Thrusters

Thrust Degradation in DP Operations
DP Model Test of an Aframaz Shuttle Tanker – Methods
Results, Operations

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Thrust Degradation in DP Operations

DP Model Test of an Aframax Shuttle Tanker

by

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www.teekay.com
Introduction

- DP model test of an IMO Class 2 Shuttle Tanker

- Focus on
  - Thrust degradation effects
  - Environmental design criteria
  - DP performance and design evaluation

- R&D project with the partners:
  Teekay, Kongsberg Maritime and Marintek
Teekay Corporation

- Transports more than 10 percent of the world’s seaborne oil
- Operates more than 190 vessels / 41 DP shuttle tankers
- Global organization / 17 countries / 6,300 employees
- More than 19,000 cargo lifts carried out by shuttle tankers during the past 25 years
- Offshore loading using DP control is a safe and reliable operation
- Continuous focus to improve design and operational excellence
Experience from operations in harsh weather conditions have shown indications of lower margins on the vessel’s station keeping performance than calculated by theoretical analyses such as DP capability plots.

A lack of industrial practices on how thrust degradation effects and environmental design criteria are defined and incorporated in DP capability analyses in general has been identified.

The main drivers are to further improve the safety, efficiency and regularity of offshore loading operations.
Dynamic Positioning - Force Balance Exercise

Propeller forces counteract drifting forces

- Propeller forces delivered by
  - Main propellers and high lift rudders
  - Tunnel and azimuth thrusters
Dynamic Positioning - Force Balance Exercise

Propeller forces counteract drifting forces

- Drifting forces determined by
  - Environmental conditions
  - Vessel’s main particulars
Environmental Design Criteria

- Environmental design criteria for offshore loading
- Corresponding to Halten area – Norwegian Sea

<table>
<thead>
<tr>
<th></th>
<th>Connection</th>
<th>Disconnection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significant wave height [Hs]</td>
<td>4.5 m</td>
<td>5.5 m</td>
</tr>
<tr>
<td>Wind speed [U10]</td>
<td>31 knots</td>
<td>38 knots</td>
</tr>
<tr>
<td>Current speed [Cv]</td>
<td>1 knot</td>
<td>1 knot</td>
</tr>
<tr>
<td>Wave spectrum peak period [Tp]</td>
<td>11 Seconds</td>
<td>12 Seconds</td>
</tr>
<tr>
<td>Wave spectrum</td>
<td>JONSWAP</td>
<td>JONSWAP</td>
</tr>
<tr>
<td>Peak enhancement factor [γ]</td>
<td>1.8</td>
<td>1.8</td>
</tr>
</tbody>
</table>
Thrust and Propeller Forces

Nominal thrust – Thrust degradation = Thrust available

- Thrust degradation

$$\tau = \frac{T}{T_{nom}}$$

- Thrust degradation affected by
  - thruster-hull interactions (Coanda)
  - thruster-thruster interactions
  - sea current
  - wave effects
  - ship motions
  - thruster ventilation
Model and Thruster Configuration

- Two aft ships; single and twin screw
- Interchangeable forebody
- Model scale 1:25, L ≈ 10 m , Displ. ≈ 6.9 mt
Model and Thruster Configuration
Thrust Loss Model Test

- Measurement of thrust degradation for
  - Main propellers and rudders - single and twin screw
  - Tunnel thrusters - fwd and aft
  - Azimuth thrusters – fwd and aft

- Loading conditions
  - Ballast
  - Loaded

- Environmental Conditions
  - Calm water
  - Offshore loading criteria; connection and disconnection
  - Corresponding to Halten Area in the Norwegian Sea
Thrust degradation measurement program comprised the following:

- Open water characteristics for all propeller and thruster units
- Thruster – thruster interactions
- Thruster – hull interactions
- Thruster – rudder interactions
- Tunnel thruster losses
- Thrust degradation due to current
- Thrust degradation due to waves
- Thrust degradation due to ventilation
Thrust Loss Model Test - Results

- Thrust degradation measurements for bow azimuth thruster

Thrust reduction coefficients - bow azimuth thruster

![Thrust Reduction Coefficients Diagram]
Thrust Loss Model Test - Results

Thrust degradation measurement for aft azimuth thruster

Thrust reduction coefficients - aft azimuth thruster

Ballast condition

Loaded condition

Thrust angle [deg]
Thrust Loss Model Test - Results

Thrust degradation measurement for main propeller and tunnel thrusters

<table>
<thead>
<tr>
<th>Tunnel degradation coefficients – Main propeller and tunnel thrusters</th>
<th>Ballast condition</th>
<th>Loaded condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main propeller single-screw</td>
<td>0.75</td>
<td>0.85</td>
</tr>
<tr>
<td>Main propeller twin-screw</td>
<td>0.75</td>
<td>0.87</td>
</tr>
<tr>
<td>Tunnel thruster – bow</td>
<td>0.65</td>
<td>0.80</td>
</tr>
<tr>
<td>Tunnel thruster - aft</td>
<td>0.65</td>
<td>0.80</td>
</tr>
</tbody>
</table>
DP Model Test

- Marintek Ocean Basin, 80m x 50m x 10m
- “Off-the-shelf” DP software
- North Sea environmental conditions
- Ballast and loaded conditions
- Intact and failure mode
- Various power settings for thrusters
- Test duration; 1 hour full scale time / 12 minutes model scale time
DP Model Test
1hour DP in FAILURE MODE

- Run # 620 :: LOADED HS5.5 TP12 UC1 UW38
- Run # 320 :: BALLAST IRR H5.5 TP12 UC1 UW38

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T:\Prosjekt\P53 Marine Vehicles\530246 Teekay Aframax IMO DPS Shuttle Tanker\Matlab\plot_TOT_dist_530233
DP Capability Plot

- Static force balance
- Auto position mode is assumed
- Tandem offshore loading is a “weather vane” operation
- Sector around the bow of relevance for shuttle tankers
- Thrust degradation calculation included in StatCap
DP Capability Plot - Example

- Worst case single failure for a DP2 single screw shuttle tanker
- North sea environmental design conditions - ballast

Plot 1: Thrust degradation not included  
Plot 2: Thrust degradation included
Conclusions

- Thrust degradation effects are of significant importance for all types of DP vessels
- Thrust degradation effects should be accounted for in design and operation of DP vessels
- Magnitude depends on vessel design, operation and environmental conditions
- Thrust degradation calculations have been included in software for DP capability analysis; KM StatCap
- Calculations correspond reasonably well with model test measurements for a shuttle tanker
- Results from DP capability analysis (capability plot) correspond well with shuttle tanker operational experience
Thank you!

Questions?