Accommodating Larger Vessels: Ship Maneuverability and Channel Depth;

A discussion of vessel motion in shallow water and future research needs.
PANELISTS:

Paul Amos: President, Columbia River Pilots.

Larry Daggett: Vice President, Waterway Simulation Technology. Previously with Army Corps ERDC labs.

Dan Jordan: Columbia River Bar Pilot, currently involved in a study of vessel dynamics on the Columbia River Bar.

Mike Morris: Houston Ship Channel Pilot.

Eric Burnette: Sr. Waterways Planner, Port of Portland, Oregon (moderator).
ORDER OF PRESENTATION:

1. Introduction of panelists.

2. Trends driving the discussion of vessel motion in shallow water.
   
   1. Presentation on basic squat and under-keel definitions and concepts.
   
   2. Very brief audience Q & A on key definitions and concepts.

1. Moderated discussion between panelists.

1. Audience Q & A.
An operational view of Vessel Motions

Squat / Sinkage
Heel / Roll
Pitch / Wave Response
Real Scale in Calm Water
Components of Under Keel Clearance

- Water surface
- Vertical Datum
  - NAVD 88 (MLLW)
- Channel depth
- Draft
  - Draft Adjustment due to Density
  - Squat allowance
  - Heel allowance
  - Wave response allowance
  - Predicted Minimum Keel Elevation
- Tide
- Survey allowance
Squat / Sinkage

Dynamic draft

Net UKC
Squat changes with speed and bottom contours
Roll / Heel
## Increase of Draft due to List

<table>
<thead>
<tr>
<th>Beam</th>
<th>1°</th>
<th>2°</th>
<th>3°</th>
</tr>
</thead>
<tbody>
<tr>
<td>60’</td>
<td>0.52’</td>
<td>1.05’</td>
<td>1.57’</td>
</tr>
<tr>
<td>80’</td>
<td>0.70’</td>
<td>1.40’</td>
<td>2.09’</td>
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<tr>
<td>100’</td>
<td>0.87’</td>
<td>1.75’</td>
<td>2.62’</td>
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<tr>
<td>110’</td>
<td>0.96’</td>
<td>1.92’</td>
<td>2.88’</td>
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<tr>
<td>120’</td>
<td>1.05’</td>
<td>2.09’</td>
<td>3.14’</td>
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<tr>
<td>140’</td>
<td>1.22’</td>
<td>2.44’</td>
<td>3.66’</td>
</tr>
<tr>
<td>160’</td>
<td>1.40’</td>
<td>2.79’</td>
<td>4.19’</td>
</tr>
</tbody>
</table>
Wave Response

Dynamic draft

Net UKC
**Wave Response**

Offshore Swell height = 2m, period = 14 seconds

- **EBB**
  - Tidal Current (5.0kn)
  - Swell (2.8m Hm0)
  - Handymax
  - PostPanamax

- **FLOOD**
  - Tidal Current (3.0kn)
  - Swell (1.7m Hm0)
  - Handymax
  - PostPanamax

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- Tidal Current (3.0kn)
- Tidal Current (5.0kn)
- Swell (1.7m Hm0)
- Swell (2.8m Hm0)
- Offshore Swell height = 2m, period = 14 seconds
- EBB
- FLOOD
- Bass Strait
- Port Phillip Bay
Effects of Squat on Vessel Maneuverability

Directionally Stable with Pivot Point forward

Directionally Unstable with Pivot Point aft
Effects of Squat on Vessel Maneuverability

Normal Bow Pressure with Pivot Point forward

Increased Bow Pressure with Pivot Point aft
Effects of Squat on Vessel Maneuverability

Normal turning forces

Increased bow pressure and shortened steering lever make turns difficult to control
Parameters used in Squat modeling and simulation predictions are as following:

- Fore Draft
- Aft Draft
- Ship Breadth
- Length Between Perpendiculars
- Length in Waterline
- Block Coefficient
- Mid-Frame Coefficient
- Volumetric Displacement
- Number of Propellers
- Bulb Type
- Type of Stern
- Transom stern width
- Metacentric height
- Gravity center
- Ship speed
- Yaw rate
- Type of bottom soil
- Channel Type: Unrestricted channel, Restricted channel (with flooded banks), Canal (with surface piercing banks)
- Depth of water ($H_{\text{average}}$)
- Width of the channel ($W$)
- Flooded bank height ($h_t$)
- Channel cross-sectional area from the longitudinal symmetry plane of the ship to STBD ($S_{\text{STBD}}$)
- Channel cross-sectional area from the longitudinal symmetry plane of the ship to PORT ($S_{\text{PORT}}$)
- Drift angle

\[ C_b = \frac{V}{L_{pp}BT} \]
PANAMA CANAL SQUAT PREDICTIONS VS. SEA-TRIALS MEASUREMENTS

Average bow or stern squat predictions to the measured DGPS values for ships

- **Majestic Maersk**
  Panamax containership

- **Elbe**
  Panamax tanker

- **Global Challenger**
  Panamax bulk carrier

- **OOCL Fair**
  Containership
PANAMA CANAL SQUAT PREDICTIONS VS. SEA-TRIALS MEASUREMENTS

![Map of Panama Canal Area](image1)

![Graph of Ship Speeds in Gaillard Cut, Panama Canal](image2)
Effects of Current on Vessel Maneuverability

A following current can increase the rate of turn.
Effects of Current on Vessel Maneuverability

An opposing current can decrease the rate of turn
Examples
600’ x 106’ (Handy-max) with 1° leeway will have a 116.4’ actual beam width
800’ x 142’ (Afro-max) with 3° leeway will have a 183.7’ actual beam width
1100’ x 141’ (Container) with 4° leeway will have a 217.4’ actual beam width
1100’ x 141’ (Container) with 8° leeway will have a 292.7’ actual beam width
Safe Channel Width
Safer Ports don’t come about by accident
Vessel Motion Analysis

a) Static observation

b) During sailing

Reference height difference

Squat + reference height difference
Short-Period Vessel Motions: Hui Hong

Variations over River Mile:
- Heave (feet)
- Pitch to Bow (degrees)
- Roll to Stbd (degrees)
- Deepest Hull Point (feet)

Graphs show data over River Mile range.
MODELING OF SQUAT IN RESTRICTED CHANNELS

Salty Laker “John B. Arid” vs Fnh (Depth Froude Number)

m/v Algoville vs. Fnh (Depth Froude Number)
Low UKC Effects on Turning

Containership: 35 deg turning circle on different water depths

$T/h = 0.9$

$T = \text{Draft}$

$h = \text{Water depth}$

Diagram showing the turning circle of a containership at different water depths with varying $T/h$ ratios.
Measured Squat Values & Prediction Equation - All Ship Types
Control with Tug Assistance
Southbound Containership, Nedlloyd Dejima
LOA=942ft, Beam=106ft, Draft=39ft

Northbound Containership, Ever Refine
LOA=965ft, Beam=106ft, Draft=29.5ft

Passing in Bas Obispo Reach Panama Canal

At High Speed and Close Quarters
What Else is on the Bottom?

Fig 20: Possibly sunken buoy
How Important in Understanding Bank Suction?
VMAX UKC Upbound 9/16/2002
LOA=333.49m,B=70m,T=10.99m