Design efficiency of ships - historical developments and impact of the EEDI

Greentech 2015 Seattle
CE Delft

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Outline

• Policy relevance of this study

• Methods for assessing design efficiency of ships

• Historical development of design efficiency of ships

• Recent developments in design efficiency

• Conclusions
Policy relevance

- Design efficiency of ships is regulated since 2013.
- New ships need to have an Energy Efficiency Design Index (EEDI) that is better than a reference line.
- In the next years, the minimum required distance to the reference line will increase by 10% (2015), 20% (2020) and 30% (2025).
- A review of the 20% target is being conducted.

- The reference line has been defined as the best fit power curve through the Estimated Index Values (EIVs) of ships that have entered the fleet between 1999 and 2008.
- The EIV is a simplified form of the EEDI.
Methods for assessing design efficiency of ships

- Estimated Index Value (EIV) (tonne CO$_2$/tonne.nm)

\[ Estimated \, Index \, Value = 3.1144 \cdot \frac{190 \cdot \sum_{i=1}^{NME} P_{MEi} + 215 \cdot P_{AE}}{Capacity \cdot V_{ref}} \]

- EIV declines with size of the ship
- Therefore, we use the average relative difference between the EIV and the EEDI reference line as the indicator of the design efficiency of ships
Methods for assessing design efficiency of ships

- Strong correlation between EEDI and EIV

![Graph showing the relation between EEDI and EIV](image)

\[ y = 0.8612x \]

\[ R^2 = 0.9179 \]
Historical development of design efficiency

Bulk carriers

![Image of a bulk carrier](image-url)

*Chart showing the average deviation from EEDI reference line for bulk carriers from 1960 to 2020.*

*Graph displaying bulk carrier best fit power curves for different periods.*

- 1999-2009
- Bulkers - 60's
- Bulkers - 70's
- Bulkers - 80's
- Bulkers - 90's
Historical development of design efficiency

Tankers
Historical development of design efficiency

Container ships

Container best fit power curves for different periods

Average deviation from EEDI reference line

Containership: all sizes

Container best fit power curves for different periods

1999-2009
Containers - 70's
Containers - 80's
Containers - 90's
Historical development of design efficiency

Example: tankers 60-100k dwt

1980-1990 improvement
- Size increase
- $P_{ME}$ decrease
- Speed slight decrease

1990 - 2000 deterioration
- Size increase
- PME increases more
- Speed constant

Hull shape, propeller, and speed can explain differences

Jasper Faber, May 29, 2015
Historical development of design efficiency

Hull shape
- Slimmer, more efficient designs (higher length/displacement ratio, lower $C_b$) in the 1980s
- Fuller designs (lower length/displacement ratio, higher $C_b$) post 1990

Propeller
- Anecdotal evidence of sub-optimal propellers in the 1990s and 2000s

Lightweight of the ship
- Heavier ships have a higher wetted surface and higher water and wave resistance
Historical development of design efficiency

Design choices driven by:

- Fuel price (higher fuel price: more efficient ship)
- Freight rate (high freight rate: higher $C_b$)
- Opportunity costs of building time (high opportunity costs: simpler designs: fuller ships)
- Steel prices, labour costs, ...
- Regulation that have had an impact on lightweight (double hull tankers, structural rules, et cetera)
Recent developments in design efficiency

Several developments may have had an impact on the design efficiency of new ships:

- Decrease in freight rates in 2008
- Fast recovery of fuel prices after 2008
- EEDI requirements for ships built since 2013
Containers

- Strong improvement in design efficiency
- Especially for large container ships
- More than 50% of new ships in 2013 and 2014 meet 2020 standards
- Lower speed, lower $P_{ME}$, larger ships

<table>
<thead>
<tr>
<th>EIV</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
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<tbody>
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<td>-2%</td>
<td>-8%</td>
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<td>63%</td>
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<td>14%</td>
<td>20%</td>
<td>51%</td>
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<tr>
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<td>&gt; 30%</td>
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<td>6%</td>
<td>9%</td>
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Bulk carriers

- Improvements in design efficiency since 2013
- About a third of new ships meet 2015 standards
- *Higher* speed, lower $P_{ME}$, *smaller* ships

<table>
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<tr>
<th>EIV</th>
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<td>53%</td>
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Tankers

- Improvements in design efficiency since 2013
- About half of new ships meet 2015 standards
- Equal speed, equal $P_{ME}$, equal size

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<td>&gt; 30%</td>
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Conclusions

- Historical efficiency of bulk carriers and tankers has improved in the 1980s, was best in the 1990, deteriorated in the 1990s and 2000s.
- Similar pattern for container ships, but efficiency deteriorations have been offset by increases in size.

- Efficiency of current ships 10% - 20% worse than best historical value.
  - Probably higher when taking into account engine improvements, propeller improvements, energy saving devices, etc.
- Large improvements are possible in relatively short time periods.

- Recent developments show that designs have improved considerably.

- EEDI: reference line -20% is not a problem.
Thank you for your attention

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All reports are available at www.cedelft.eu
Sources

CE Delft, 2015, *Historical trends in ship design efficiency*, Delft