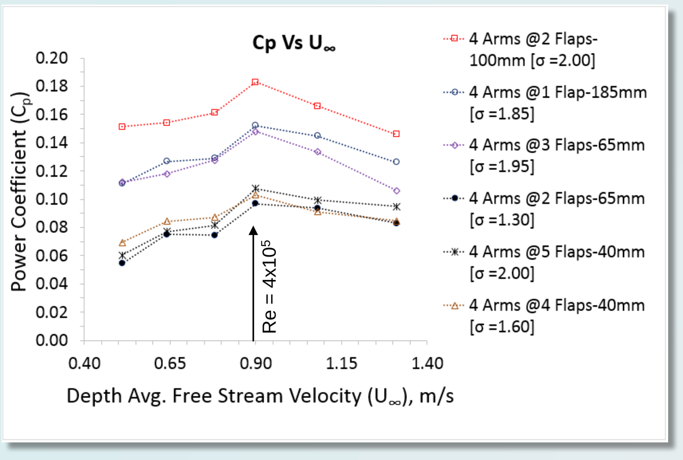
Results so far

✓ Free Stream velocity provides an insight into the theoretical power potential of a water channel



Free Stream Velocity Contour at Re = 4x10⁵

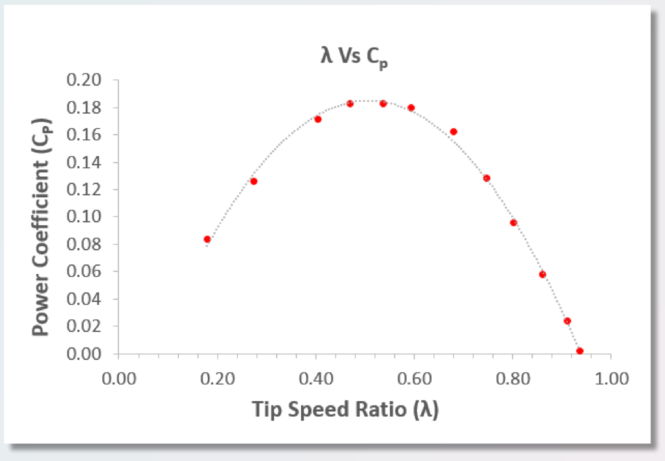
✓ Turbine performance not only varies with changes in turbine blade numbers but also depends on the Reynolds Number (R_e) due to channel turbulences



Turbine Performance Peaking at Re = 4x10⁵

✓ Turbine with 2 flaps at each four arms shows a promising performance among the six different turbine options trialled so far.

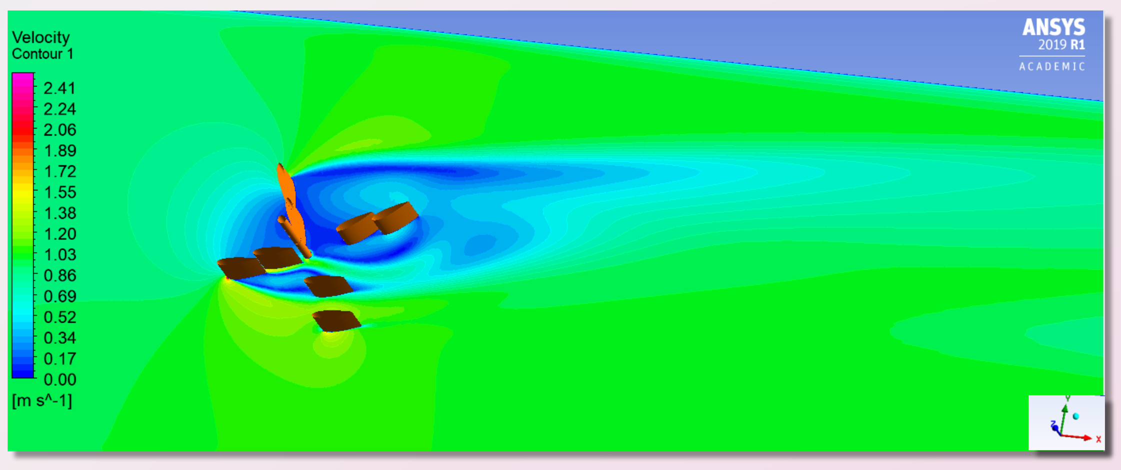
✓ C_p of 0.18 provides an extra room for improvement with further experimental study



Turbine Performance Curve at Re = 4x10⁵

✓ CFD model works as a supporting tool for turbine model optimisation alongside the experimental testing that allows a comprehensive flow field visualisation

✓ The maximum torque developed on the turbine blades are compared with the experimental results which show a varying degree of agreements with the experimental results (2% to 12%)



Average Velocity Contour Plot of Turbine by Pseudo-Transient Modelling Approach

What Next ?

✓ Develop further CFD models for all approaches with ANSYS CFX® and validate with experimental outcomes

✓ Suggest a computationally low cost modelling approach for an *Early Stage Design Optimisation* of turbine with multiple moving parts

✓ Experimentally test the turbine with further modification of flume channel and blades shapes

✓ Establish an optimum turbine configuration and understand the impact of channel shapes on its performance

Further Information:
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