Comparison of water jets and conventional propeller jets

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conventional propellers

- propeller with rudder
- outflow velocity: 5 - 8 m/s
- azimuthal system
- bow thruster

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Deltanes
water jets

- low-powered small boats
- high-powered fast ferries

outflow velocity: 20 – 25 m/s !!!
principles of water jets

forward mode

reverse mode

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Deltasres
CFD simulations

forward mode

reverse mode

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Deltareas
berthing manoeuvres

relevant aspects:

- manoeuvres
- applied power
- location quay wall
inland navigation: pump jets
high-powered jets

Stena Discovery: 4 x 17,000 kW

resulting formulas:

\[ V_0 = 0.9 \left( \frac{f_p P}{\rho A} \right)^{0.33} \]

\[ V_{x,r} = 12.4 \left( \frac{1}{x} \right)^{1.17} V_0 \exp\left( -92.8 \frac{r^2}{x^2} \right) \]
low-powered jets

resulting formula:

\[ V_{x,r} = 2.8 \frac{D_0}{(x)^{0.85}} V_0 \exp\left(-25 \frac{r^2}{x^2}\right) \]

ferry Terschelling: 2 x 750 kW
comparison of flow velocities in the jet axis

- high-powered water jet
- circular free jet
- low-powered water jet
- propeller jet
### Comparison Flow Field Formulas

<table>
<thead>
<tr>
<th>Thruster</th>
<th>Outflow Velocity</th>
<th>Velocity in the Jet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Propeller</td>
<td>$V_0 = 1.1 \left( \frac{f_p P}{\rho D^2} \right)^{0.33}$</td>
<td>$V_{x,r} = 2.8 \left( \frac{D}{x} \right)^{1.0} V_0 \exp \left( -15.4 \frac{r^2}{x^2} \right)$</td>
</tr>
<tr>
<td>Water Jets:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Low-powered</td>
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</tr>
<tr>
<td>Circular Free Jet</td>
<td>$V_0 = \frac{Q}{A}$</td>
<td>$V_{x,r} = 6.2 \left( \frac{D}{x} \right)^{1.0} V_0 \exp \left( -69 \frac{r^2}{x^2} \right)$</td>
</tr>
</tbody>
</table>

**Conclusions:**
1. Low-powered jets resemble conventional propeller jets.
2. High-powered jets resemble circular free jets.
observed jet scour

cracks in a road due to jet scour
Scour: means a longer sheet piling taking into account scour depth
Protection: means additional dredging to realize the constriction thickness
mitigating measures

scour or a bed protection is the consequence of the chain:


• bed protection: \( d \geq 0.5 \frac{V_{bed}^2}{2g} \)

  rock <> mattrasses:
   a rock protection is thicker than a mattress, but might be cheaper

• no protection but allowing the development of a scour hole:

  \[
  \frac{S}{d_{85}} = \frac{h_p}{d_{85}} C_{ad} C_{m,r} \left[ a \frac{B}{B_{crit}} - 1 \right]
  \]

• avoiding scour forces by reduction of the applied engine power to
  less than 10\%
conclusions

• there are significant differences between a high-powered jet and a low-powered jet regarding:
  - the decrease of the flow velocities in the jet axis, and
  - the diffusion of the jet in radial direction
• the characteristic flow field seems to depend on the power and induced turbulence
• low-powered jets resemble the flow field of a conventional propeller jet, although the flow velocities are about 50% higher
• high-powered jets resemble the flow field of a circular free jet
• pump jets installed in inland vessels: probably comparable with a low-powered jet, but no proof