Numerical / Experimental Comparison of a Scaled Model Horizontal Axis Marine Hydrokinetic (MHK) Turbine

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Motivations & Goals

- Need for an experimental database to benchmark numerical methodologies to model MHK turbines.

- Understand the trade offs in numerical models to simulate the flow field of MHK turbines.

- Develop a validated numerical methodology to support design of full-scale horizontal axis MHK turbines.
Numerical Methodology

1. Sliding Mesh Model
2. Rotating Reference Model
3. Blade Element Theory
4. Actuator Disk Theory
Rotating Reference Frame Model
Computational Domain (Zoomed-in)
Numerical vs. Experimental Results
Efficiency ($C_p$) – Tip Speed Ratio (TSR) Curves
Limited Streamlines + Wall Shear Stress along the Blade
Limited Streamlines + Wall Shear Stress along the Blade

- TSR = 5.5
- TSR = 6.15
- TSR = 7.16
Numerical vs. Experimental Results

Efficiency ($C_p$) – Tip Speed Ratio (TSR) Curves
Dynamic Fluctuations in Experiment at Low TSRs

Normalized rotational speed for high and low TSR

- TSR 5
- TSR 10

Time (seconds)

Normalized rotational speed
Numerical vs. Experimental Results
Efficiency ($C_p$) – Tip Speed Ratio (TSR) Curves
Numerical vs. Experimental Results
Reynolds Number Effect

Experimental

Numerical
Numerical Results – Velocity Field
(TSR=7.16, Re=100,000)
Numerical vs. Experimental Results

Velocity Deficit Profiles

Experimental vs. Numerical

Streamwise velocity profiles for TSR 7

Normalized vertical distance from centerline

Normalized streamwise velocity

Experimental

Numerical
Numerical vs. Experimental Results
Velocity Deficit Profiles

Streamwise velocity profiles for TSR 7

- 2D up
- 2D down
- 3D down
- 5D down
- 7D down

Normalized vertical distance from centerline

Normalized streamwise velocity
### Numerical vs. Experimental Results

**Sliding Mesh Model – TSR=8.17**

<table>
<thead>
<tr>
<th></th>
<th>Efficiency [-]</th>
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<tbody>
<tr>
<td>Experiment</td>
<td>0.38</td>
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<tr>
<td>Sliding Mesh Model</td>
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<tr>
<td>Rotating Reference Model</td>
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Summary & Conclusions

- 3D RANS numerical models are validated to characterize the performance of a scaled model MHK turbine.

- The error between the measured and predicted power values was between 1% to 25%.

- 3D RANS predicted better results in flow fields with high Reynolds number and not existing or small flow separation.

- Experiment shows that the wake of nacelle enhances velocity deficit recovery, but the current 3D RANS model is limited to capture this physical phenomenon.
Single Rotating Reference (SRF)

- The idea is to render an unsteady problem in the fixed ref. frame into a steady problem in the rotating ref. frame.

- RANS equations are solved in the rotating reference frame.
Computational Domain

- Pressure Outlet
- Slip free surfaces
- Blade wall (no slip)
- Planes of Symmetry
- Velocity Inlet (flow direction)
Lift/Drag Coefficients and AOA along the Blade Span (TSR=7.16)