Hydrodynamic characteristics of a full-scale kelp model

1. Build a full-scale model representing *Saccharina latissimi* (*Sugar Kelp*) densely grown in Saco Bay Maine.
2. Match the exposed length, flexural rigidity, the number of blades, the mass/length of biomass, and mass density.
3. Tow model in the 116m x 7.9m x 4.9m with the model at aligned and perpendicular orientations.
4. Resolve the normal and tangential drag area characteristics.
5. Use results in numerical model validation.

Hydrodynamic characteristics of a full-scale kelp model

Kelp Model
- Length: 3m, Width: 1m, flexural rigidity
- 178 strips of LDPE (534 m)
- Actual 300-400 blades/m
- ≈ 16 kg/m

Aligned Orientation
- Forces measured with two force blocks
- Tangential forces obtained with coordinate transformation
- Normal forces resolved as a balance from weight and buoyancy
- Tows done at 5 speeds from 0.25 to 1.25 m/s
Hydrodynamic characteristics of a full-scale kelp model

Aligned Orientation

\[ S_{Dx} = \frac{f_{Dx}}{\frac{1}{2} \rho_w U_x^2} \rightarrow D_n C_n \]

\[ S_{Dza} = \frac{\left( \frac{f_{Dza}}{2} \right)}{\rho_w U_{za}^2} \rightarrow D_t C_t \]

Perpendicular Orientation

\[ S_{Dy} = \frac{f_{Dy}}{\frac{1}{2} \rho_w U_y^2} \rightarrow D_n C_n \]

\[ S_{Dzp} = \frac{\left( \frac{f_{Dp}}{2} \right)}{\rho_w U_{zp}^2} \rightarrow D_t C_t \]

Normal

Tangential

Used in a “Morison Equation” type approach in the FEM
Hydrodynamic characteristics of a full-scale kelp model

Results

1. Normal and tangential drag-area values per 3m length of model obtained for a 1m aggregate.

2. Small difference between tow orientations.

3. Defines the hydrodynamic scale for FEM approach as a 1 meter section on the grow line

4. Consistent with “Morison equation” approach using relative velocity components

5. Discretized beam elements (sub-meter) – will want to reproduce the angles

<table>
<thead>
<tr>
<th>Tow Speed (m/s)</th>
<th>Normal Orientation</th>
<th>Tangential Orientation</th>
<th>Normal Orientation</th>
<th>Tangential Orientation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$s_{Dx}$ (m²/m)</td>
<td>$s_{Da}$ (m²/m)</td>
<td>$\theta_x$ (deg)</td>
<td>$s_{Dy}$ (m²/m)</td>
</tr>
<tr>
<td>0.25</td>
<td>2.35</td>
<td>0.225</td>
<td>25.1</td>
<td>2.49</td>
</tr>
<tr>
<td>0.50</td>
<td>1.95</td>
<td>0.0803</td>
<td>14.1</td>
<td>2.03</td>
</tr>
<tr>
<td>0.75</td>
<td>1.66</td>
<td>0.0478</td>
<td>10.1</td>
<td>2.46</td>
</tr>
<tr>
<td>1.00</td>
<td>1.39</td>
<td>0.0401</td>
<td>8.3</td>
<td>1.57</td>
</tr>
<tr>
<td>1.25</td>
<td>1.45</td>
<td>0.0326</td>
<td>6.5</td>
<td>1.88</td>
</tr>
</tbody>
</table>
Hydrodynamic characteristics of a full-scale kelp model

Characterization of the transition from normal to tangential drag

\[ 0 = f_{Dx_i} - \left[ \rho_{aggregate} A_c g - f_B \right] \cos(\theta_{x_i}) \]

\[ 0 = f_{Dy_j} - \left[ \rho_{aggregate} A_c g - f_B \right] \cos(\theta_j) \]