Ship Propulsion Performance bookkeeping - case studies

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How to create a propulsion bookkeeping

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- Hull & Propeller degradation

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- Effects of Hull & Propeller cleaning

**Case study 4**: Chemical Tanker
- Trim

**Case study 5**: Chemical Tanker
- Effect of CPP

From bookkeeping to decisions

Conclusions
How to create a Propulsion Bookkeeping
How to create a Propulsion Bookkeeping

1. Fuel → Engine + Propeller + Ship Hull → Ship speed

2. Fuel → Engine → Torque → Propeller + Ship Hull → Ship speed

3. Fuel → Engine → Torque → Propeller → Thrust → Ship Hull → Ship speed
How to create a Propulsion Bookkeeping

Separate the propeller performance from the hull performance

For separate measurement of:

- **The propeller condition**
  - Fouling
  - Damages:
    - Leading edges
    - Cavitation erosion
  - Redesign

- **The hull condition**
  - Fouling
  - Damages
  - Coating
  - Retrofit Bow

~-3% loss per propeller
How to create a Propulsion Bookkeeping

In order to measure:
- **Thrust**
- **Torque**

A thrust & torque sensor can be applied

The working principle is based on measuring the propeller shafts:
- Torsion (due to torque)
- Compression (due to thrust)

TT-Sense® location
How to create a Propulsion Bookkeeping

The VAF IVY® solution:
As an example for the possibilities of the Thrust sensor, results are provided for a +10000 TEU container vessel:

Measurements are performed from 2014 – 2015 over a period of 1.5 years.

Over this period there is analysed the change in:
- Propeller efficiency
- Hull resistance
Case Study 1: +10000 TEU container vessel

Measured propeller torque / power compared to model test predictions:
Case Study 1: +10000 TEU container vessel

Measured propeller thrust compared to model test predictions:
Case Study 1: +10000 TEU container vessel

Measured propeller “open water” characteristic at full scale in behind condition (dots), compared to model test predictions (lines):

Fairly independent of weather and draft (constant J for FPP)
Case Study 1: +10000 TEU container vessel

Propeller performance over time (>3000 individual measurement points), decrease is 3.7% (equals 2.6% per year).

Propeller performance over time (>3000 individual measurement points), decrease is 3.7% (equals 2.6% per year).
Hull resistance over time (>3000 individual measurement points), total increase is 5.2%, (equals 3.6% per year).
Case Study 1: +10000 TEU container vessel

**Propeller**
-3.7%

**Ship Hull**
-5.2%

**Torque**

**Ship speed**

**Thrust**

**Engine**

**Fuel**

Engine + Propeller + Ship Hull

**Fuel**

**Engine**

**Fuel**

Engine + Propeller + Ship Hull

**Propeller**
-3.7%

**Ship Hull**
-5.2%

**Torque**

**Propeller + Ship Hull = -9.2%**
**Propulsion Bookkeeping:** What is the energy / cost saving potential?

<table>
<thead>
<tr>
<th></th>
<th>Efficiency decrease</th>
<th>Fuel increase mton / year</th>
<th>Fuel increase US$ / year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propeller efficiency decrease</td>
<td>3,7%</td>
<td>1110</td>
<td>333.000,-</td>
</tr>
<tr>
<td>Hull resistance increase</td>
<td>5,2%</td>
<td>1560</td>
<td>468.000,-</td>
</tr>
</tbody>
</table>

* For this +10000 TEU container vessel, annual fuel consumption assumed to be 30.000 metric tons. Assumed fuel oil price of US$ 300,- per metric ton.

✔ **Large cost and energy saving potentials**

✔ **Next to the hull also the propeller contributes significantly to the increased fuel costs (±- 40% of total).**

Published in white paper: “Fuel saving potentials via measuring propeller thrust and hull resistance at full scale experience with ships in service“
Hull Performance & Insight Conference 2016 (HULLPIC2016), Italy 13-15 April 2016
Large container vessel:

- Slow steaming
- Retrofit for new design point:
  - New propeller design (> Dprop ; < Ae/Ao)
  - New bulbous bow design
- Old condition measured for 1.5 years (2014 – 2015)
- Retrofitted condition measured for 0.5 year (2016)
- Both periods measured:
  - Thrust
  - Torque /Power
  - Fuel

<table>
<thead>
<tr>
<th></th>
<th>Light draught</th>
<th>Design draught</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original propeller design</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Original bulbous bow design</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>New propeller design</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>New bulbous bow design</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Case Study 2: Retrofit large container vessel

Fuel → Engine + Propeller + Ship Hull → Ship speed

Fuel → Engine → Torque → Propeller + Ship Hull → Ship speed

Fuel → Engine → Torque → Propeller → Thrust → Ship Hull → Ship speed

TT-Sense
Case Study 2: Retrofit large container vessel

**TT-Sense measured propeller performance at full scale:**

[Graphs showing original and new propellers' performance]

Original propeller, before retrofit
Light draught conditions

New propeller, after retrofit
Light draught conditions

Dots: TT-Sense full scale measurements (IVY enriched data); Lines: model test open water predictions

**Conclusions:**
- Model tests correlate well with full scale measured values
- New propeller has higher measured efficiency compared to original
Case Study 2: Retrofit large container vessel

**TT-Sense measured propeller performance improvement at full scale:**

![Graph showing performance improvement of new propeller design at full scale](image)

**Conclusions:**
- New propeller design has higher measured efficiency at full scale compared to original design measured at full scale.
- The propeller efficiency improvement is depending on speed and draught.
**TT-Sense** measured **bulbous bow resistance improvement** at full scale:

Conclusions:
- New bulbous bow has smaller efficiency gain than compared with propeller
- Strong effect of sailing conditions
Case Study 3: Cruise Vessel – Hull cleaning

**TT-Sense** measured effects of Hull Cleaning:

+ 3.4% in performance

Hull cleaning in drydock
TT-Sense measured effects of Propeller Polishing:

+ 2.2% in performance
Case Study 4: Chemical Tanker - Trim

Fuel → Engine + Propeller + Ship Hull → Ship speed

Fuel → Engine → Torque → Propeller + Ship Hull → Ship speed

Fuel → Engine → Torque → Propeller → Thrust → Ship Hull → Ship speed
Case Study 4: Trim

**TT-Sense** measured hull resistance due to trim

*(Passenger vessel example)*

Up to 15% difference in hull resistance due to trim
Case Study 5: Chemical Tanker – Effect of CPP
TT-Sense measured Controllable Pitch Propeller (CPP) performance full scale @ constant RPM operation:
Theoretical efficiency curves for CPP:

- Graph showing propeller efficiency ($\eta_o$) versus advance coefficient ($J$).
- Indication of maximum efficiency envelope.
- Multiple operating curves per pitch angle.
Conclusion: the largely varying efficiency of the CPP influences the optimal trim condition if determined at power measurements alone.
Conclusions

Measuring Propeller Thrust via **TT-Sense**® offers the unique possibility to:

- Separate the propeller performance from the hull performance
- Provide largest detail in the propulsion efficiency bookkeeping of your vessel

In addition **IVY**® translates sensor measurements into a bookkeeping which can support decisions on the ship propulsion performance
Thank you for your attention