Technologies for estimating and improving ships' performance in wind and waves

Masaru Tsujimoto

Performance of Ships in Actual Seas Research Group,
Fluids Engineering & Hull Design Department
(C/A) Center for International Cooperation

NMRI National Maritime Research Institute

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What is f_w guidelines?

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How to evaluate new technologies

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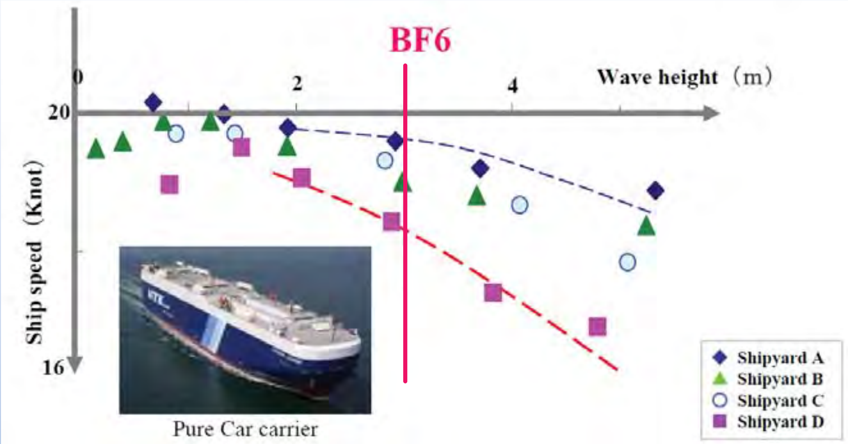
Introduction *Motivation*

Awareness of a ship owner

Decrease of ship speed is not the same even if the ships are designed under the same specification



- This is related to fuel consumption in the life cycle.
- Ship should be designed for performance in actual seas.
- To evaluate and check the performance in actual seas, it is necessary to make a standard method/index.

Ref) Y.Tanaka: Optimum speed and Performance difference in actual seas, TECHNO MARINE, No. 884, 2005

Introduction *Concept*

Evaluation of ship performance

fw is a non-dimensional coefficient indicating the decrease of speed in representative sea conditions.

The guidelines should promote GHG reduction in actual sea conditions.

- ◆ We should evaluate ship performance in wind and waves.
- ◆ We should evaluate new technologies which can make f_w increase (improve).

Introduction

Scheme of f_w and *EEDIweather*

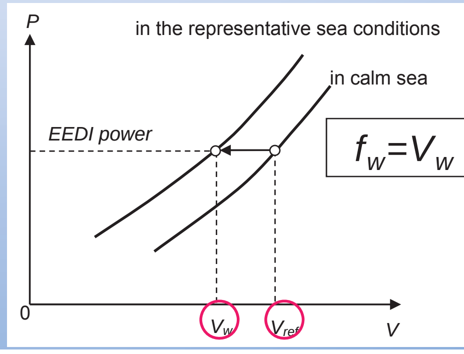
■ *To evaluate and check the performance in actual seas, it is necessary to make a standard method/index.*

□ f_w is a non-dimensional coefficient indicating the decrease of speed in representative sea conditions

attained EEDIweather

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

Res.MEPC.212(63);
f_w and *attained EEDIweather*, if calculated, with the representative sea conditions under which those values are determined, should be indicated in the EEDI Technical File.



$f_w = V_w / V_{ref}$

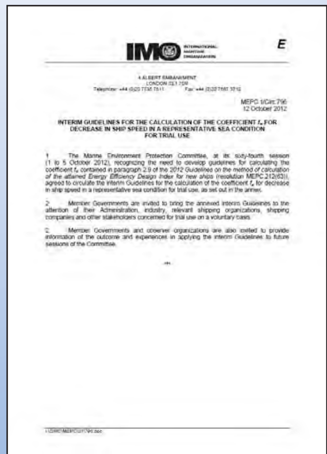
Introduction

f_w guidelines

Discussion on f_w guidelines through the informal corresponding group and MEPC

IMO/MEPC64 (Oct., 2012)
approves f_w interim guidelines for trial use, where the representative sea condition is BF6 of head winds and waves.

BF6
significant wave height 3m
wind speed 12.6m/s



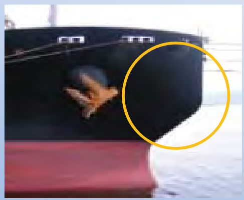
MEPC.1/Circ.796

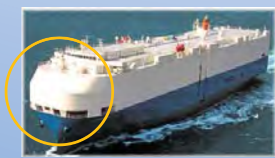
Introduction

f_w can be obtained by

Ship specific Simulation

☆ The simulation should be accurately evaluated new technologies, e.g. special bow shapes/devices.





Standard curves

Alternative method when the f_w simulation can not be performed.

☆ Working the incentive for f_w simulation and from the viewpoint of navigation safety, the standard curves should prevent calculating a greater value than the truth.

Technologies

Ship Performance in actual seas

The answer is at the sea!

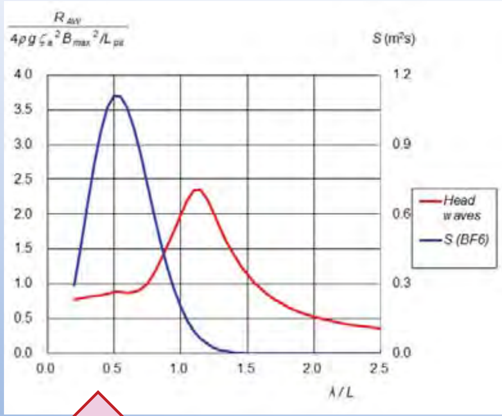
Ocean waves have irregularity

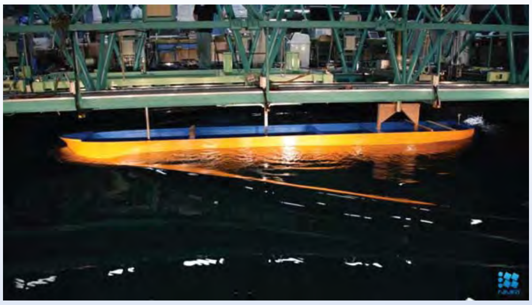
short crested irregular waves

Technologies

Irregular waves is expressed by superposition of regular waves in frequency and direction

Frequency response of added resistance in regular waves (*L*=225m, head waves)





λ/*L*=1.1

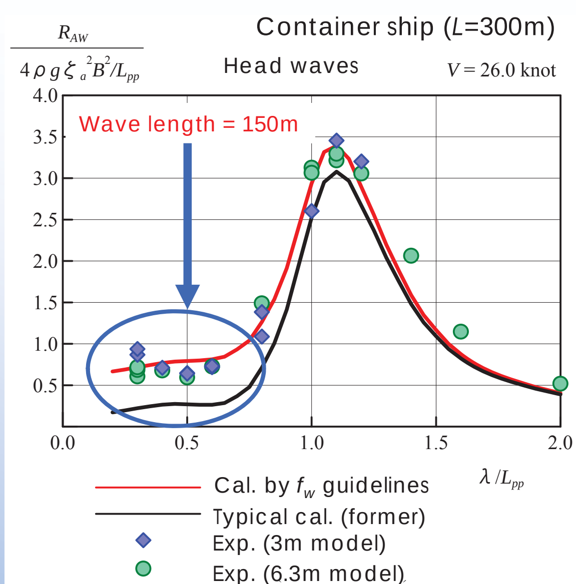
λ/*L*=0.4

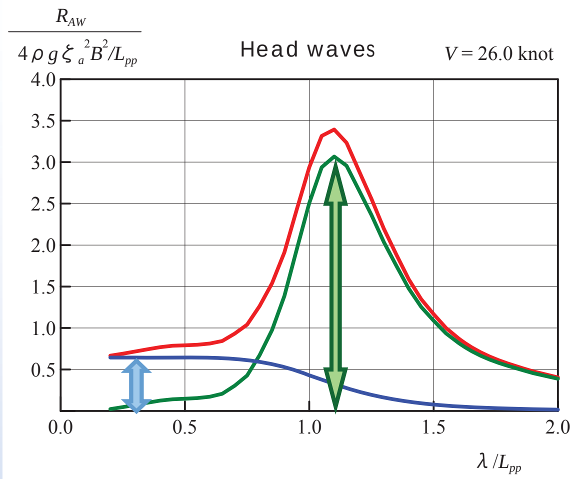
Spectrum is concentrated *in short waves*

regular short waves

Technologies

Accurate estimation on added resistance in waves





reflection + Radiation and Diffraction

⇒ Total

Poor agreement of calculated and experimental values are known in short waves.

Accuracy improvement was required!

Improvement of reflection component

⇒ Hybrid method (f_w guidelines)

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☆Radiation and Diffraction components are calculated by Maruo's theory

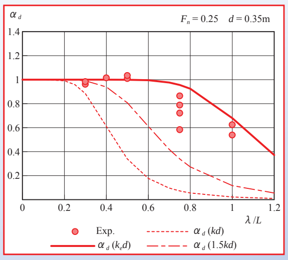
☆Reflection component is calculated as follows.

$$R_{AWr} = \frac{1}{2}\rho g \zeta_a^2 B B_f \alpha_d (1 + \alpha_U)$$

added resistance due to wave reflection (semi empirical formula)

$$\alpha_d = \frac{\pi^2 I_1^2(k_e d)}{\pi^2 I_1^2(k_e d) + K_1^2(k_e d)}$$

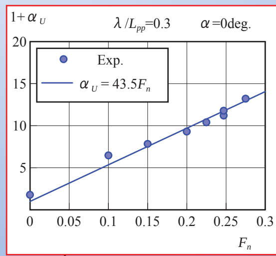
Term of draft and frequency extended by Ursell's formula



$$\alpha_U = C_U F_n$$

Coefficient of advance speed

The coefficient is obtained by tank tests in short waves of different speed (hybrid)



$$B_f = \frac{1}{B}\left\{ \int_I \sin^2(\alpha + \beta_w)\sin\beta_w dl + \int_{II} \sin^2(\alpha - \beta_w)\sin\beta_w dl \right\}$$

Bluntness coefficient derived by Havelock

ref) M. Tsujimoto et al.: A Practical Correction Method for Added Resistance in Waves, Journal of JASNAOE, Vol.8, 2008
M. Kuroda et al.: Investigation on Components of Added Resistance in Short Waves, Journal of JASNAOE, Vol.8, 2008

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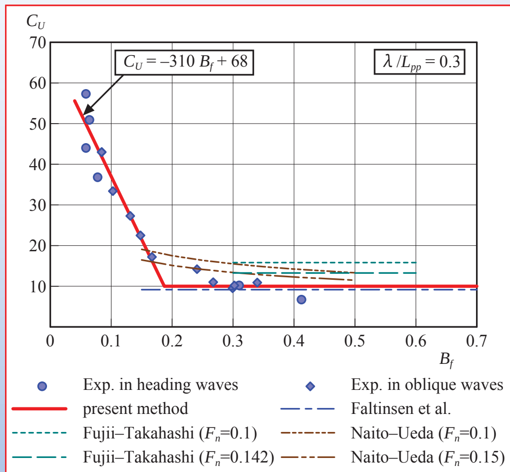
Application to the oblique waves

From many results of the tank tests by NMRI, an empirical chart is prepared.

Relation between coefficient of advance speed (C_U) and bluntness coefficient (B_f).

This chart is derived from tests of conventional ships



☆ Tank tests in oblique waves are not necessary.

☆ *This chart is available for ship design stage to estimate C_U before the tank test.*

The effect of bow shape, including special bow shape, can be evaluated by hybrid method.

ref) M. Tsujimoto et al.: A Practical Correction Method for Added Resistance in Waves, Journal of JASNAOE, Vol.8, 2008

Technologies

Hybrid method
on added resistance in waves

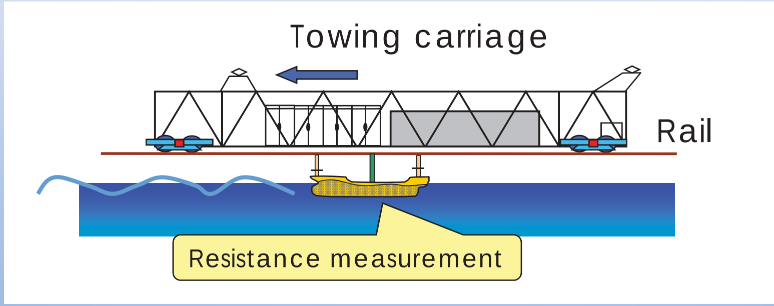
Resistance test in short head waves

Less ship motion
- Same setting with resistance test in still water is possible.
- Setting of radius of inertia is unnecessary.

Test procedures: 3 speed but 1 frequency; each two points (for reproducibility check)
- 3 hours to perform

Minimizing the implementation cost

Resistance test in short waves



Validation by round-robin tests

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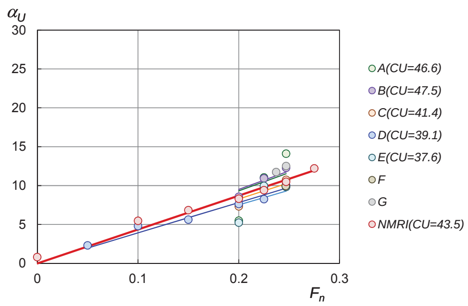
Validation by round-robin tests

Resistance test in short head waves

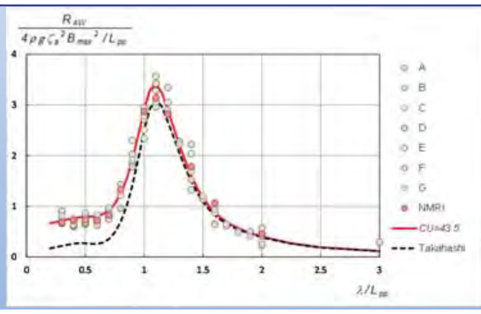
Round-robin tests were conducted (container ship / bulk carrier / tanker) at 9 institutes in total having a large towing tank in Japan and EU



Linearity of effect of advance speed (α_U) is confirmed.

Speed difference at BF6 is confirmed within ± 0.2% (about 0.04knot)

RAO of added resistance in waves (container ship)



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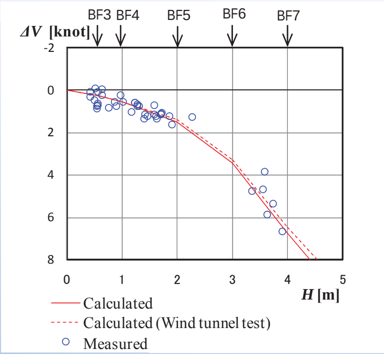
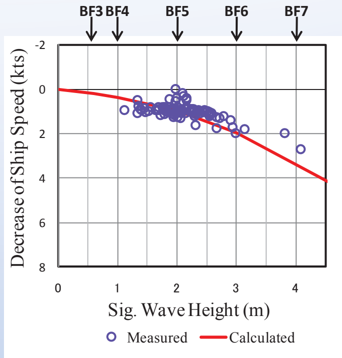
Validation by onboard measurements

PCC (L=190m)

VLCC(L=320m)





Similar results are resulted in container ship (L=280m) and bulk carrier (L=160m)

These results show the calculation method has sufficiently accurate.

The hybrid method is described in the f_w guidelines as an example which is confirmed accuracy.

ref) N. Sogihara et al.: Verification of Calculation Method on Ship Performance by Onboard Measurement, Proc. of ISOPE2010, Vol.4, 2010.
N. Sogihara et al.: Onboard Measurement for Verification of a Calculation Method on Decrease of Ship Speed -for a RoRo Cargo Ship and an Oil Tanker-, Proc. of ISOPE2011, Vol.4, 2011.

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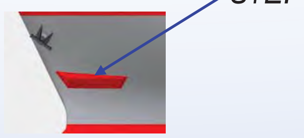
Application to special bow shape

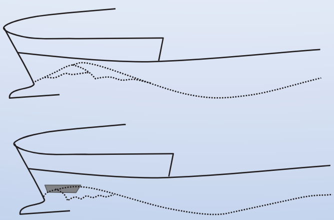
Application to *STEP*; energy saving device in actual seas

Tank test in short waves

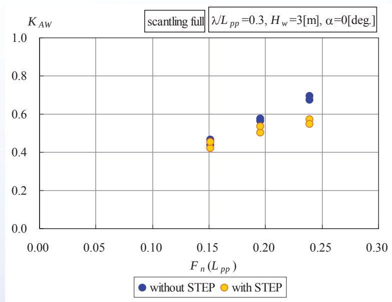
Without *STEP*

With *STEP*

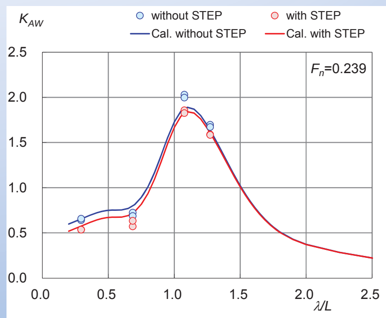




Result of tank test in short waves



Evaluation



18% of added resistance in short waves can be reduced.

Effect of *STEP* can be calculated by the hybrid method!

STEP is developed by NMRI and Naikai Zosen Corporation

ref) M. Kuroda et al.: Development of STEP for the Reduction of Added Resistance in Waves, Proc. of ISOPE2012, Vol.3, 2012.

Technologies

Estimation on wind resistance

Reliable Method Based on the Wind Tunnel Test Data

➤ Empirical formula based on wind tunnel data base

$$C_{Dwind} = 0.922 - 0.507 \frac{A_L}{L_{OA} B} - 1.162 \frac{C}{L_{OA}}$$

Non-dimensional coefficient of wind resistance.

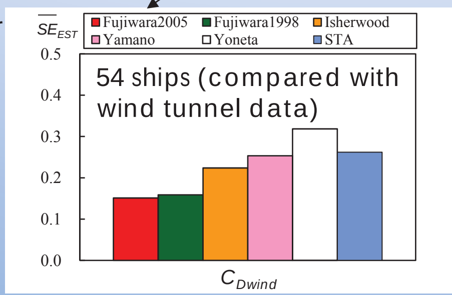
Wind tunnel test

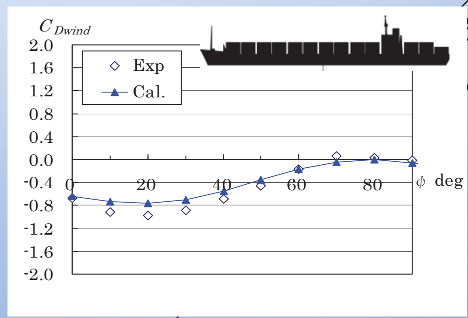
Validation study by ITTC

f_w guidelines

Standard error

The most accurate method is used in f_w guidelines.





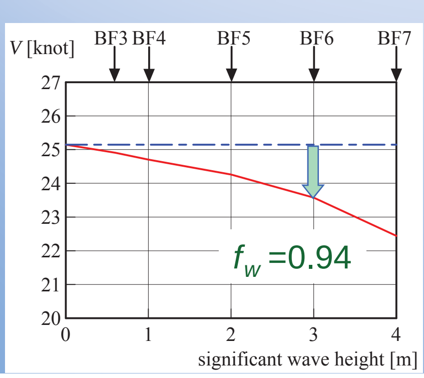
ref) T. Fujiwara et al.: Cruising performance of a large passenger ship in heavy sea, Proc. of ISOPE2006, Vol3, 2006.
ITTC: Report of the Specialist Committee on Performance of Ships in Service, Proc. of 27th Conference, Vol.2, 2014

Technologies

Simulation example

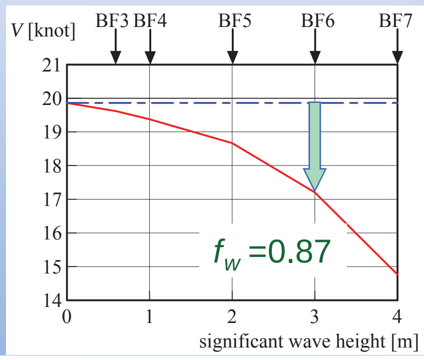
Container ship

L	300	m
B	40	m
d	14	m
75%MCR	44,650	kW



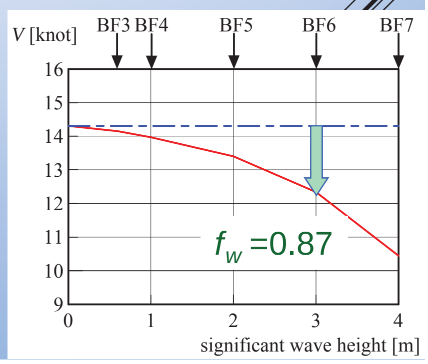
PCC

L	190	m
B	32.26	m
d	9	m
75%MCR	11,940	kW



Bulk carrier

L	217	m
B	32.26	m
d	14	m
75%MCR	6,800	kW



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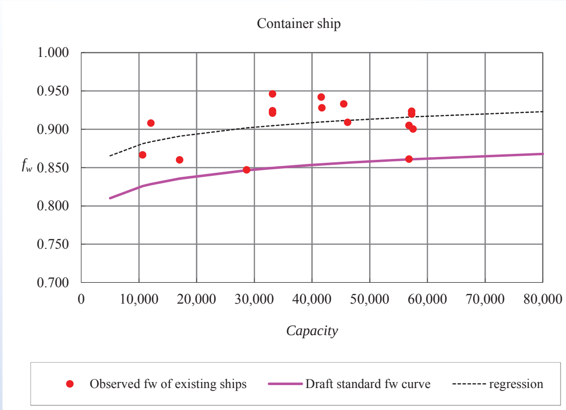
Standard f_w curves

The standard curves are created by analyzing the operational data (abstract log data) of about 180 existing vessels.

e.g. Container ship



$$f_w = 0.0208 \cdot \ln(Capacity) + 0.633$$

☆ Working the incentive for f_w simulation and from the viewpoint of navigation safety, the standard curves should prevent calculating a greater value than the truth.

➡ The curves are passing through the lower limit value of the data

Survey & Certification

Kitanihon Shipbuilding Co., Ltd. and NMRI worked on the certification of EEDIweather

Press release (July 2014)

The World's first certification of EEDIweather is received from class NK.
The Chemical tanker of 19,000 DWT was delivered.

EEDIweather is certified for 19,000 DWT Chmical tanker and 35,000 DWT Chemical tanker.

Chemical tanker of 19,000 DWT 'CHEM HOUSTON' (L=145m)

Tank test for certification of f_w

Survey & Certification

Certification process

When a calculated f_w is used, the attained EEDI using calculated f_w is to be presented as attained EEDIweather.

$$EEDI_{weather} = EEDI / f_w$$

← f_w is determined at the preliminary certification stage.

Preliminary certification — After performing tank test

- Certification is issued by hull number/model number.
- EEDI of the preliminary certified value is used.

Final certification — After performing sea trials

- Certification is issued by name of ship.
- EEDI of the final certified value is used.

f_w tank test results can be used to correct wave effect at sea trial.

Summary & Conclusions

Concept of f_w guidelines is to promote GHG reduction in actual sea conditions.

- The guidelines for this purpose have been developed and the certification of EEDIweather has started.
- The calculation method in the guidelines is confirmed validity through tank tests, onboard measurements and ITTC study.
- The effect of bow shape, including special bow shape, can be evaluated by the hybrid method on added resistance in waves.
- The hybrid method can be applied to estimate performance in actual seas at design stage using the empirical chart (C_U-B_f).

NMRI


Thank you for your attentions.