IMO EEDI from design perspective

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Even if greenhouse gas (GHG) emissions of shipping sector account only 3% of global emissions, this share is expected to rise to 5% due to growth of economy and the associated transport demand.
Introduction

• International
  – UNFCCC is aiming at stabilizing Green house Gas (GHG) in atmosphere and preventing harmful impact of human behaviors of excessive emission of such gas.
  – Kyoto protocol specifies that each member included in Annex I shall pursue limitation or reduction of emission of greenhouse gases from aviation and maritime bunker fuels. United Nations (UN) adopted United Nations Framework Convention on Climate Change (UNFCCC) on 9 May 1992,

• Europe
  – Directive 2009/29/EC calls for contributions from all sectors of the economy to achieve emission reductions, including the international maritime shipping sector
  – Regulation 2015/757 establishes the monitoring, reporting and verification of CO₂ emissions from maritime transport (the MRV system)

• IMO
  – A.963(23) urges the Marine Environment Protection Committee (MEPC) to identify and develop the mechanism or mechanisms needed to achieve the limitation or reduction of GHG emissions from international shipping
  – IMO adopted technical and operational measures, in particular the Energy Efficiency Design Index (EEDI) for new ships and the Ship Energy Efficiency Management Plan (SEEMP), which will bring improvement in terms of reducing the expected increase in greenhouse gas emissions
History of the EEDI

• Introduction of new chapter 4 in MARPOL Annex VI
• 1st January 2013: EEDI is made mandatory for specific categories of ships

New Guidelines on:
• Method of calculation of attained EEDI
• Survey and certification of EEDI
• Calculation of reference lines for use with EEDI

Amendments in 2012
Guidelines on the method of calculation of the attained EEDI, regarding the calculation of main and auxiliary engines power.
History of the EEDI

Proposal for the extension of EEDI application to:
• LNG carrier,
• ro-ro cargo ship (vehicle carrier),
• ro-ro cargo ship,
• ro-ro passenger ship, and
• cruise passenger ships having non-conventional propulsion

1st September 2015: EEDI requirement is extended and made mandatory for 4 new additional categories of ships

Amendments in guidelines of survey and certification, as well as on the method of calculation of the attained EEDI.

[Diagram showing the progression from 62nd MEPC to 68th MEPC with a highlighted box indicating phase 4 (2030-...).]
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Energy Efficiency Design Index (EEDI) indicates the efficiency that is expected for a ship to achieve, based on the ship specifications.

\[
EEDI = \frac{\text{Power} \cdot \text{SFOC} \cdot f_{CO_2}}{\text{Deadweight} \cdot \text{Speed}}
\]

- **CO_2 emissions**
- **Transport work**
EEDI definition

Attained EEDI \leq \text{Required EEDI}
Required EEDI (1)

Required EEDI = (1 - x/100) x Reference Line

- Each reference line is estimated by real ship data
- The reference line depends on:
  - Ship category
  - Ship size (DWT or GT)

Source: IHS Fairplay
Required EEDI (2)

- Reduction coefficient ‘x’ depends on the date of contract or commencement date of conversion

- There are four phases:
  - Phase 0 (1/1/2013-31/12/2014)
  - Phase 1 (1/1/2015-31/12/2019)
  - Phase 2 (1/1/2020-31/12/2024)
  - Phase 3 (1/1/2025-…)

![Graph showing reduction percentage for different phases and ship types]
Attained EEDl formula

- Main engines
  \[ \prod_{j=1}^{n} f_j \cdot \sum_{i=1}^{n_{ME}} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)} \]

- Shaft generators/motors
  \[ \left( \prod_{j=1}^{n} f_j \cdot \sum_{i=1}^{n_{PTI}} P_{PTI(i)} \cdot \sum_{i=1}^{n_{eff}} f_{eff(i)} \cdot P_{AEeff(i)} \right) \cdot C_{FAE} \cdot SFC_{AE} \]

- Auxiliary engines
  \[ P_{AE} \cdot C_{FAE} \cdot SFC_{AE} \]

- Energy efficiency
  \[ \sum_{i=1}^{n_{eff}} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME} \]

- Transport work
  \[ f_i \cdot f_c \cdot f_l \cdot \text{Capacity} \cdot f_w \cdot V_{ref} \]
Application

Ship Category
- Buk carrier
- Gas carrier
- Tanker
- Container ship
- General cargo ship
- Refrigerated cargo carrier
- Combination carrier
- LNG carrier
- RO-RO cargo ship (vehicle carrier)
- RO-RO passenger ship
- Cruise passenger ship having non-conventional propulsion

New Ships
- Building contract ≥1/1/2013
- Keel laid ≥1/7/2013
- Delivered ≥1/7/2015

New ships in service & Existing Ships
- Building contract ≥1/1/2013 for existing ships with major conversion
- Keel laid ≥1/7/2013
- Delivered ≥1/7/2015
- Building contract ≥1/9/2015 for existing ships with major conversion
- Keel laid ≥1/3/2016
- Delivered ≥1/9/2019

Ships ≥ 400GT
Application

• EEDI does **NOT** apply to:
  – Ships solely engaged in voyages within waters subject to the sovereignty or jurisdiction of the State the flag of which the ship is entitled to fly.
  – Ships with non-conventional propulsion (e.g. diesel-electric, turbine & hybrid systems) except of passenger ships and LNG carriers
  – Cargo ships with ice-breaking capability

• Administrations may delay EEDI implementation by 4 years without penalty
EEDI Surveys

• Attained and Required EEDI shall be recorded on the International Energy Efficiency Certificate (IEE Certificate) of the ship.

• Before the issue of IEE Certificate, an initial survey shall be conducted on board, in order to verify that the attained EEDI is in accordance with the required EEDI.
EEDI Surveys

Shipowner
- Basic Design, Tank Test, EEDI Calculation
- Development of EEDI Technical File
- Application for EEDI pre-verification
- Submission of EEDI Technical File
- Application for EEDI verification
- Sea Trial
- Modification and Resubmission of EEDI Technical File
- Delivery of ship

Shipbuilder
- Basic Design, Tank Test, EEDI Calculation
- Development of EEDI Technical File
- Submission of additional information

Verifier
- Verification:
  - EEDI Technical File
  - additional information
  - sea trial condition
  - ship speed
  - revised EEDI Technical File
- Issuance of Statement of Compliance
- Issuance of IEEC (International Energy efficiency Certificate)
- Final Verification
- Start of ship construction
- Pre-Verification
Contents

• Introduction
• EEDI description
• Marine design
• Survey and Certificates
EEDI & Ship Design

- Depends on the ship design and marine systems on board
- Many solutions to decrease the required power

- Measure of system’s efficiency
- Depends mainly on the system

- Depends only by the fuel type

\[
\text{EEDI} = \frac{\text{Power} \times \text{SFOC} \times f_{\text{CO}_2}}{\text{Deadweight} \times \text{Speed}}
\]

- Depends on many parameters
- Direct impact to the ship’s dimensions and space arrangement

- Basic parameter of ship design
- Direct connection with main propulsion system and ship’s resistance
EEDI & Ship Design

- Hull Design
- Machinery Systems
- Energy efficient technology
Hull resistance

• Longer ship reduces wave-making resistance
• B/T ratio, hull form and midship coefficient $C_M$ affects the wetted surface
• Reduction of wetted surface area reduces frictional resistance for slow ship vessels
• Slender hull reduces wave resistance by shifting water plane downwards.
• Modification on dimensions has direct impact to the deadweight of the ship
Hull resistance

Other methods to reduce hull resistance:

- Application of hull coating techniques for hull friction/viscous resistance reduction
- Bow and aft optimization for the operational speed
  - Bulb optimization
  - ‘Axe-bow’ formation
  - Reduction of transom immersion
- Minimizing resistance of hull openings
Hull resistance

Application of appendages to the propulsion system at the stern of a vessel improves the water flow and reduces the total resistance of ship

– Kort nozzle
– Mewis Duct
– Wake equalizing duct
– Pre-swirl stator
– Propeller boss cap fins
Propeller selection

- Selection of propeller depends on hull resistance and design speed.
- Modification of number of blades and diameter of propeller affects the final selection of the main propulsion system.
- Increase of draft may increase wetted surface but it aims at the fitting of a bigger, more efficient propeller, working in lower RPMs.
- Draft shall be modified in respect of water depth limitations, maneuverability and ship’s size.
Propeller selection

• Application of various optimization techniques and new technologies can improve the efficiency of the ship:
  – Counter floating propellers (CRPs)
  – Propeller-hull interaction
  – Propeller-rudder combination
  – Advanced propeller blade sections
  – Propeller tip winglets
Propulsion system

• Propulsion system has indirect impact to the EEDI
• Optimization of propulsion system and improvement of hull resistance will lead to the selection of lower power engine for a constant speed
Ship structure

- Use of lightweight material can reduce the ship weight
- Use of high tensile steel, aluminum alloys, composite materials and other non-ferrous materials, as well as optimization of hull strengthening will reduce the weight of hull.
- Reduction of ship weight will reduce the power requirements of propulsion system.
Machinery systems

- Selection of the engine that fits to vessel needs is the most important step to improve vessel’s efficiency index.
- Attained EEDI is based on the MCR of the installed engine.
- Based on the operational speed, ship type and the estimated hull resistance, the size and power of engine has to be selected.
Machinery systems

• Design of marine engines shall focus on fuel efficiency
• Selection of techniques (e.g. exhaust gas bypass) and methods that improve engine’s total efficiency in respect of NO\textsubscript{x} and SO\textsubscript{x} emission
• Proper design and matching of turbine with the engine for the maximum exploitation of their power output
Machinery systems

• Improvements on machinery parts and systems will reduce the specific fuel oil consumption and the energy demand from auxiliary systems, improving the efficiency for specific power
• For a specific engine, improvements may include the optimization of fuel injection timing and valves, lubrication system and cooling system
• Application of electronic control system improves the total performance and efficiency of engine and provides the capability for tuning/de-rating
• Power losses from the main engine to the propulsion system have to be minimized through selection of low friction bearings and efficient gear ratios.
Auxiliary systems

- Efficient operation of auxiliary systems on board will improve the total power performance of ship, reducing the required energy production
- Installation of low energy consumption systems will reduce the power of generators on board, improving the EEDI of the ship
Auxiliary systems

• Configuration of service diesel generators
  – Number
  – Size
  – Connection

• Installation of shaft generators, connected with main engine
  – Fixed
  – Variable speed

• Use of high efficiency motors
Auxiliary systems

- Pumps and piping system can be optimized, depending on the ship size and type.
- Variable speed motors and piping network with low losses improve the power performance on board.
- Dynamic operation of pumps, depending of the on board demand, may offer a solution to decrease the required installed power.
Auxiliary systems

• Minimization of energy demands on board
  – Reduction of energy consumption for the lighting system of the ship
  – Efficient operation of HVAC system
  – Cargo loading/unloading
  – Ballasting/de-ballasting procedure
Innovative energy efficient technology

• Air cavity system provides a thin layer of air over the flat bottom of hull, decreasing hull friction.
• Use of micro-bubbles air lubrication (disadvantages on stability and bubble formation)
• Hull surface texturing pattern
Innovative energy efficient technology

• Different type of wind propulsion technologies may be used to reduce GHG emissions
• Such technologies include:
  • Towing kites
  • Flettner rotor sails, windmills
• Low impact
• Unclear if they can improve overall efficiency
Innovative energy efficient technology

• Use of photovoltaic power generation system
• Mature technology but with extremely low applicability
• Generated energy is used for on board systems and applications
• Covers large surface on board
Innovative energy efficient technology

- Heat recovery system improves total efficiency
- Methods to recovery some of the wasted heat:
  - Heat exchanger
  - Power turbine
  - Thermocouples
- Additional weight and blocked-space on board
- More complicated system
Innovative energy efficient technology

• Impact of energy efficient technologies to the EEDI is determined by MEPC.1/Circ.815.

• GHG reduction depends on the ship type and the installed systems on board.

• Impact on lightship weight distribution, space arrangement and sea keeping of the ship shall be taken into consideration.
EEDI & Ship Design

• There are many ways to improve the energy efficiency on board but not all of them affect the energy efficiency index.

• Even for specific type of vessel, there are many constraints and limits for the calculation of EEDI.
EEDI & Ship Design

Source: ABS
EEDI & Ship Design

• EEDI aims to improve the efficiency of ships with conventional propulsion systems
• Target of IMO is not only the reduction of GHG emission but to increase the fuel savings, sustaining a green & efficient environment
EEDI & Ship Design

[Graph showing projected CO₂ emissions and fuel savings with and without EEDI implementation over time.]
EEDI & Ship Design

• EEDI provides a new objective to the ship design

• Selection of ship dimensions and the design of hull form and machinery systems shall improve the energy efficiency.

• Nevertheless, safety, stability, strength, sea keeping and operability of ship shall be maintained.
EEDI & Ship Design

• EEDI calculation is based on the installed power and the transport work, on the operational design point.

• EEDI focus only on the design of the ship

• Ship Energy Efficiency Management Plan (SEEMP) provides the instructions for the efficient operation of the systems on board.

• Ship’s performance is monitored by the Energy Efficiency Operational Indicator (EEOI)
Thank you for your attention