Practical Technology for Green Ship

Hull Performance Improvement for GHG Emission Reduction

International Workshop on Ship Technologies
Related to Energy Efficiency Design Index

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EEDI Regulation

- Revised MARPOL Annex VI entered into force on 1st January, 2013.
- EEDI (Energy Efficiency Design Index) for new ship shall be calculated and verified.

$$EEDI = \frac{\left(\prod_{j=1}^{n} f_j\right).\left(\sum_{i=1}^{nME} P_{ME(i)}.C_{FME(i)}.SFC_{ME(i)}\right) + P_{AE}.C_{FAE}.SFC_{AE}}{f_i.f_c.Capacity.f_w.V_{ref}}$$

$$+\frac{\left\{\left(\prod_{j=1}^{n} f_j\right).\sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)}.P_{AEeff(i)}\right\}.C_{FAE}.SFC_{AE} - \sum_{i=1}^{neff} f_{eff(i)}.P_{eff(i)}.C_{FME}.SFC_{ME})}{f_i.f_c.Capacity.f_w.V_{ref}}$$

Simply expression

$$EEDI = \frac{Output \times SFC \times CF}{DWT \times Speed} = \frac{CO_2\ emission}{Transport\ work}$$

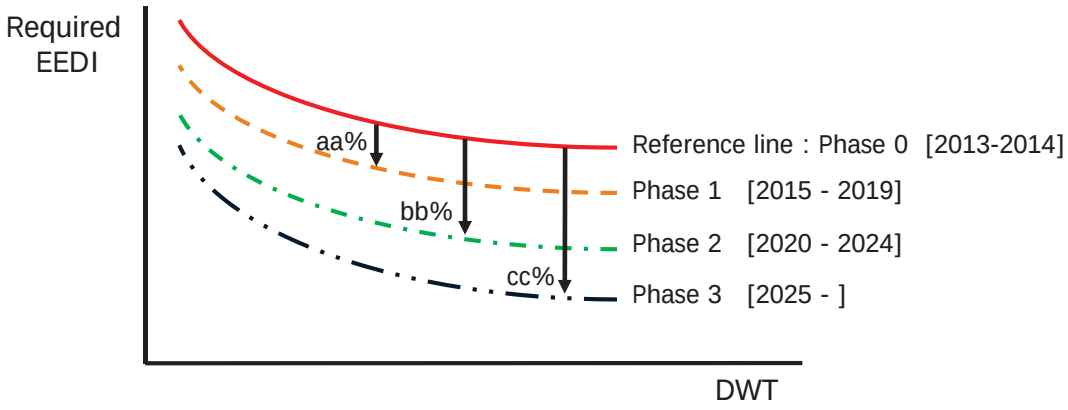
EEDI indicates the energy efficiency that is expected for a ship to achieve, based on the ship specifications, calculated by “Engine output”, “DWT” and “Speed”.

EEDI Regulation

- Attained EEDI ≦ Required EEDI = (1-X/100) × Reference line value

  where X is the reduction factor for the required EEDI of the each phase of new building contract

- Reference line is defined as a curve representing an average index value for a each type of ship delivered in 10 years from 1999.

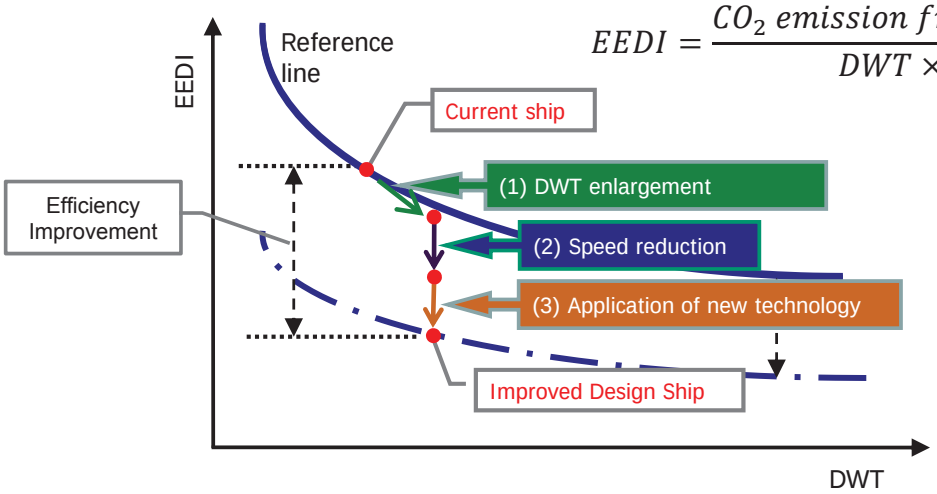


- The reduction factor will be strengthened by each phase.
- The reduction factor for Tanker or Bulk carrier,

  aa%=10%, bb%=20%, cc%=30%

How to reduce EEDI?

$$EEDI = \frac{CO_2\ emission\ from\ machinary}{DWT \times Speed}$$



- Enlargement of DWT is not effective in the EEDI regulation, though it is one of the reduction measures. Because, the reference line is a function of DWT.
- The speed reduction is not always possible for shipping service. And this option is restricted by the guideline of minimum propulsion power.
- Attained EEDI should be achieved without changing the main character of ships (speed, DWT). Shipbuilders should find out the **Technologies**, which could be applied to improve the energy efficiency.

JMU G-Series Ship : G209BC with WHR system

JMU is working to achieve the reduction of GHG emission by technologies

Hybrid Turbo Charger
recovers the exhaust gas energy from the engine without heat loss and with minimum mechanical loss.

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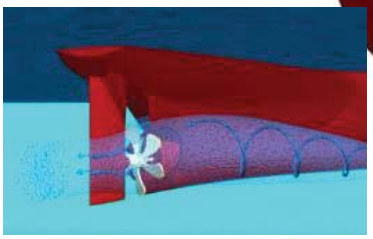
Low wind resistance accommodation

LEADGE-Bow can reduce the added resistance due to wave.

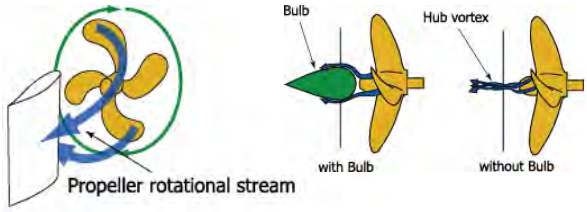


Optimized hull form, High efficiency propeller and **Pre/Post Swirl Type Energy saving devices** improve the propulsive efficiency.

Low frictional resistance type antifouling coating

Pre/Post Swirl Type Energy Saving Devices

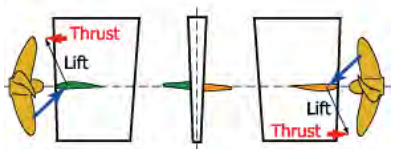
SURF-BULB Swept-back Up-thrusting Rudder Fin with BULB



Study for optimized shape of SURF-BULB

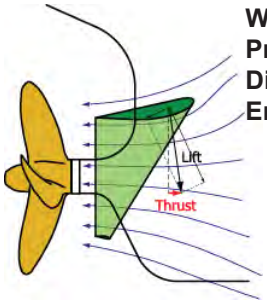
Optimized Bulb size, cord length of Fin and attack angle of Fin for each type of vessel

Energy Saving Effect is comfirmed by Tank Test and CFD simulation



Fins generate a thrust.
Bulb smoothens hub vortex.
Energy Saving Effect : 3~5%

SSD Super Stream Duct



Wing section of duct generates thrust.
Propeller inlet flow is stabilized by a duct.
Displacement effect improves wake fraction.
Energy Saving Effect : 3~8%

Study for optimized shape of SSD

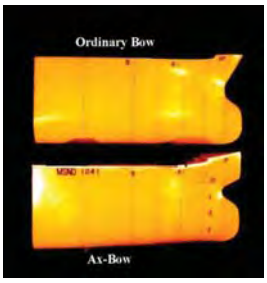
Optimized duct size and position for each type of vessel

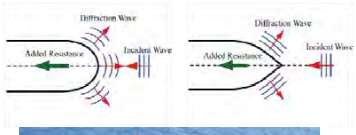
Energy Saving Effect is confirmed by Tank Test and CFD simulation

Reduction of added resistance at sea

Bow shape to reduce the added resistance due to wave

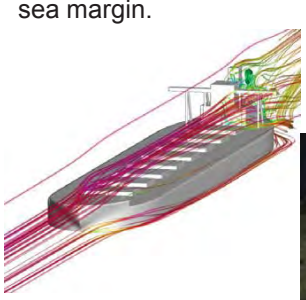
- Ax-Bow, which can reduce the added resistance due to wave in laden condition, was investigated by co-study with Osaka University.
- LEADGE-Bow was developed to reduce the added resistance in various loading conditions.
- According to the test results, about **20%** of added resistance due to wave can be reduced in head sea.
- In terms of the effect on the actual sea of Beaufort scale 6, it is equal to the effect of **5%** reduction of sea margin.





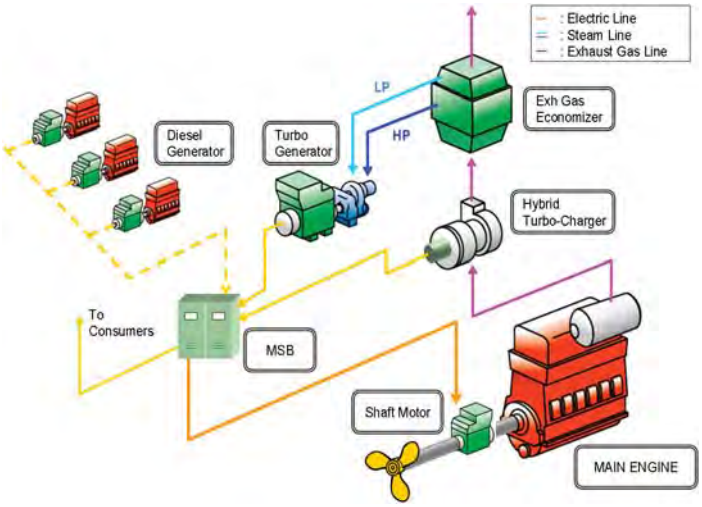
Reduction of wind resistance

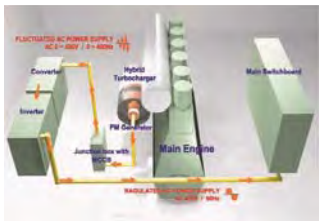
- Lower wind resistance type accommodation shape was investigated by co-study with Yokohama National University.
- The wind tunnel tests were performed to confirm the effect to reduce the wind resistance by proposed shape.
- According to the test results, about **20% – 30%** of wind resistance of the head wind can be reduced.
- In terms of the effect on the actual sea of Beaufort scale 6, it is equal to the effect of **2%** reduction of sea margin.

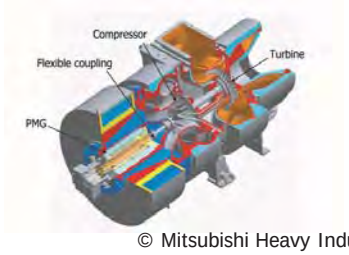


Waste Heat Recovery System

- **Hybrid turbocharger** and **turbo generator** generate electricity, which can satisfy the actual demand of electricity on the normal seagoing.
- The diesel generator can be stopped during normal seagoing, it means zero emission from the auxiliary engine.
- Propulsion system would be assisted by **shaft motor** utilizing surplus electricity, it means the reduction of M/E power keeping the service speed.







EEDI verification for the first vessel of G209BC

- The first vessel of G-Series cape size bulk carrier (G209BC with WHR system) was delivered in August 2013.
- ClassNK verified EEDI and issued the statement of fact.


NIPPON KAIJI KYOKAI

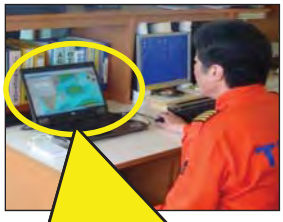
COPY

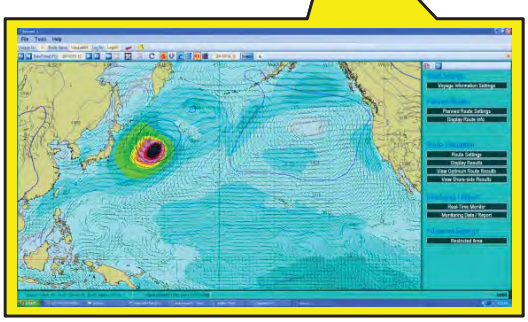
Attained EEDI of G209BC with WHR system can already satisfy the Phase-2 level of required EEDI.

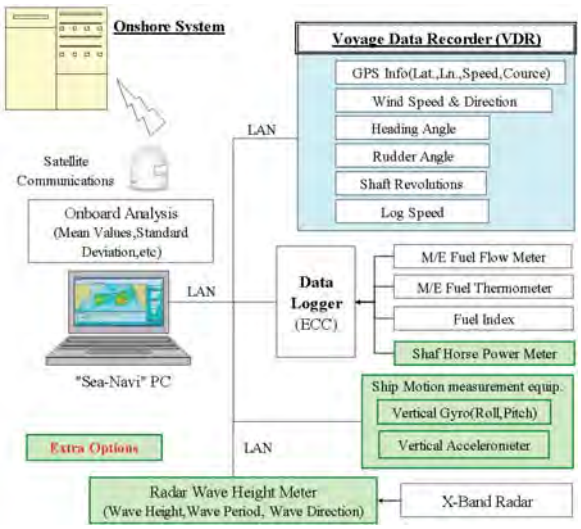
Confirmation at sea : Monitoring Test

- Sea trial of Bulk Carrier is carried out in ballast condition.
- The actual hull performance in laden condition could not be confirmed by Sea Trial.
- JMU developed the voyage support system "Sea-Navi®" that has weather routing and monitoring function.
- To confirm the hull performance in laden condition at sea, JMU conducted hull performance monitoring test (24H full automatic monitoring) of G209BC by using the monitoring function of "Sea-Navi®".

Sea-Navi®
On-board PC

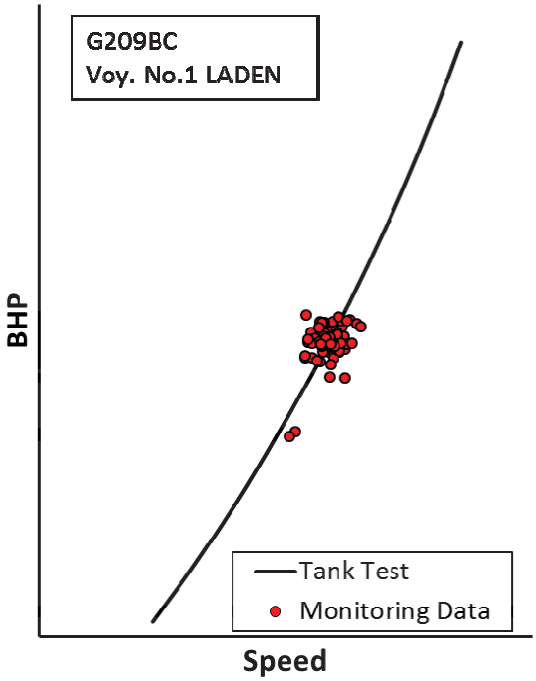






Confirmation at sea : Monitoring Test

- "Sea-Navi®" recorded the average data in every 20 minutes.
- To evaluate the normal seagoing performance in a calm sea, data are selected with these filtering.
  - Rudder angle < 1.0deg.
  - Shaft speed > around 60% MCO
  - Beaufort scale < 4
    (Wind velocity < 5.5m/s)
- The added resistance due to wave and wind is corrected.
- The hull performance in actual voyage shows as same as the estimated result.



Monitoring and evaluation techniques are essential for not only confirmation of actual performance, but also MRV system discussing in IMO.

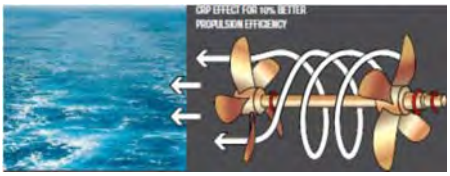
Additional technology for next target : Phase-3

CRP

Contra-Rotating Propeller

- The effect of CRP is **max. 10%** improvement of propulsive efficiency.
- Already over 20 ships with CRP system have been delivered.

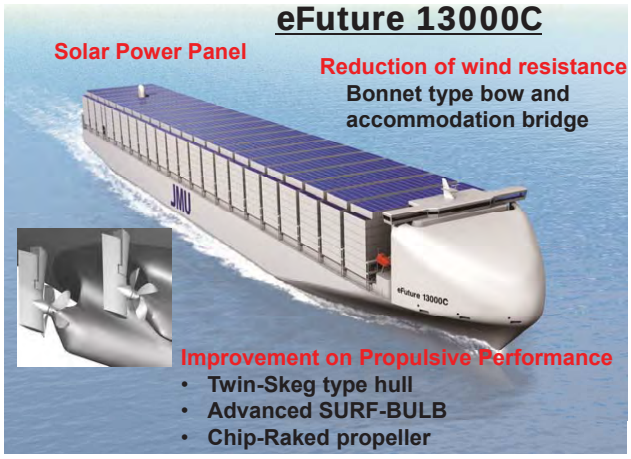
The rotate component of flow induced by propeller does not act on the propulsion.

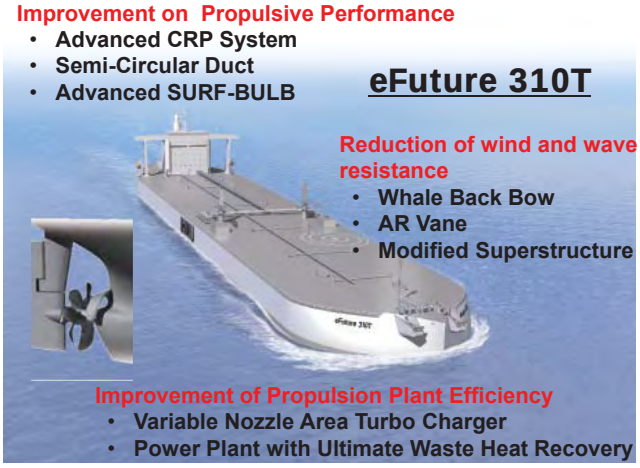


CRP recovers the propeller rotational flow and improves the propulsive efficiency.

Future works

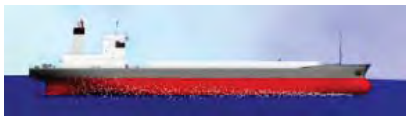
Further technologies and conceptual design ship





The other innovative technologies

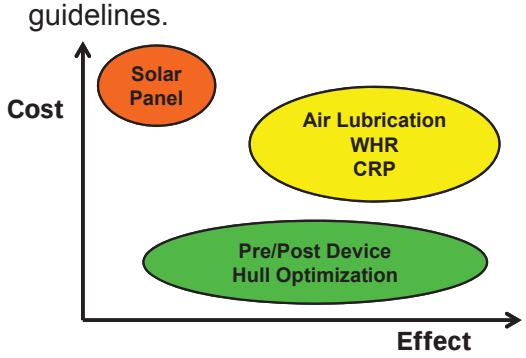
- Wind power
- Air lubrication system
- Gas fuelled plant ship
- Etc.

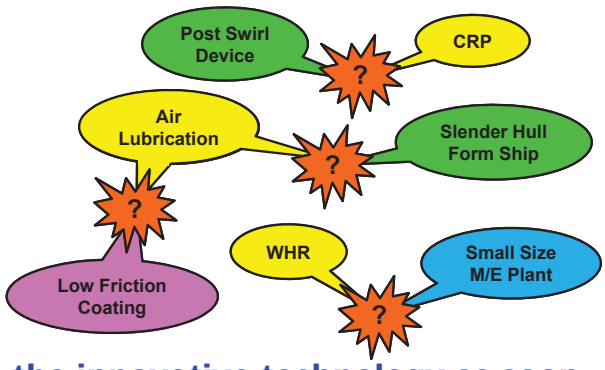


Problems to be solved until Phase-3

To clear Phase-2 is becoming a reality, but it is necessary for Phase-3 to exceed the higher hurdles.

- Technologies, which have low cost and high performance, will be already applied before entering into Phase-3.
- The other technologies, which are not in popular this moment, might have to pay too high installation cost in comparison with their performance to reduce the GHG emission.
- Some technologies conflict their effect with the other technologies.
- Some technologies are not effective for all types and size of vessels.
- Slow steaming would hardly to be applied because of the minimum propulsion power guidelines.





Shipping industries have to develop the innovative technology as soon as possible to achieve the EEDI Phase-3 level.

Thank you very much for your kind attention!

JMU Japan Marine United Corporation