中国船舶科学研究中心
China Ship Scientific Research Center

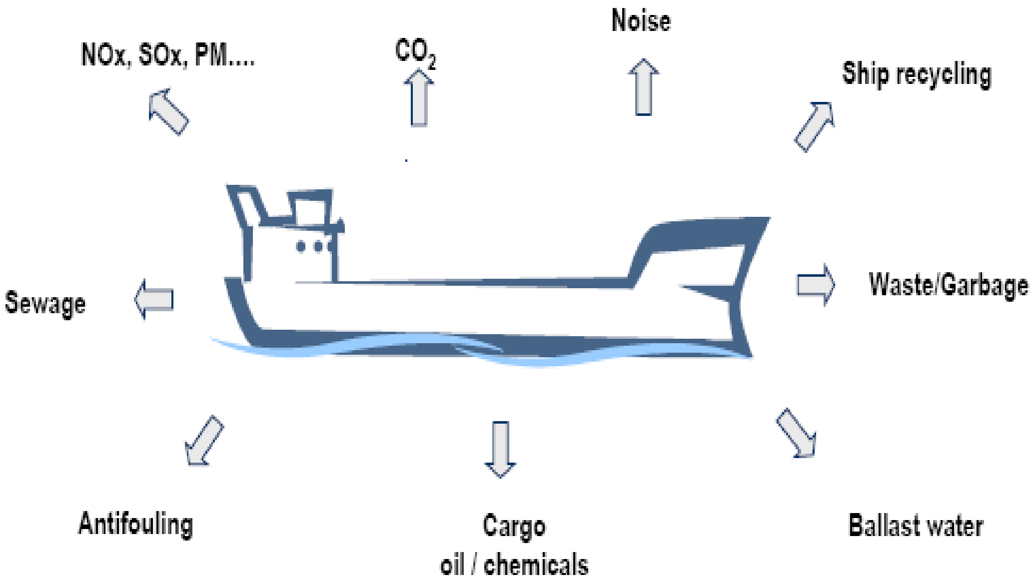
Advances in EEDI Research

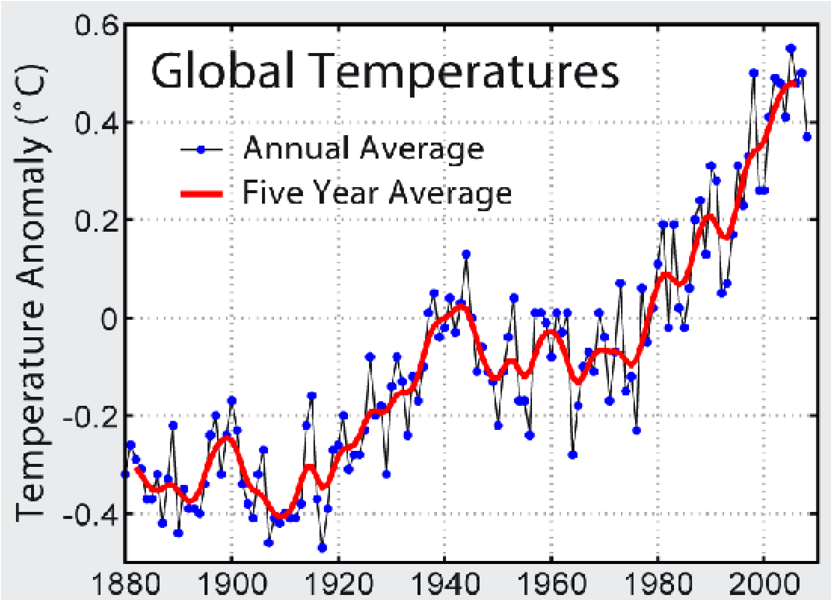
November 2015

CONTENT

1. Background

Shipping is the primary means of transport world widely. But now, more and more serious environmental pollution problems from ships have been the focus of attention.





Pollutants Released by Ships

1. Background

IMO put forward a series of new conventions, new codes and new standards for energy saving and emission reduction

- Goal Based Standard
- 2G Intact Stability
- Ballast Water Management
- Energy Efficiency Design Index
- ……

Green ship

- ✓Safety
- ✓Environment protection
- ✓High efficiency
- ✓Healthy

1. Background

◆ Solution to IMO EEDI rules in China:

- EEDI verification
- Application of ISO15016:2015
- Coefficient of decrease of ship speed (fw)
- Minimum Propulsion Power

1. Background

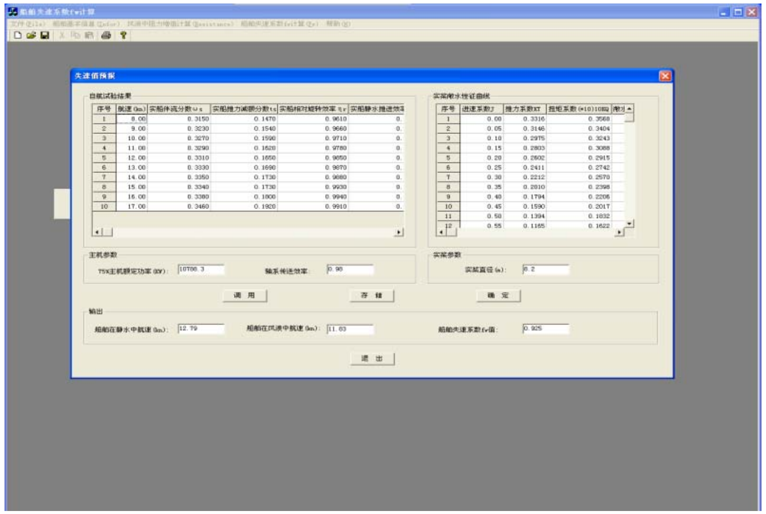
◆ **Software platform for EEDI survey and evaluation**

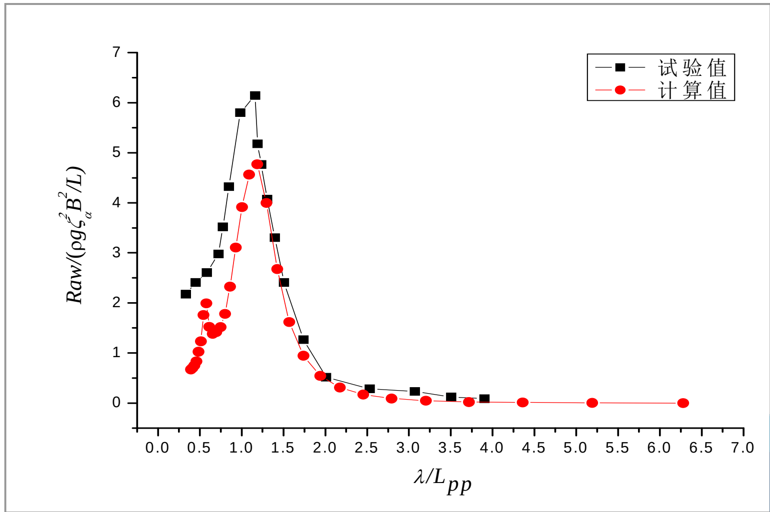
Website：www.eedi.org.cn

1. Background

◆ Software(shipfw) for the prediction of f_w

- Wave added resistance by strip method
- Wind resistance by empirical method
- Influence on propulsion efficiency by propeller load change

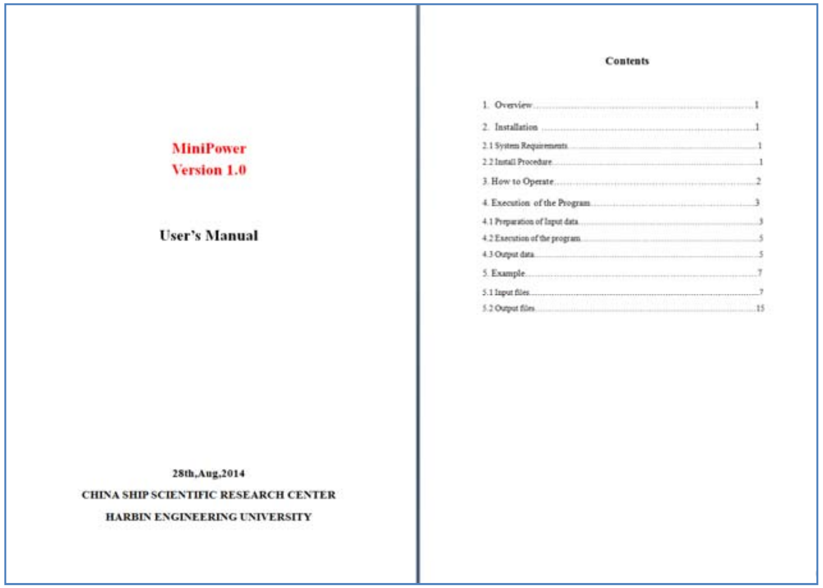




1. Background

◆ Tools for the assessment of minimum power

- **Software for the assessment of minimum propulsion power**
- **Computational method for added resistance in short waves**

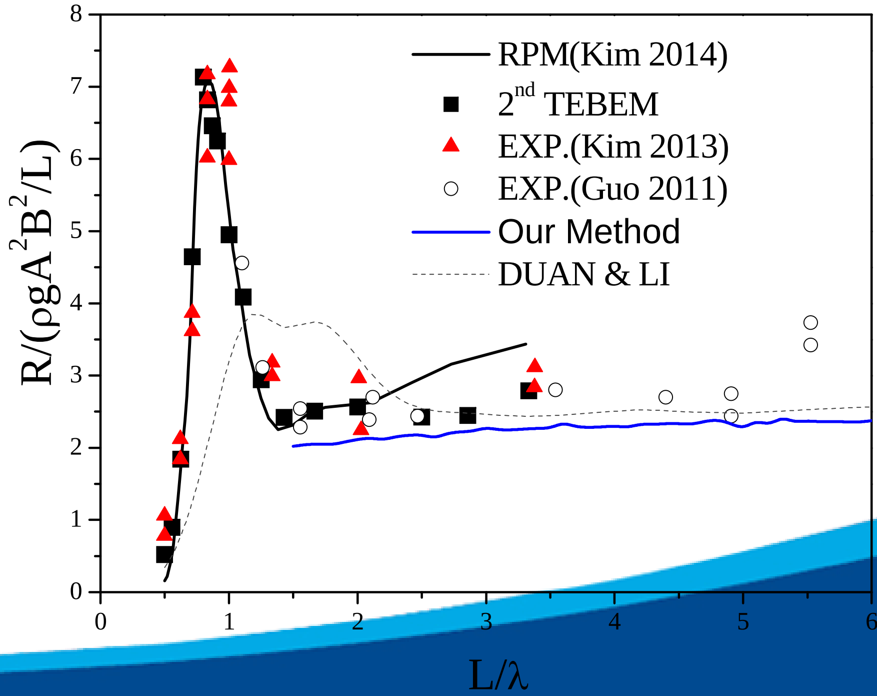


MiniPower
Version 1.0

User's Manual

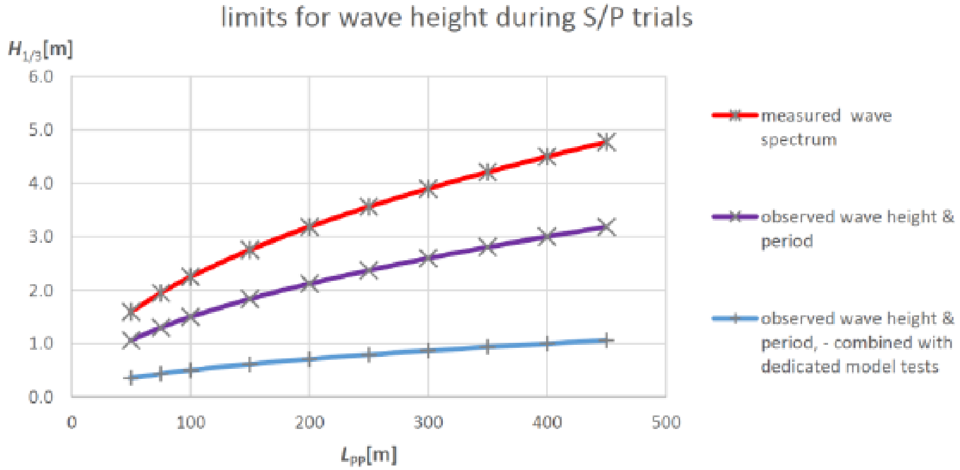
28th,Aug,2014
CHINA SHIP SCIENTIFIC RESEARCH CENTER
HARBIN ENGINEERING UNIVERSITY

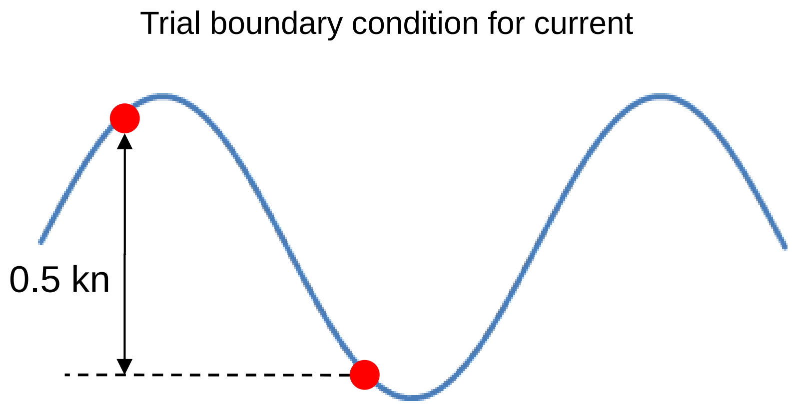
Contents



2. Application of ISO15016:2015

- In MEPC 68, it was agreed that the use of ISO15016:2015 to ships for which the speed trial is conducted on or after 1 September 2015.
- Various restrictions on speed trial, especially on the environmental conditions during the speed trial, were newly added into ISO15016:2015.





2. Application of ISO15016:2015

◆ Comparison of different speed correction method

No.	Ship	V_{ref} from ISO 15016:2002	V_{ref} from ISO 15016:2015	Deviation
1	64000DWT BC	13.87 kn	13.76 kn	- 0.11 kn
2	82000DWT BC	13.80 kn	13.66 kn	- 0.14 kn
3	82000DWT BC	13.81 kn	13.50 kn	- 0.31 kn

Run No.	Power setting	Heading [deg]	Relative wind direction [deg]	Relative wind speed [m/s]	Significant wave height [m]	Relative wave direction [deg]
1	50%	180	327	5.4	0.7	84
2	50%	0	19	9.3	0.7	-96
3	75%	0	17	9.1	0.7	-96
4	75%	180	329	7.3	0.7	84
5	85%	180	332	9.4	0.7	84
6	85%	0	20	9.1	0.7	-96
7	100%	0	27	9.6	0.7	-96
8	100%	180	333	11.7	0.7	84

➢ For No.3 example, wave direction in not from head (within 0 to ±45°)

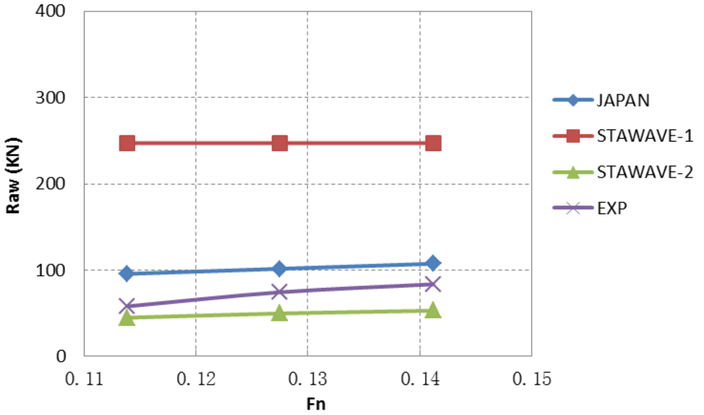
2. Application of ISO15016:2015

Comparison of different calculation method for R_{AW}

- 320,000 DWT VLCC

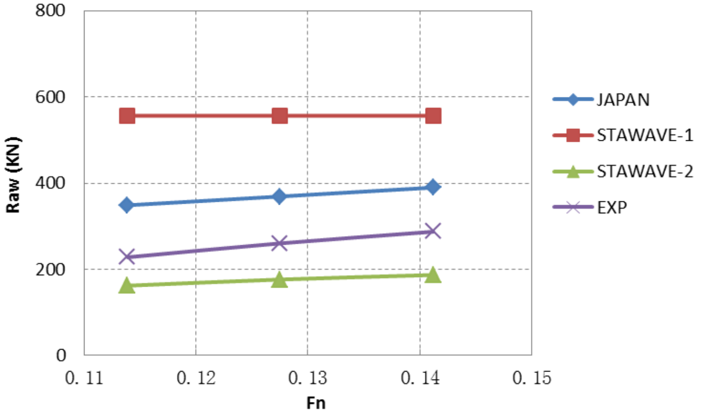
➢Sea state: BF5

Fn	EXP	JAPAN	STAWAVE-1	STAWAVE-2
0.1139	228	349	556	162
0.1275	260	369	556	176
0.1412	287	390	556	187



➢Sea state: BF6

Fn	EXP	JAPAN	STAWAVE-1	STAWAVE-2
0.1139	228	349	556	162
0.1275	260	369	556	176
0.1412	287	390	556	187



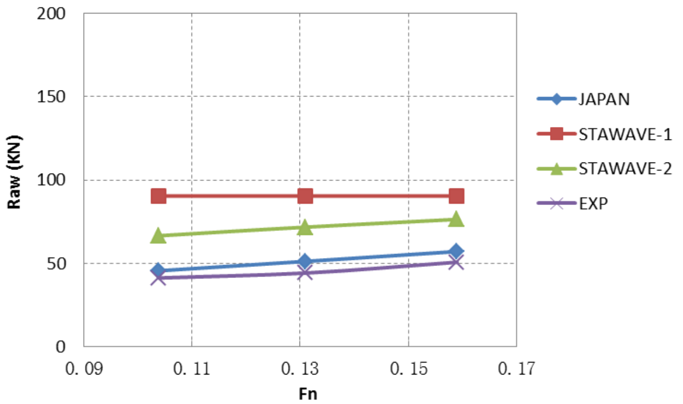
2. Application of ISO15016:2015

◆ Comparison of different calculation method for R_{AW}

- 82,000 DWT Bulk Carrier

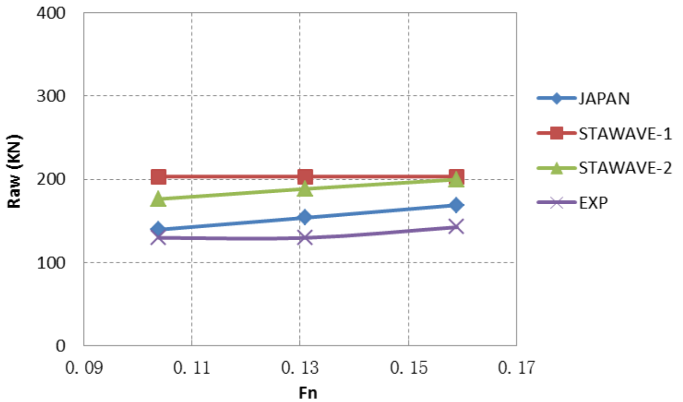
➢Sea state: BF5

Fn	EXP	JAPAN	STAWAVE-1	STAWAVE-2
0.1039	41	46	90	67
0.131	44	51	90	72
0.159	51	57	90	76



➢Sea state: BF6

Fn	EXP	JAPAN	STAWAVE-1	STAWAVE-2
0.1039	130	140	203	176
0.131	130	154	203	188
0.159	143	169	203	200



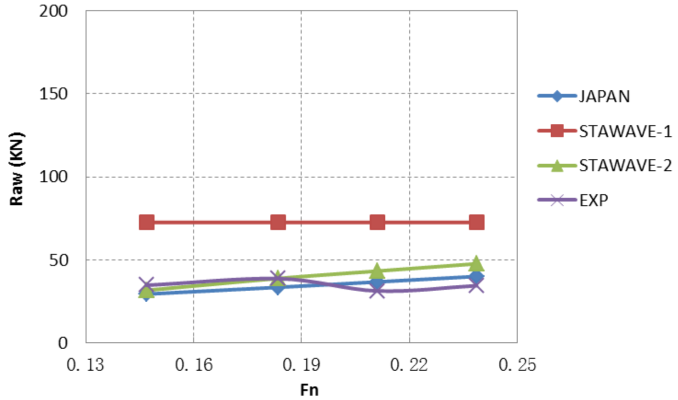
2. Application of ISO15016:2015

◆ Comparison of different calculation method for R_{AW}

● 8,800TEU Container Ship

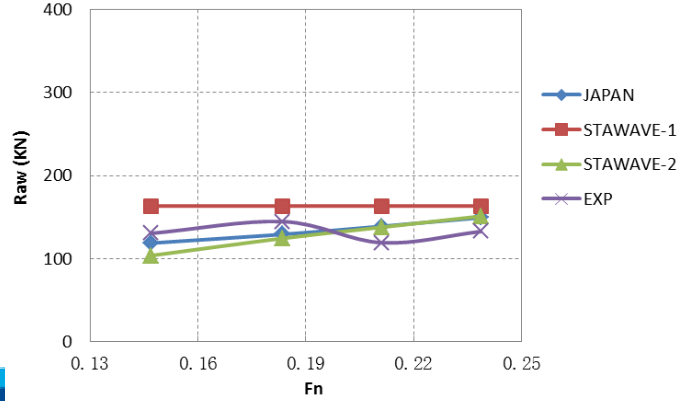
➢Sea state: BF5

Fn	EXP	JAPAN	STAWAVE-1	STAWAVE-2
0.1469	35	29	73	32
0.1836	39	34	73	39
0.2112	31	37	73	43
0.2387	35	40	73	48



➢Sea state: BF6

Fn	EXP	JAPAN	STAWAVE-1	STAWAVE-2
0.1469	130	119	163	104
0.1836	145	129	163	124
0.2112	119	139	163	138
0.2387	133	149	163	151

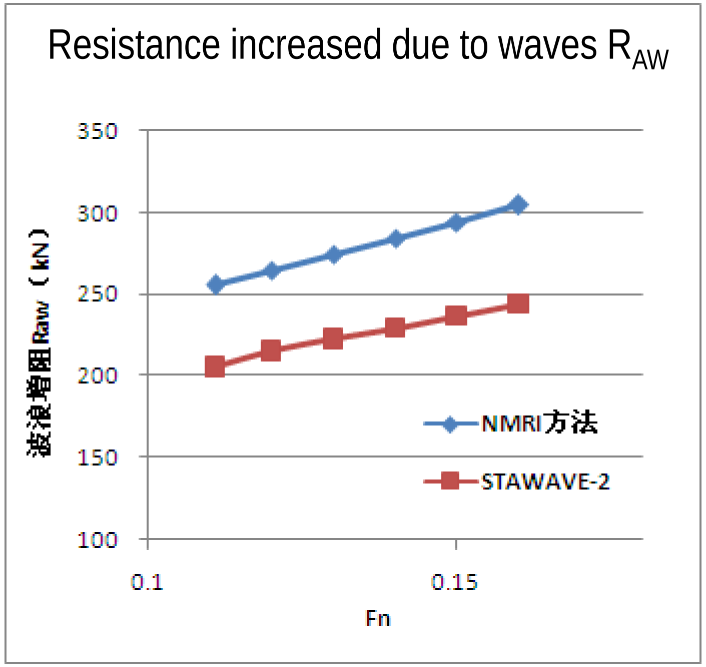


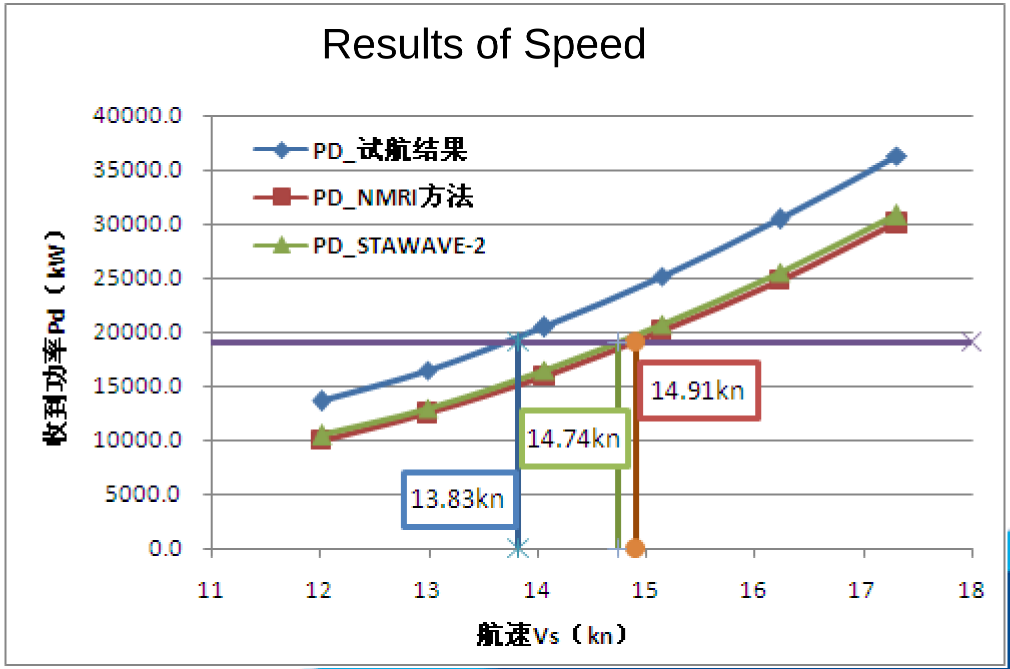
2. Application of ISO15016:2015

◆ Influence on Speed by different calculation method for R_{AW}

- 298,000DWT VLCC
  - **NMRI Method: 14.91 kn**
  - **STAWAVE-2: 14.74 kn**

Deviation: 0.17 kn





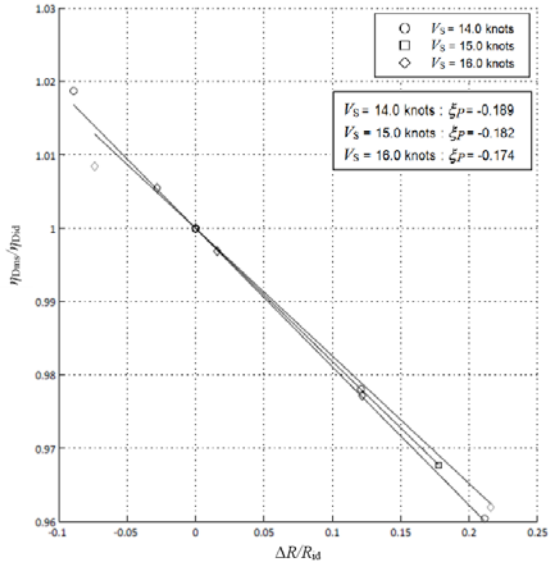
2. Application of ISO15016:2015

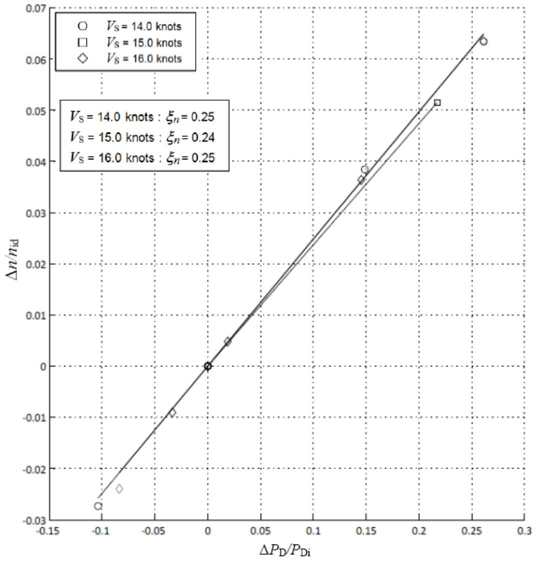
◆ Derivation of load variation coefficients

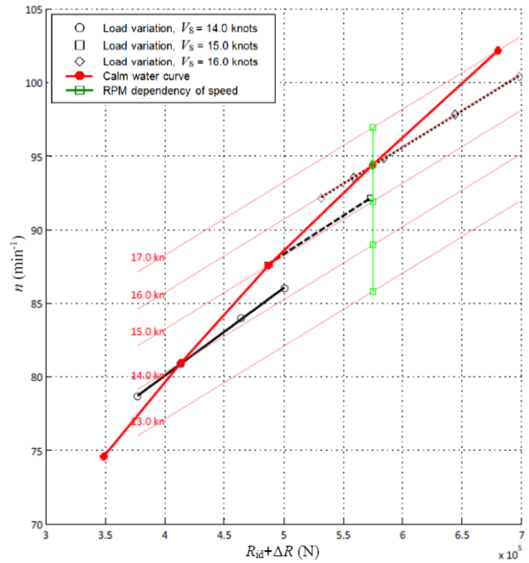
- **ε_P, ε_n, ε_V — Derived from load variation test**
  - ε_P : Dependency of propulsive efficiency with resistance increase
  - ε_n : Dependency of propeller shaft speed with power increase
  - ε_V : Dependency of propeller shaft speed with speed change

$$\frac{\eta_{\mathrm{Dms}}}{\eta_{\mathrm{Did}}} = \xi_P \frac{\Delta R}{R_{\mathrm{id}}} + 1$$

$$\frac{\Delta n}{n_{\mathrm{id}}} = \xi_n \frac{P_{\mathrm{Dms}} - P_{\mathrm{Did}}}{P_{\mathrm{Did}}} + \xi_V \frac{\Delta V}{V_{\mathrm{S}}}$$







2. Application of ISO15016:2015

◆ Derivation of load variation coefficients

- It is found that those three coefficients can not be derived from model test report provided by any tank test organization directly, and also can not be calculated based on the data from the model test report.
- It is necessary to develop reference values for those three coefficients, and the universality of the reference values should be demonstrated.

2. Application of ISO15016:2015

Conclusion

- ship condition, environmental condition and restriction of correction method should be paid extra attention to when speed trial is planned based on ISO15016:2015.
- It is unreasonable that only resistance increased due to head waves can be corrected, new method considering resistance increased due to following waves should be developed.
- Develop reference values for load variation coefficients.

3. Research on Coefficient f_W

◆ Computational Method for f_w proposed by China

● Total resistance in the representative sea condition : R_{TW}

$$R_{Tw} = R_T + \Delta R_{wind} + \Delta R_{wave}$$

● Added resistance due to waves : ΔR_{wave}

$$\Delta R_{wave} = 2\int_0^{\infty} \frac{R_{wave}(\omega)}{\zeta_a^{\ 2}} \cdot S_{\zeta}(\omega) d\omega$$

$$R_{wave} = R_{wm} + R_{wr}$$

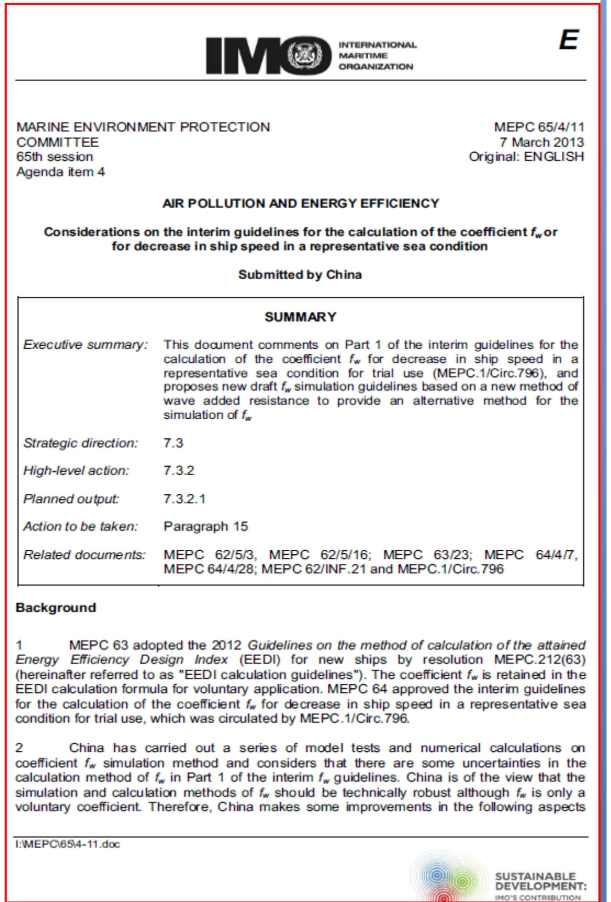
Combined method

$$R_{wm} = \frac{k\cos\alpha}{2\omega_e} \int_L b'(x) V_{za}^2 dx_b$$

Radiated energy method

$$R_{wr} = \overline{F_x} = \frac{\rho g \zeta_a^2}{2} \left(a + \frac{4b\omega V}{g} + 2c\left(\frac{\omega V}{g}\right)^2\right) \cdot \alpha_d$$

DSG method



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INTERNATIONAL MARITIME ORGANIZATION

MARINE ENVIRONMENT PROTECTION COMMITTEE
65th session
Agenda item 4

MEPC 65/4/11
7 March 2013
Original: ENGLISH

AIR POLLUTION AND ENERGY EFFICIENCY

Considerations on the interim guidelines for the calculation of the coefficient f_w or for decrease in ship speed in a representative sea condition

Submitted by China

SUMMARY

Executive summary:	This document comments on Part 1 of the interim guidelines for the calculation of the coefficient f_w for decrease in ship speed in a representative sea condition for trial use (MEPC.1/Circ.796), and proposes new draft f_w simulation guidelines based on a new method of wave added resistance to provide an alternative method for the simulation of f_w
Strategic direction:	7.3
High-level action:	7.3.2
Planned output:	7.3.2.1
Action to be taken:	Paragraph 15
Related documents:	MEPC 62/5/3, MEPC 62/5/16; MEPC 63/23; MEPC 64/4/7, MEPC 64/4/28; MEPC 62/INF.21 and MEPC.1/Circ.796

Background

1 MEPC 63 adopted the 2012 *Guidelines on the method of calculation of the attained Energy Efficiency Design Index* (EEDI) for new ships by resolution MEPC.212(63) (hereinafter referred to as "EEDI calculation guidelines"). The coefficient f_w is retained in the EEDI calculation formula for voluntary application. MEPC 64 approved the interim guidelines for the calculation of the coefficient f_w for decrease in ship speed in a representative sea condition for trial use, which was circulated by MEPC.1/Circ.796.

2 China has carried out a series of model tests and numerical calculations on coefficient f_w simulation method and considers that there are some uncertainties in the calculation method of f_w in Part 1 of the interim f_w guidelines. China is of the view that the simulation and calculation methods of f_w should be technically robust although f_w is only a voluntary coefficient. Therefore, China makes some improvements in the following aspects

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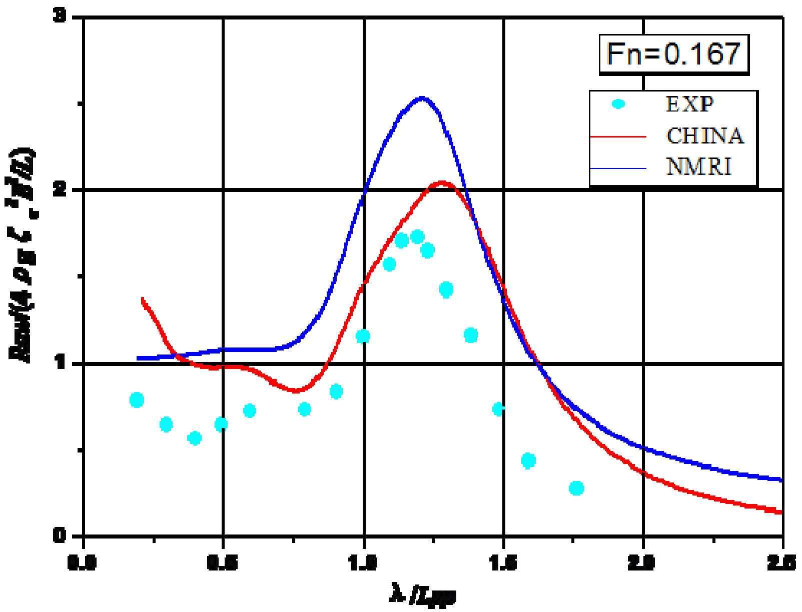
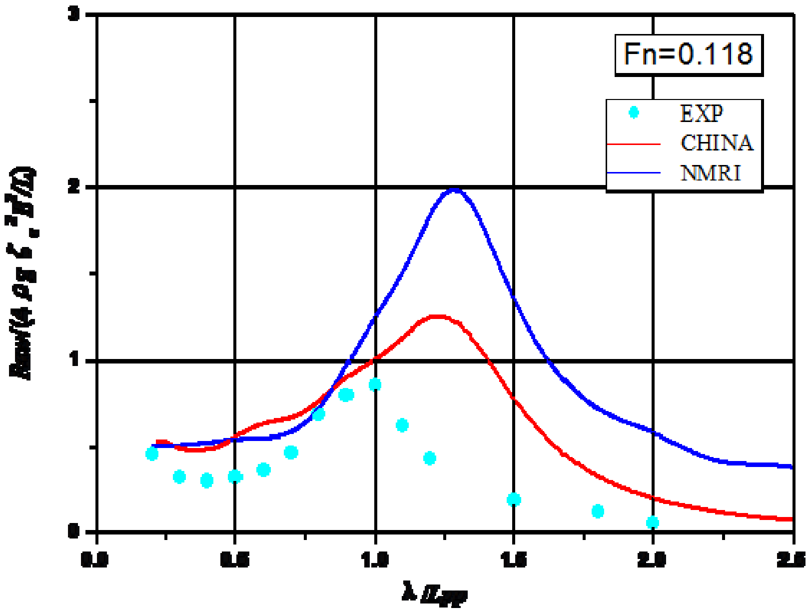
SUSTAINABLE DEVELOPMENT: IMO'S CONTRIBUTION

More details refer to DUAN & LI(2013) and MEPC65/4/11

3. Research on Coefficient f_W

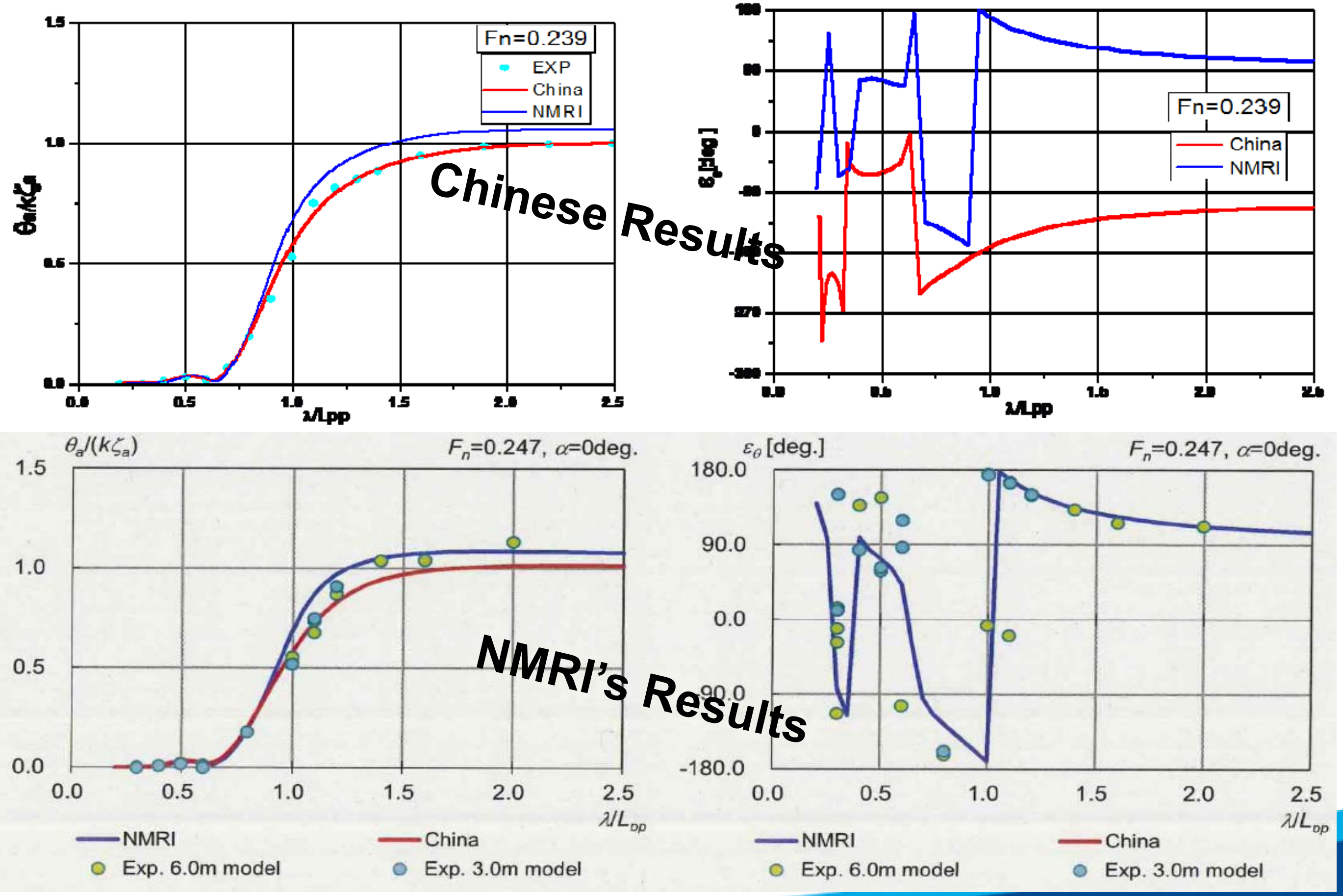
◆ Added resistance comparison





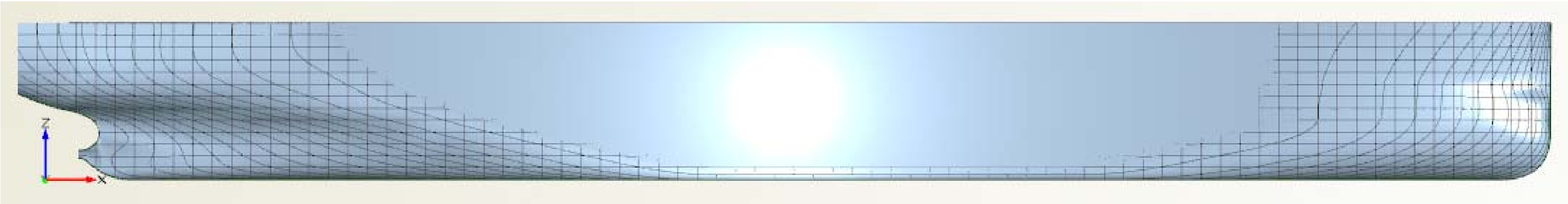
3. Research on Coefficient f_W

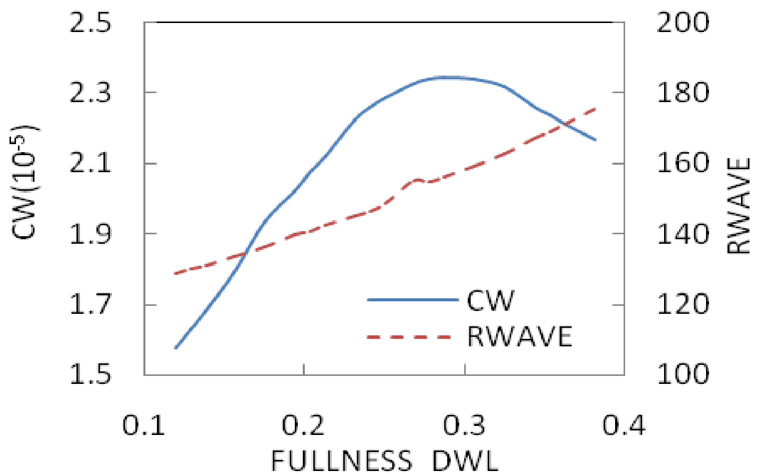
◆ Motion comparison

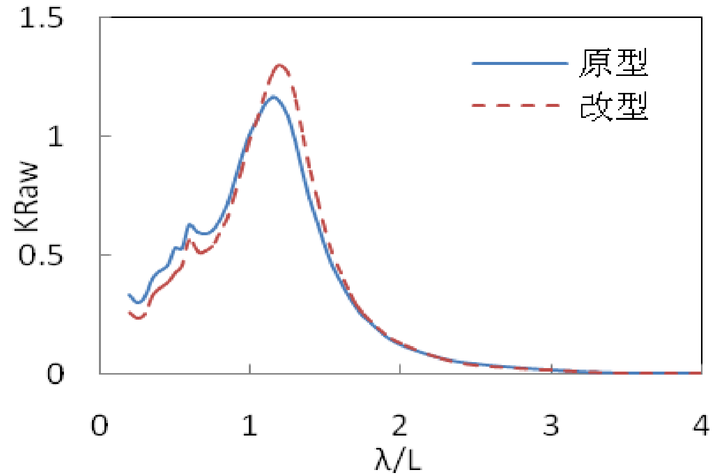


3. Research on Coefficient f_w

◆ Hull Form Optimization for f_w







- **fw optimization based on a multiple target hull form optimization system developed by CSSRC**

3. Research on Coefficient f_w

◆ Conclusion

- It's very important for ship design to predict the decrease of ship speed in real sea, f_w has become the current hot issue.
- China proposed a new combined method to calculate added resistance in waves, and this new method has good agreement with model test.
- Model test of added resistance in short waves is different to conduct, so we suggest that：larger ship model may be a appropriate way to solve it.
- There exists many methods to improve the performance of ships in representative sea condition.

4. Research on Minimum Propulsion Power

Hot Issues at the IMO

2012
- **Interim Guidelines**
- MSC-MEPC.2/Circ.11

2013
- **2013 Interim Guidelines**
- Resolution MEPC.232(65)

2014
- **Amendments to the 2013 Interim Guidelines**
- Resolution MEPC.255(67)

2015
- **Amendments to the 2013 Interim Guidelines, as amended**
- Resolution MEPC.262(68)

Amend definition of "Adverse conditions"

Extend the scope of application:

Phase 0 to Phase 1

Amend criteria line for Level 1 assessment

4. Research on Minimum Propulsion Power

◆ Utilization of the concept of weather factor "fw"

utilization of the concept of weather factor "f_w"

While the present Interim Guidelines contain two assessment levels, an alternative approach could be warrant for consideration. In this respect, attention should be paid to *the Interim Guidelines for the calculation of the coefficient f_w for decrease in ship speed in a representative sea condition for trial use* (MEPC.1/Circ.796). In accordance with these Interim Guidelines, the weather factor f_w may be obtained for representing ship speed reduction in the actual sea condition, that is BF=6. It might be possible that this concept could be utilized as an alternative to the level 2 Criterion in the Interim Guidelines. To be more concrete, if we are able to extend/modify the concept of f_w to correspond to the "adverse condition" to be developed in accordance with the previous sentence, and this extended/modified factor of a specific ship in adverse condition results in more than zero, this would mean that that ship may be considered as it has the manoeuvrability in that adverse condition as it at least has a advancing speed. In this way, the analogy of f_w concept could be employed as an alternative for level 2 assessment method.

4. Research on Minimum Propulsion Power

◆ Summary of the 2013 Interim Guidelines

Level-1 assessment by minimum power lines

Installed propulsion power (total main engine output) is not to be less than the specified value calculated using formula as a function of deadweight for each ship type.

If a ship does not satisfy the level-1 criteria, level-2 assessment is to be considered.

Level-2 simplified assessment by indirect assessment

Level-2 simplified assessment is an indirect assessment procedure based on an assumption that, in the following adverse condition, if a ship has sufficient installed power to move with a certain advance speed in head waves and wind, and if it is lower than the torque limit within the operating range of the installed engine, the ship can also be expected to maintain course in waves and wind from any other direction.

Ship length Lpp (m)	Significant wave height (m)	Peak wave period (s)	Mean wind speed (m/s)
Lpp＜200	4.0	7.0 to 15.0	15.7
200≦Lpp＜250	*		*
Lpp≧250	5.5		19.0

* Linearly interpolated depending on ship's length

4. Research on Minimum Propulsion Power

◆ Level-1 Assessment(Minimum Power Lines)

$$\text{Minimum Power Line Value} = a \times (DWT) + b$$

where:

DWT is the deadweight of the ship in metric tons; and *a* and *b* are the parameters given in table 1 for tankers, bulk carriers and combination carriers.

Before MEPC 68

Table 1: Parameters a and b for determination of the minimum power line values for the different ship types

Ship type	a	b
Bulk carrier	0.0687	2924.4
Tanker	0.0689	3253.0
Combination Carrier	see tanker above	

After MEPC 68

Table 1: Parameters a and b for determination of the minimum power line values for the different ship types

Ship type	a	b
Bulk carrier which DWT is less than 145,000	0.0763	3374.3
Bulk carrier which DWT is 145,000 and over	0.0490	7329.0
Tanker	0.0652	5960.2
Combination carrier	see tanker above	

4. Research on Minimum Propulsion Power

◆ Level-1 Assessment(Minimum Power Lines)

Deadweight	Bulk Carrier		difference
	Before MEPC 68	MEPC68	Bulk Carrier
20000	4298.4	4900.6	14.01%
40000	5672.4	6426.6	13.30%
60000	7046.4	7952.6	12.86%
80000	8420.4	9478.6	12.57%
100000	9794.4	11004.6	12.36%
150000	13229.4	14679	10.96%
200000	16664.4	17129	2.79%
240000	19412.4	19089	-1.67%
320000	24908.4	23009	-7.63%

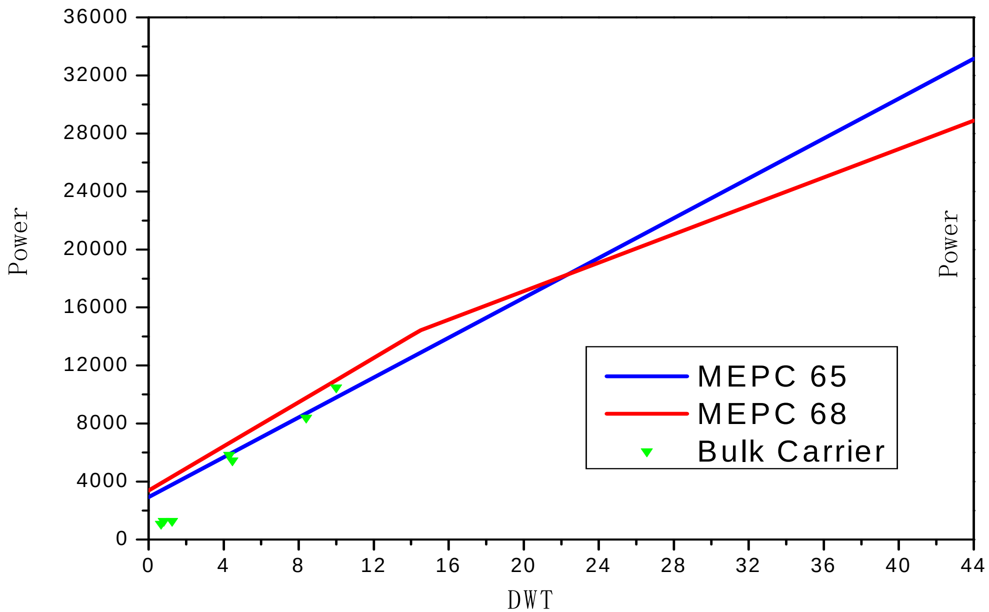
4. Research on Minimum Propulsion Power

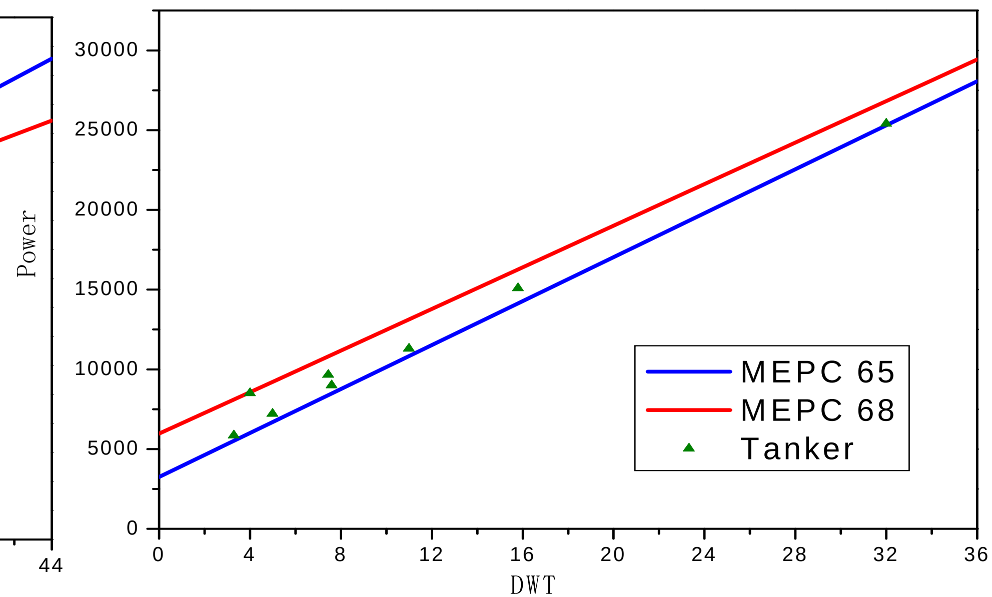
◆ Level-1 Assessment(Minimum Power Lines)

Deadweight	Tanker		difference
	Before MEPC 68	MEPC68	Tanker
20000	4631	7264.2	56.86%
38000	5871.2	8437.8	43.72%
60000	7387	9872.2	33.64%
80000	8765	11176.2	27.51%
100000	10143	12480.2	23.04%
140000	12899	15088.2	16.97%
180000	15655	17696.2	13.04%
220000	18411	20304.2	10.28%
320000	25301	26824.2	6.02%

4. Research on Minimum Propulsion Power

◆ Level-1 Assessment(Minimum Power Lines)

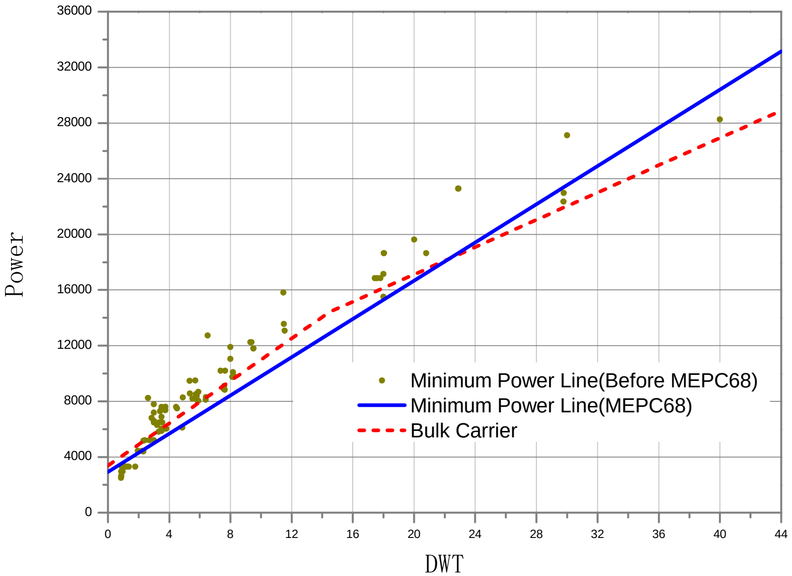


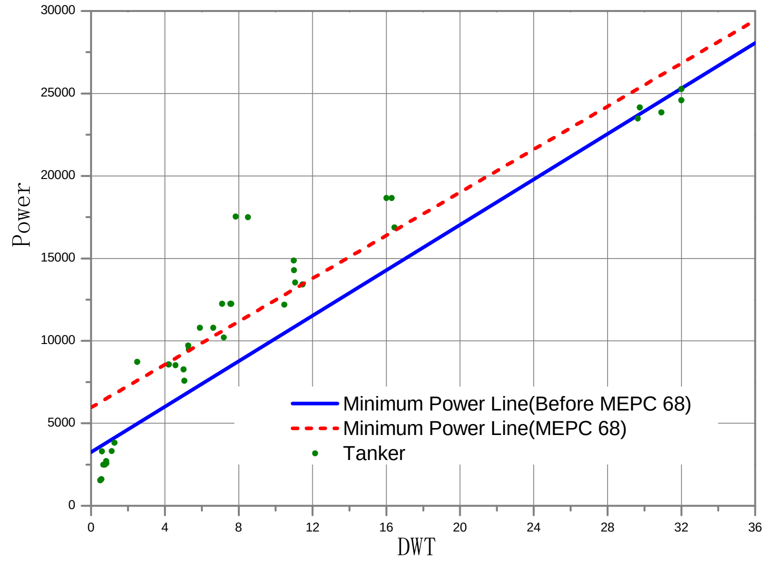


✓**New Ships: All of the 7 bulk carriers and 8 tankers can not satisfy the Level-1 assessment**

4. Research on Minimum Propulsion Power

◆ Level-1 Assessment(Minimum Power Lines)

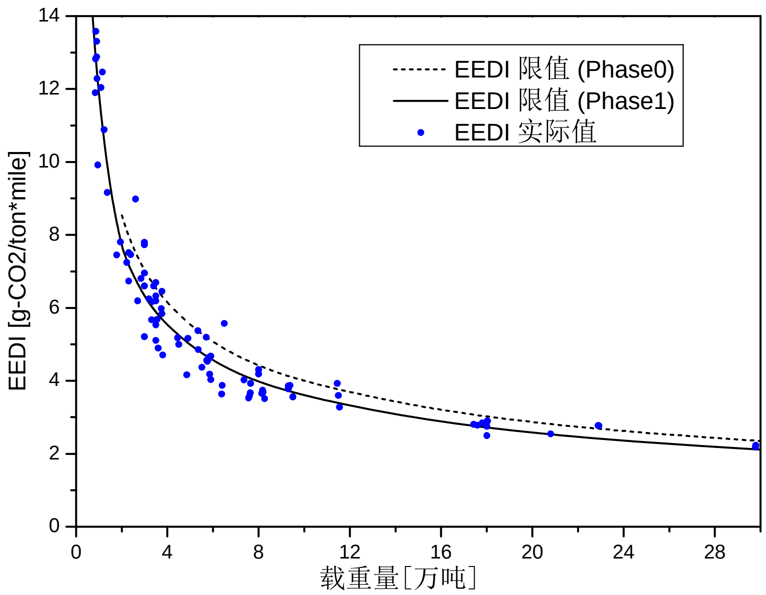


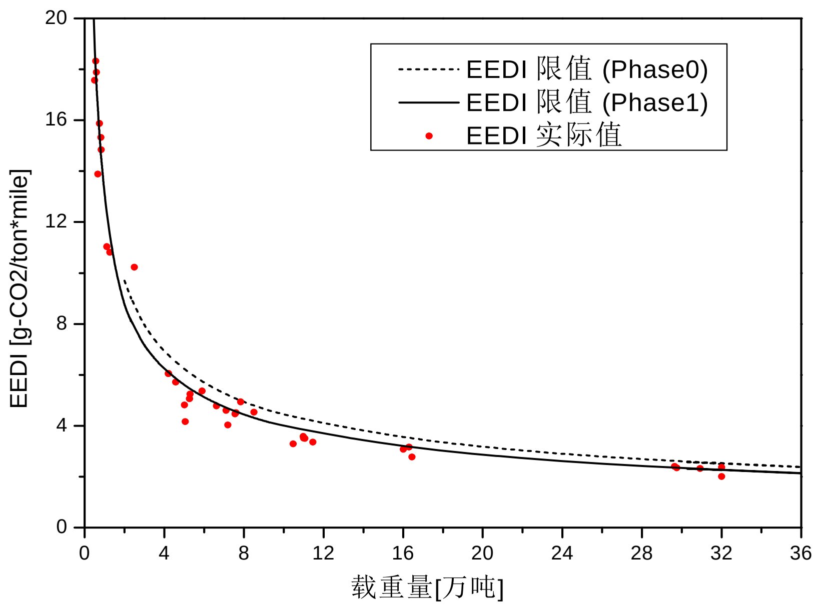


✓**Old Ships: Many small ships and large scale tankers can not satisfy the Level-1 assessment.**

4. Research on Minimum Propulsion Power

◆ Level-1 Assessment and EEDI Calculation





✓**Ships from EEDI data base: The great majority can not satisfy the EEDI Phase 1, especially for large scale ships.**

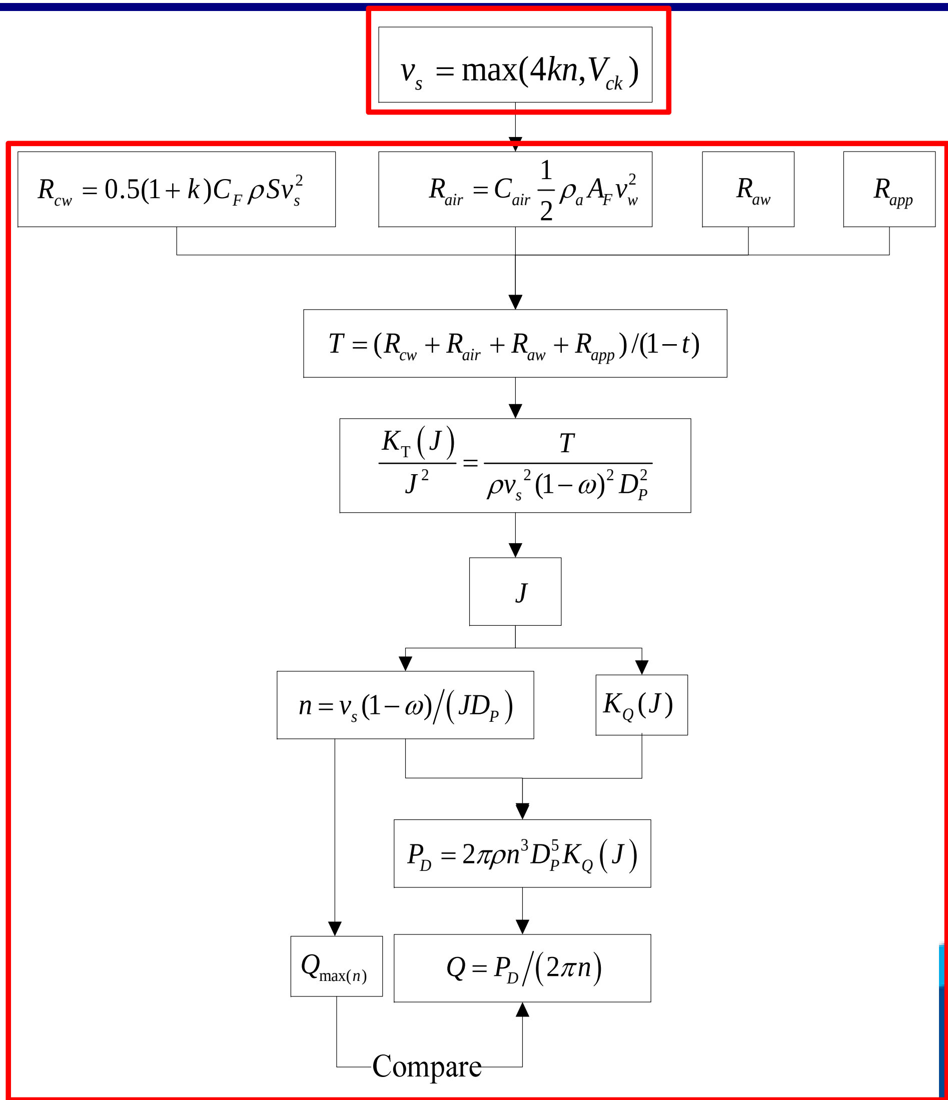
4. Research on Minimum Propulsion Power

◆ Level-2 Assessment

The assessment consists of two steps:

1. Definition of the required advance speed(Vs),ensuring course-keeping in all wave and wind direction;

2. Assessment whether the installed power is sufficient to achieve the required advance speed in head wind and waves.



4. Research on Minimum Propulsion Power

38000DWT Chemical Tanker

Main Parameters	Lpp	177.000	m
	Tm	11.100	m
	Bwl	32.000	m
	submerged lateral area for breadth effect	3570.124	m^2
	rudder area (AR)	30.940	m^2

Level-1 Assessment	Time	REQUIRE POWER	S.M.C.R	Satisfy?
	Before MEPC68	6009.0	7610	Yes
	MEPC68	8568.2		No

4. Research on Minimum Propulsion Power

◆ 38000DWT Chemical Tanker

$K_T(J)/J^2$	8.150	-	
J	0.196	-	
n	1.173	rps	67.70%
$K_Q(J)$ (see open water results)	0.037	-	
P_D	3822.776	kW	
Ps	3900.792	kW	51.26%

Conclusion: **the required minimum power is less than engine SMCR, but restricted by the torque-speed limitation curve ,this ship can not satisfy the Level-2 assessment.**

4. Research on Minimum Propulsion Power

◆ Conclusion

● It’s very important for shipyard and ship-owner to know whether their ships satisfy the minimum propulsion power assessment.

● Studies conducted by CSSRC indicate that many small ships and large scale tankers can not satisfy the Level-1 assessment, especially the new ships.

● The 2013 Interim Guidelines exists many problems , China will conduct more research to proposed an reasonable assessment guidelines.

5. Topics of Future Research

◆ EEDI Verification & ISO 15016:2015

- influence of environmental parameters on ship speed
- calculation method for R_{AW} considering following waves
- reference values for load variation coefficients

◆ Coefficient f_W

- larger scale ship model test to analyze added resistance in short waves

◆ Minimum Propulsion Power

- Level-3 assessment method

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THANKS

FOR YOUR ATTENTION!

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