The Specialist Committee on Ships in Operation at Sea-SOS 2017-2021

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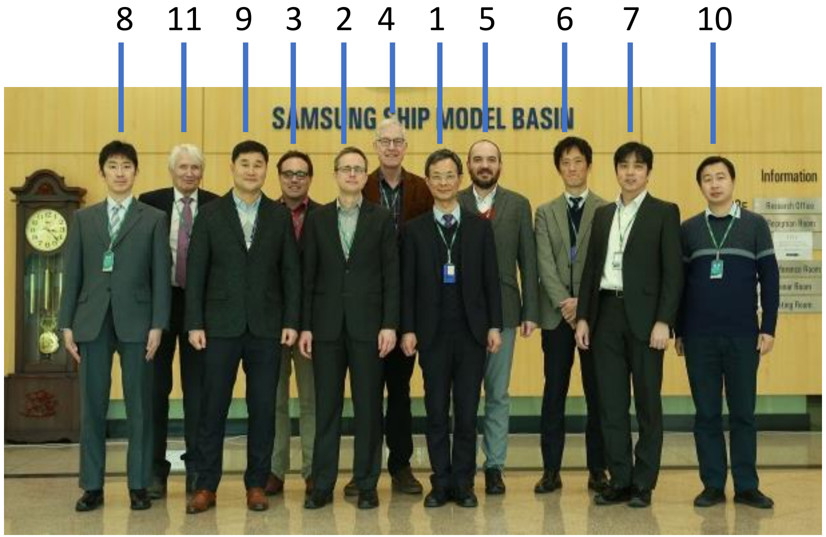
9-Se-Myun Oh, SHI, South Korea
10-Gongzheng Xin, CSSRC, China

Observer:
11-Prof. Gerhard Strasser



Introduction- Meetings

- Four Committee meetings were held.

  - 17-19, Jan, 2018 CTO, Poland. All members except Henk van den Boom from MARIN attended.
  - 10-12, Sep, 2018, Mitsui, Japan. All members except Gongzheng Xin from CSSRC attended.
  - 08-10, May, 2019, HSVA, Germany. All members attended.
  - 15-17, Jan, 2020, Samsung Ship Model Basin, Daejeon, South Korea, All members attended.

  - The AC representative to IMO Prof. Gerhard Strasser attended all the four meetings in order to keep close eye on the progress of the speed/power trial procedure, C_A guideline and provide feedback from IMO/MEPC meetings.

Contact with ITTC committees

◆Contact CFD/EFD committee

- CFD/EFD committee chair Sofia Werner recommended Prof. Takanori Hino, to attend SOS meeting and provided valuable guidance on how to proceed CFD related issues.
- SOS refers to Guideline 7.5-03-01-02 “Quality Assurance in Ship CFD Application” when developing “Guideline on CFD based determination of wind resistance coefficients”.

◆Contact other committees

- SOS committee has Contacted R&P committee regarding Load Variation Coefficient example.
- Contact to Prof. Hironori Yasukawa from Manoeuvring in waves committee regarding combined current correction method.
- Contact Quality Systems Group to obtain instruction on Uncertainty Analysis matters.

Joint meeting with CFD/EFD and R&P committee

◆On a new method to predict delivered power using CFD/EFD combination.

- The method obtained form factor from CFD while other data from model test.
- Model tests were carried out intensively in MARIC towing tank according to ITTC procedure.
- Delivered power prediction using this method agrees well with sea-trial results on two typical series of sister ships-208k bulk carrier and 20k container ship. It shows that the combination of CFD/EFD method is practical and feasible.
- CFD/EFD and R&P committee chair agree to refer paper (by Jinbao Wang et al), in their final reports to full conference.

IMO issues from AC chairman

- Major outcome/comments from IMO MEPC 71 meeting.
  - IMO has received submission from ITTC with overview on all procedures that have changed after the 28th ITTC
  - Either Raven method should be improved with sufficient validation, or a new method should be proposed

- Major outcome/comments from IMO MEPC 72-73 meeting
  - China has submitted a proposal on Evaluation of ISO15016_2015 MEPC 72-INF.15
  - Submission by ITTC on sea-trial procedure(7.5-04-01-01:2017) proposed to MEPC73 (MEPC 73/5/7) was accepted by the meeting
  - IACS 2014 industry guidelines shall be updated to reflect the new ITTC sea trial procedure

IMO issues from AC chairman

◆Major outcome/comments from IMO MEPC 74 meeting

- Amendments to MARPOL Annex VI adopted
- Discussions on introduction of EEDI phase 3 and early implementation for container ships as they are far below the current baseline. Without data, the reduction rate cannot be adjusted for container vessels
- Intense discussion on alternative fuels and main focus on new fuels, marine plastic litter
- Some people raised questions about Raven-method unofficially

◆Comments from AC

- Sea trial procedure（2017 version） was highly appreciated by AC – gained much maturity.
- ITTC shall have a representative in ISO committee on 15016 sea trial procedures to coordinate
- All modification to guidelines shall be done in word using tracking mode; track-changes version shall be submitted together with clean version; modified guideline to be sent to QSG Chairman.

Terms of Reference- After Coordination with AC

1. Address the following aspects of the analysis of speed/power sea trial results

(1) Shallow-water correction

- Formulate, validate and recommend a single method for correcting speed/power sea trial measurements for shallow water effects based on first principles, using full scale and model scale tests and CFD analyses of a suitable range of vessel designs and sizes, water depths and ship speeds.

(This task is considered the highest priority for the specialist committee and shall be commenced immediately. If possible, the procedure 7.5-04-01-01.1 shall be updated to in-corporate the new procedure. If this is not possible, the specialist committee shall liaise with the Advisory Council on which action to take).

(2) Wave correction

- More extensive validation of the present wave correction methods and expand range of application, introduce other methods where necessary.
- Monitoring the development of CFD methods for added resistance due to waves

Terms of reference-TOR

(3) Wind correction

- Guidance on the location and height of the anemometer and whether a dedicated anemometer is necessary
- Investigate limitations of averaging wind correction method and suggest improvements
- Establish guideline for CFD to get wind coefficient.
- Extend wind coefficient database for more ships.
- Initiate and conduct benchmark study for evaluation of CFD applicability to determine the wind resistance coefficients.

(4) Current correction

- Further validation on the present cur-rent correction methods.
- To find the possibility of using long track on 2 double runs.

Terms of reference-TOR

(5) Comprehensive correction

- Further validation on Extended-Power-Method
- More investigation on existing methods for the speed/power sea trial analysis

(6) Study and validate model-ship correlation factors at different drafts when possible.

(7) Provide a practical guidance for installation of measuring equipment on a propeller shaft with regard to the shaft material properties (e.g. G modulus), shaft geometry and alignment.

(8) Other

- Water temperature and density influence on ship's performance
- Noise in the measured data during the ship performance assessment and identify the method for filtering it.
- Measurement error and influence on power

2. Update the speed/power sea trial procedures 7.5-04-01-01.1 where appropriate.
3. Update guideline to determine model-ship correlation factors at different draft.

Terms of reference-TOR

4. Explore 'ship in service' issues, to get feedback to towing tanks with respect to:

① Key performance indicators identifying and establishing performance baseline when appropriate.

② More accurate measurement of environmental data, including wind, waves, current, etc, and comparison with forecast data when available.

③ Speed-Power related info monitoring, including fuel consumption, shaft torque, speed, draught, trim and rudder angle etc.

④ On board recording.

⑤ To find possibilities to analyze ship performance, including speed-power relation, decrease of ship speed, etc. on a single run.

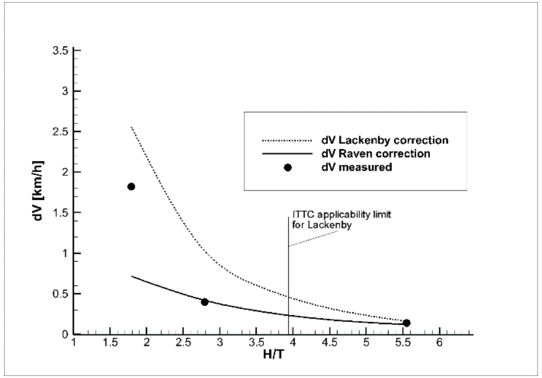
⑥ The applicability of unmanned (flying, floating or underwater...) vehicles and devices.

5. Monitor the new information and communication (ICT) technologies applied on board ships to collect and process data as well as ship control systems, and identify their influence on ship performance prediction.

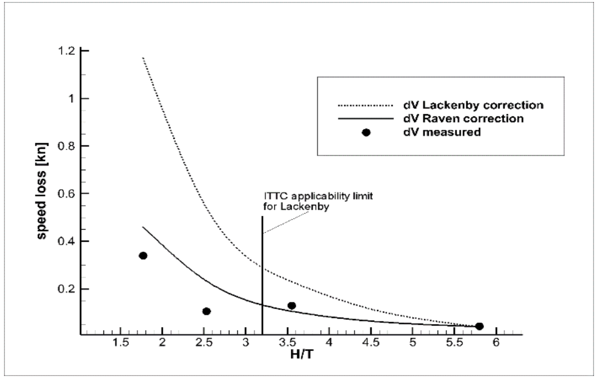
SHALLOW WATER CORRECTION

Methods in ITTC 2017:

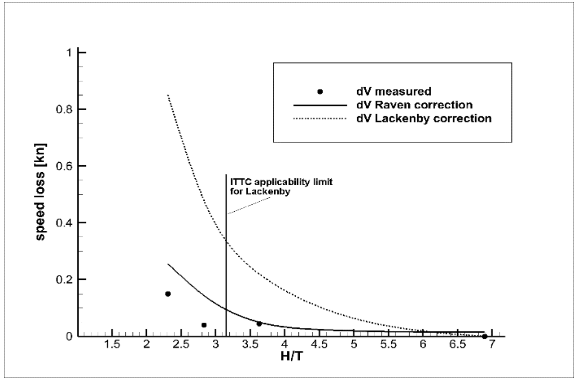
1. Lackenby- used for trial corrections since 1965
2. Raven- developed for ITTC 2017



Inland tanker



Hopper dredger

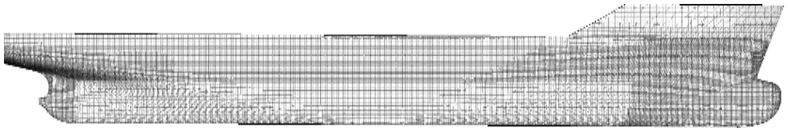


Research vessel

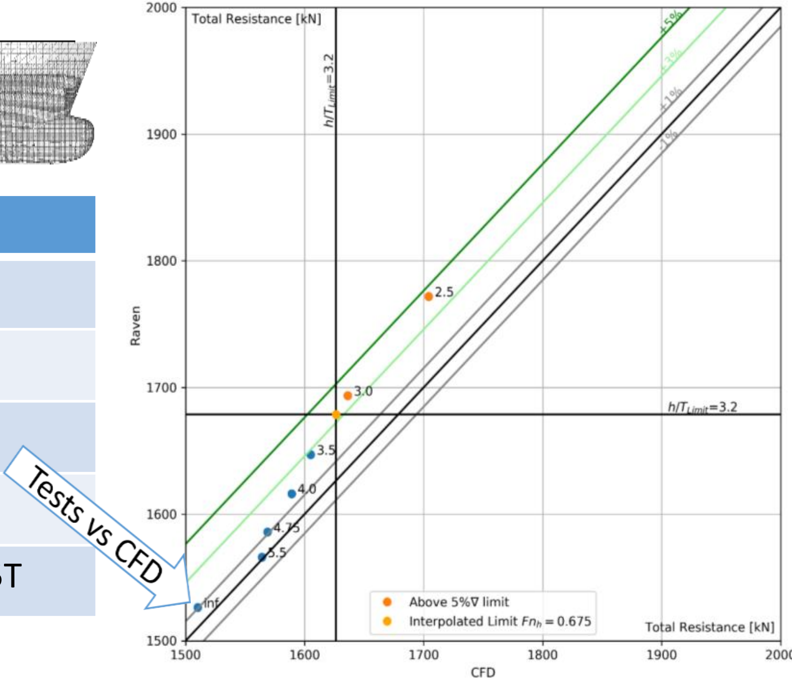
Work conducted

- CFD analysis were conducted for KCS
- Model tests in shallow and deep water corrected with Raven
- Waterdepth limits for Raven

CFD analysis for KCS

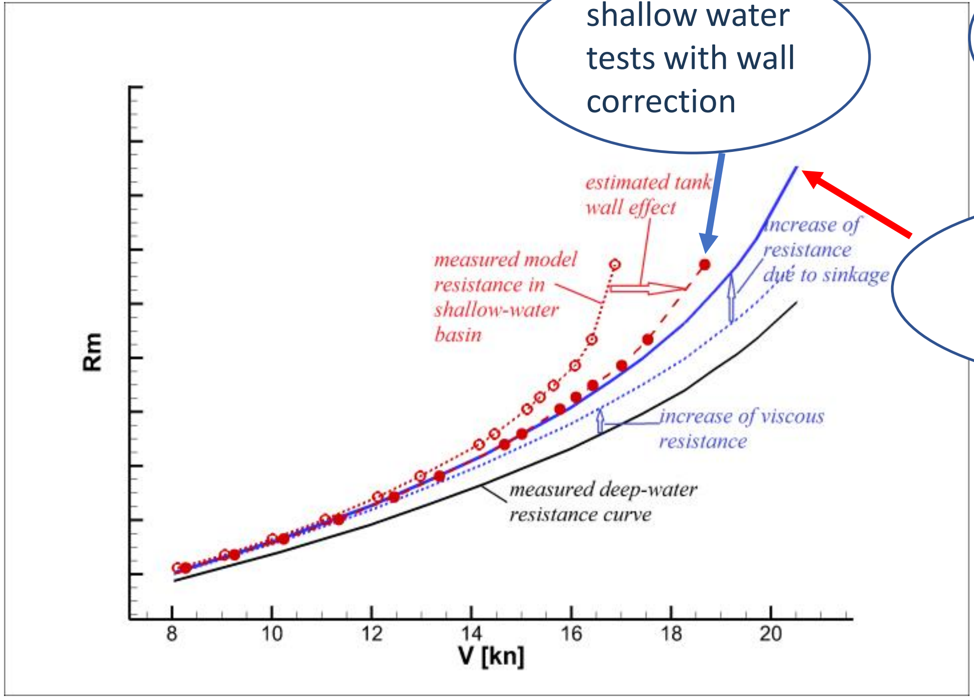


CFD computation domain size (half hull)		
Inlet	Upstream to the hull	2L
Outlet	Downstream to the hull	3L 30B
Side	Domain width	3L
Top	Height to the keel	1L
Bottom	Water surface to ground	2.5T÷5.5T



- The difference of Raven corrected resistance vs CFD resistance does not exceed 3% below $Fr_h = 0.675$
- Sinkage estimation has influence on this difference

Model tests results corrected with Raven



shallow water tests with wall correction

Agree with each other well Until 18kn

Model test in deep water corrected to shallow water

Conclusions Shallow Water Correction

- Raven provides more consistent and accurate correlation
- Lackenby is removed from the Procedure
- Raven method is accepted as the single method for shallow water correction in S/P trials
- New water depth limits have been set

Main Improvements of shallow water correction method -comparing with 2017

Item	ITTC2017 version	ITTC2021 version
Correction method	Lackenby、 Raven	Only Raven method retained, and only resistance corrected
Lower limit	$h=\max(2\sqrt{BT},\ 2\frac{{V_S}^2}{g})$	$h=\max(2.5\mathrm{T},\ 2.4\frac{{\mathrm{V_S}}^2}{\mathrm{g}})$
Upper limit	$h=\max(3\sqrt{BT},\ 2.75\frac{{V_S}^2}{g})$	Cancelled to keep continuity of water depth correction

New Wave Correction method- development & validation

◆ **Rwave exists outside 45° from heading， can't be ignored!**

An example of a large containership from model test

➢ At ballast
- 60° , remarkable Rwave observed
- Even 135° , still over 2% Rwave exists

➢ At full load
- Almost the same situation as ballast

Ballast		
Vs(kn)	Angle	Ratio of Rwave/Rcalm
23.5	60°	5.4%
	135°	2.3%
	Average	3.9%

Full load		
Vs(kn)	Angle	Ratio of Rwave/Rcalm
22.5	45°	6.2%
	135°	2.5%
	Average	4.4%

Wave Correction-background

- **When will wave angle be larger than 45° ?**

➢ While Iterative method is often used, the heading should be kept unchanged. For large ships as VLCC/VLOC/Container, **1+2+1** double runs could last about **10 hours** and the wave direction is very likely to change over 45° during this period. Even 2 double runs could encounter the same problem.

➢ Angle between Wind & wave/swell are over 45° , the wind is strong.

➢ Both wind wave & swell have to be considered, and angle between is over 45° ……

- **In-force empirical method can't deal with above situation when line is NOT available. Necessary to develop new method**

Development of the SNNM Method

- The first stage of development was conducted within the EU-FP7 SHOPERA research project (2013-2016) coordinated by Prof. A. Papanikolaou, NTUA-SDL/Athens that has longstanding expertise in seakeeping and drift/nonlinear motion and force predictions (since 1980).

- It was further developed and validated at NTU/Singapore by Dr. S. Liu during 2017-2020.

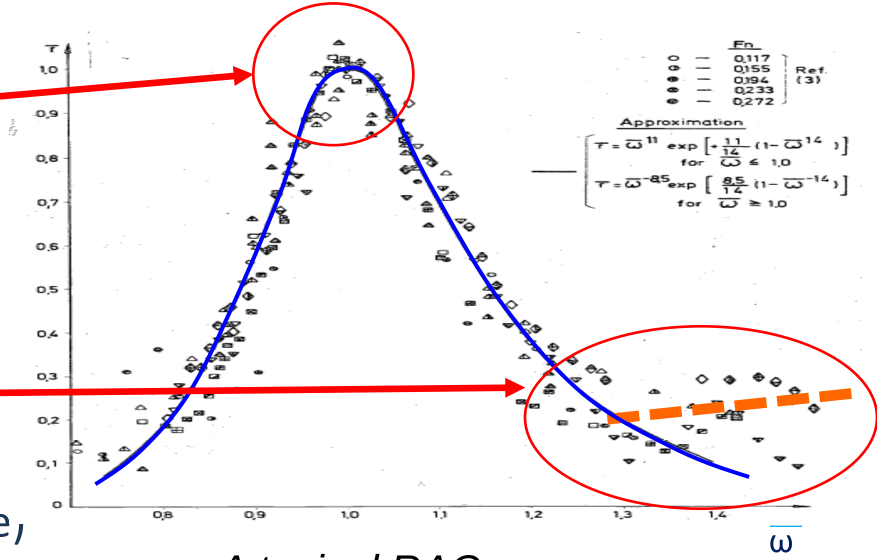
- MARIC noticed the technical progress at an early stage and supported its development and validation through a joint project (2016-2018).

- The SNNM method has attracted much attention of both academia and industry, and is widely cited/used, due to its wide applicability in practice.

Concept of the SNNM Formula

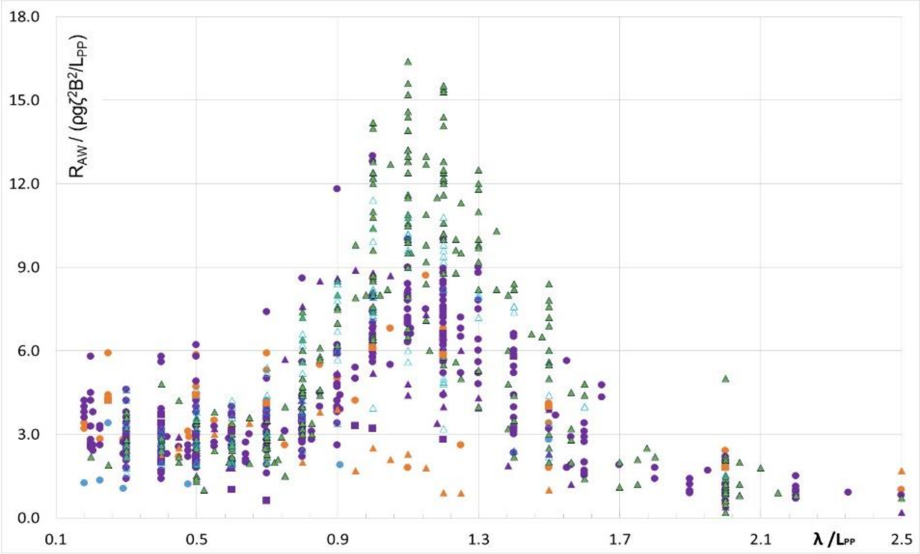
- $\mathbf{R_{AW}} = \mathbf{R_{AW,\,R}}$ (Faltinsen et al., 1980) + $\mathbf{R_{AW,\,M}}$ (Jinkine & Ferdinande, 1974)

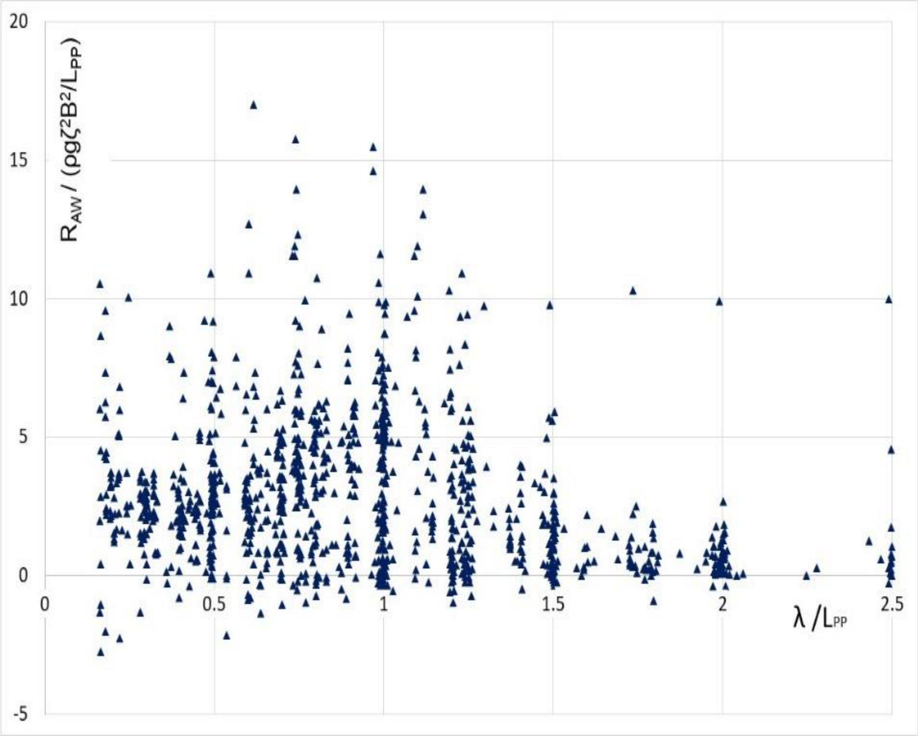
- **Improvements**
  - Motion/Radiation effect, includes
    - Hull form effect (B/T)
    - Speed effect
    - Wave heading
  - Diffraction/Reflection effect, includes
    - Partial reflection & finite draft effect
    - Hull form effect (L_E, L_R, trim&draft, flare,
    - Simplification



A typical RAO

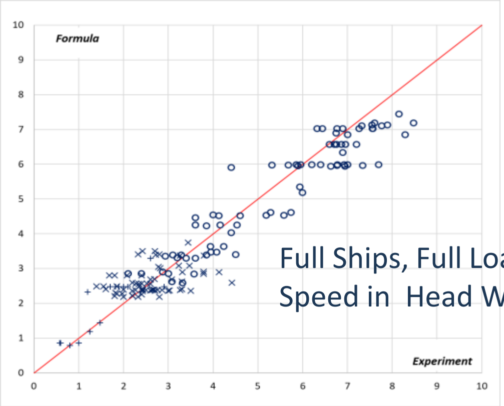
Experimental Database for development & self-validation



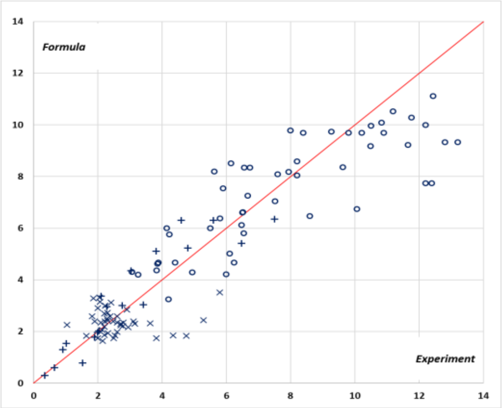


Experimental data of added resistance of about 130 ships at different draft/speed in regular head (left) and quartering (right) waves (abt. 3,000 data points)

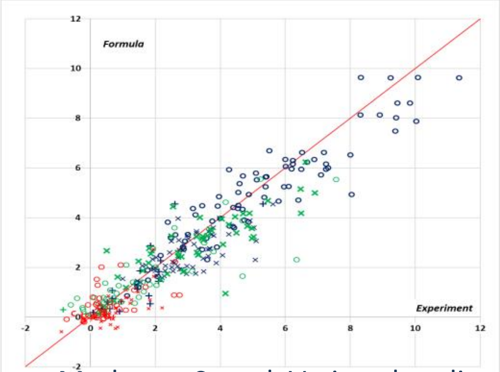
Self Validation: Correlation in Regular waves



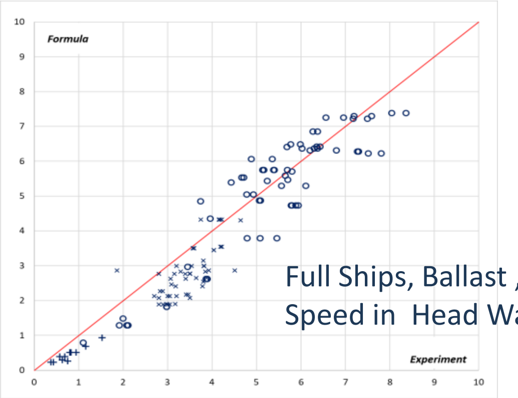
Full Ships, Full Load, Design Speed in Head Waves



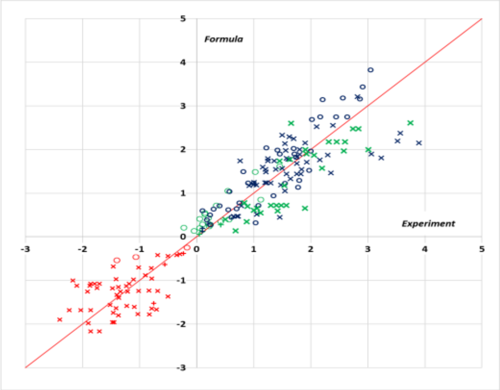
Fine Ships, Full Load, Moderate Speed in Head Waves



Moderate Speed, Various headings



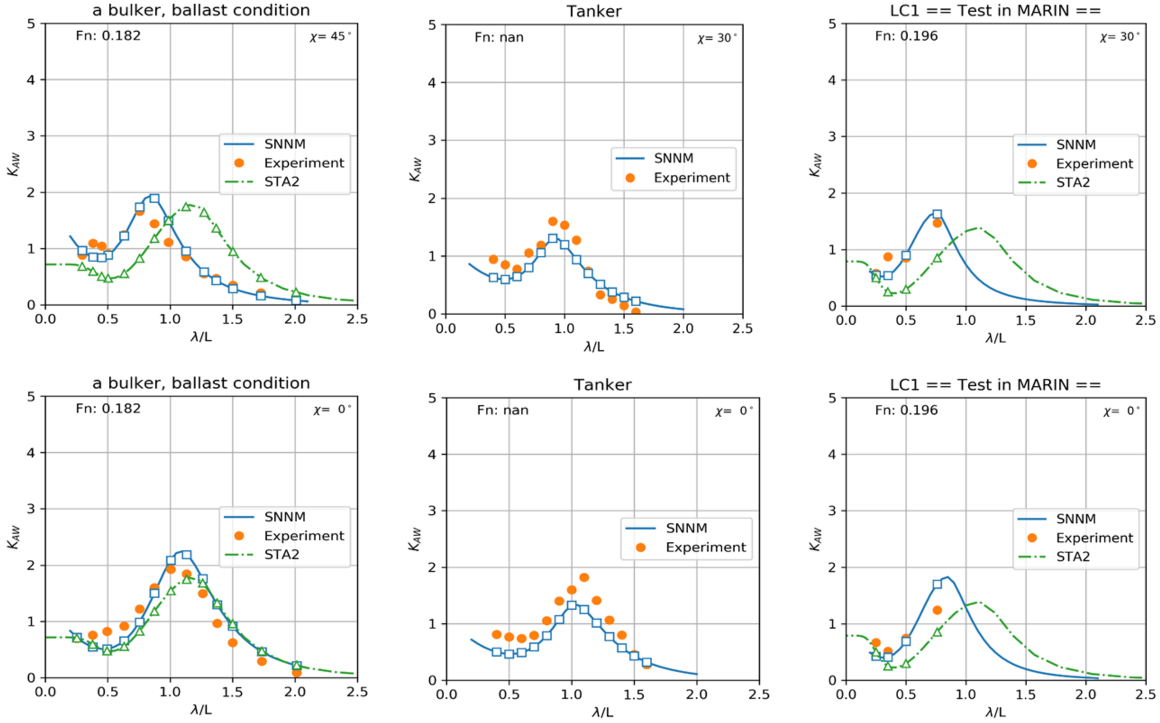
Full Ships, Ballast ,Design Speed in Head Waves



Low Speed, Various headings

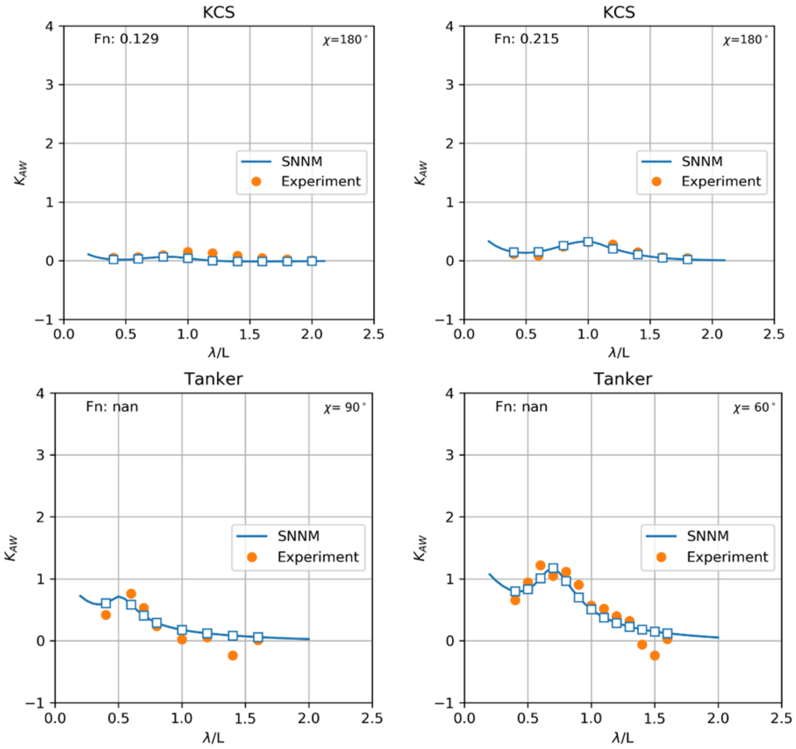
Open validation in SOS-Bulker/Tanker/Container

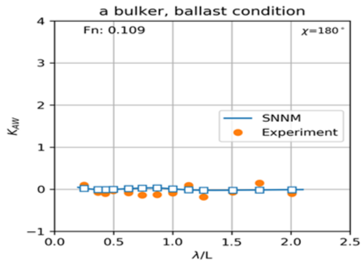
- [0, 45°] **Agree** with model test, **slight under-estimation** in short waves

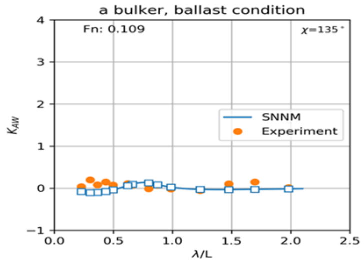


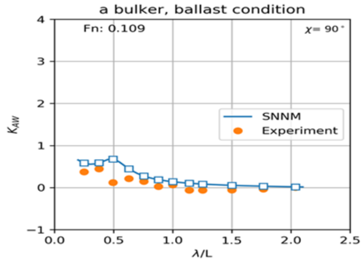
Open validation in SOS- Bulk/Tanker/Container

- [45°, 180°] - Agree well with model test



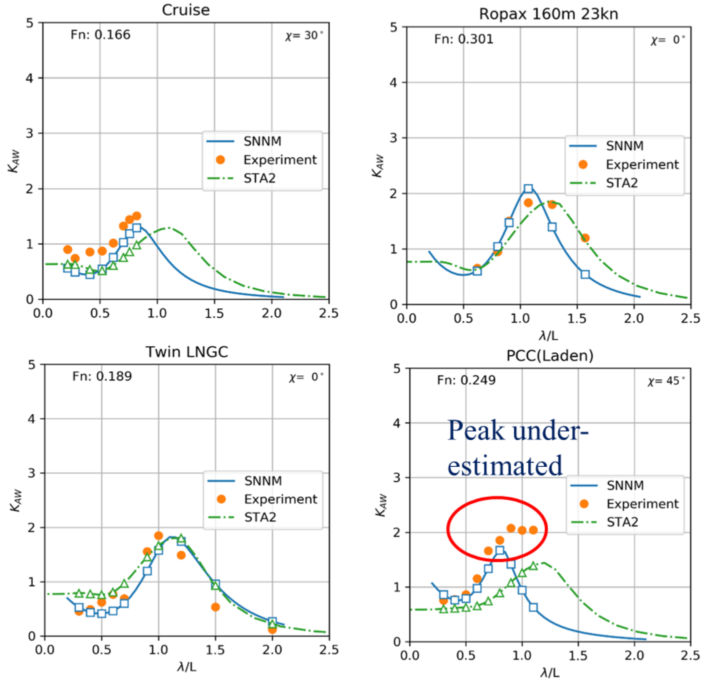


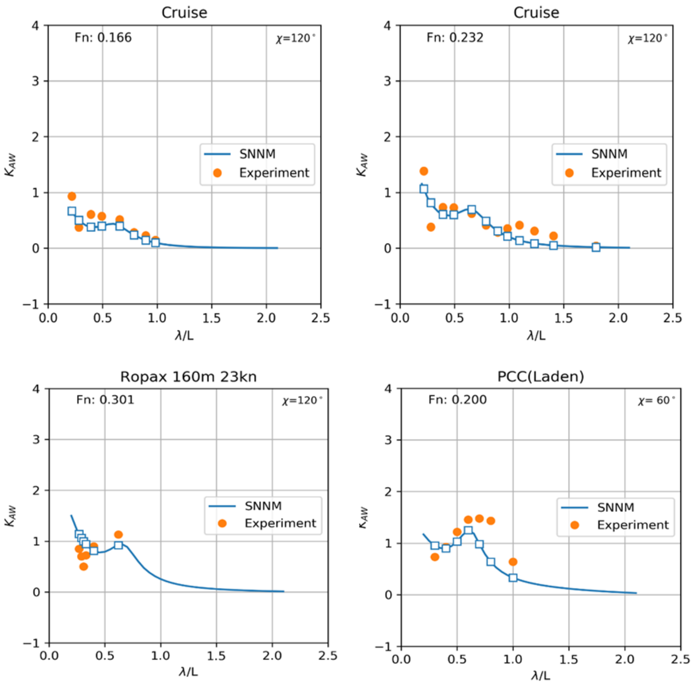




Open validation in SOS- Cruise/Ropax/LNGC/PCC

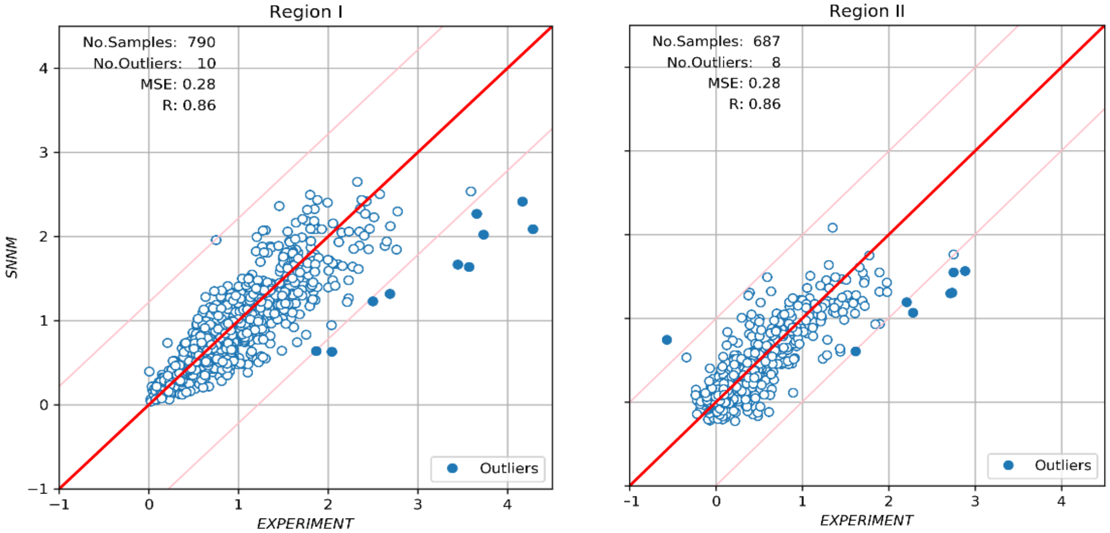
- [0,45°]– Generally Agree well with model test
- [45° ,180°] – Acceptable





Open validation in SOS

Region	Points	$R_{attained}$	R_{agreed}
I= [0°, 45°]	790	**0.86**	0.78
II= (45°, 180°]	687	**0.86**	0.70



- Attained R is **better** than agreed ones

Summary and Conclusions

- Wave-added resistance can't be ignored in the range of (45^o,180^o] and in-force empirical method can't deal with this situation **when line is NOT available**.
- A large experimental database has been established to support SNNM development. The formula uses simple inputs and can deal with various ship types ,drafts and wave conditions.
- 1477 points for 29 ships has been contributed from 8 members in SOS with balanced ship types and wave directions. Attained correlation coefficient R of SNNM are **0.86 in both regions**, higher than agreed criterion. Voluntary validation has demonstrated that error distribution is within acceptable limit.
- Further **detailed RAO**s comparison on each ship type demonstrated that, the SNNM results generally agree with model test, thus make the present sea-trial procedure more competent and valuable.

Monitoring the development of CFD methods for wave-added resistance

◆ Purpose

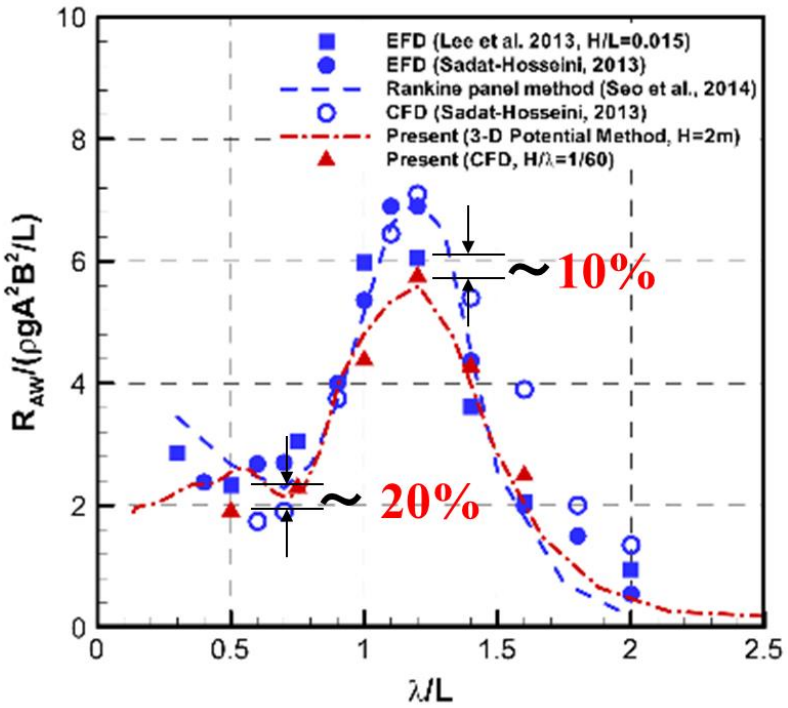
- Review of the state of the art of CFD for the prediction of added resistance and related flow properties in waves.
- In particular, to assess differences between CFD and Model-Test results.
- Raise challenges: Application of CFD to determine added resistance in waves for the accurate correction of speed trial results.

Summary of examined CFD cases

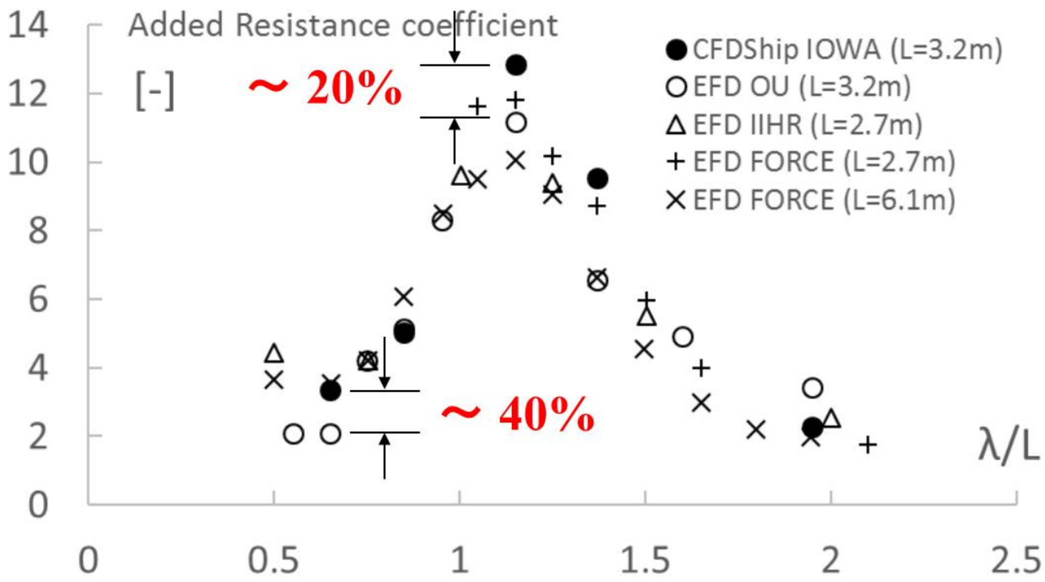
Form	Type	Code		Wave Dir.	
S175	Container (750TEU)	**STAR-CCM+** **SURF (NMRI)**	1 1	Head	2
KCS	Container (3500TEU)	**CFDShip-Iowa** **STAR-CCM+** **NAGISA (NMRI)** **naoe-FOAM-SJTU** **In-house code**	3 1 1 1 1	Head	7
DTC	Container (14000TEU)	**naoe-FOAM-SJTU**	1	Head	1
KVLCC2	Oil Tanker (VLCC)	**STAR-CCM+** **WAVIS (KRISO)** **Naval Hydro Pack** **Ship-Motion** **In-house code (PNU)**	2 1 1 1 1	Head	6
Others	Private forms	**STAR-CCM+** **SNU-MHL-CFD** **NAGISA (NMRI)** **In-house code (Univ. Tokyo)**	3 1 1 2	Head Head ~ Beam	5 2

Example of CFD comparison cases

KVLCC2 (Head wave)



KCS (Head wave)



Experimental data available for comparison with CFD in waves of all headings

Form	Type	Year	Wave Dir	Speed	Model Basin
S175	Container (750TEU)	c.1975	180°(head) ~ 0° (30°interval)	Vs=12,20kt	MHI Nagasaki (L = 4.0m)
KCS	Container (3500TEU)	c.2010	180°(head) ~ 0° (45°interval)	Vs=24kt.	IIHR (L = 2.7m)
DTC	Container (14000TEU)	c.2015	180°(head) ~ 0° (30°interval)	Vs= 6kt.	MARINTEK (L = 5.58m)

! Open model test data other than head waves is not enough for CFD to compare

Summary (1, Difference CFD / Model Tests)

- 10% ∼ 40% in shorter waves (∼ $\lambda/L=0.5$).
- 5% ∼ 20% around peak (∼ $\lambda/L=1.0$)
- Absolute differences of non-dimensionized added resistance are of similar magnitude for both shorter & longer wave cases.

Summary (2, Model-test data for evaluation)

- Only a few Model-test data (S175, KSC, DTC) are available for evaluating CFD prediction capability in waves of all headings.
- Search and establish of high-fidelity model test data of a variety of hull forms and from multiple facilities are indispensable for the examination of applicability of CFD predictions to the wave correction in speed-trial analysis.

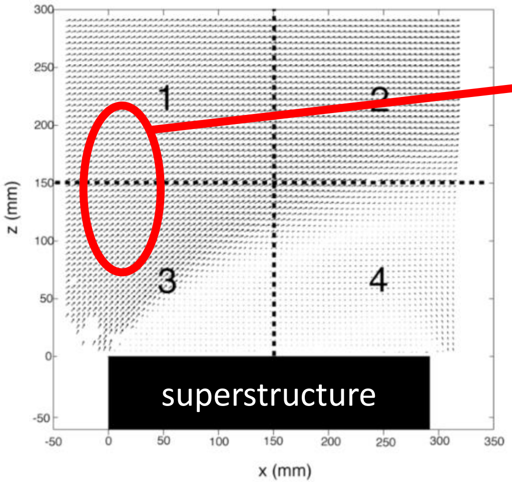
Guidelines on the position of the anemometer

- Ideally should measure undisturbed wind field
  - Deploy buoy measurement Seems to improve vs shipboard
  - Investigate and adopt LIDAR technology common to offshore wind industry for undisturbed wind measurements
- Corrections for vertical height differences from buoy or hindcast data with standard wind profiles is source of uncertainty
- Wind tunnel and CFD analysis can be used to guide anemometer location

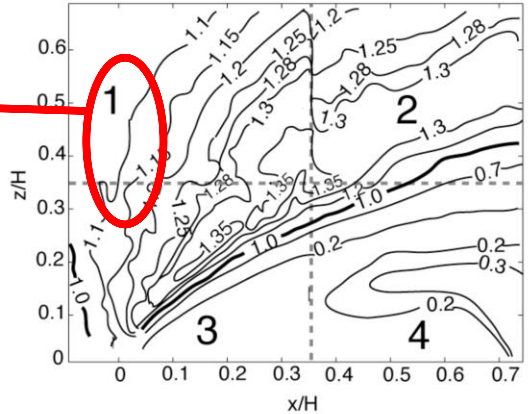
Guidelines on the location and height of the anemometer

➤ Guidance for anemometer location based on combination of wind tunnel and CFD analysis

Onset flow



Preferred anemometer location



Wind tunnel measurements (PIV)

Guidelines on the location and height of the anemometer

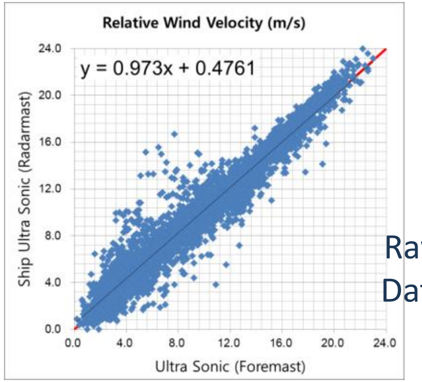
- High as can above decks (ideally foremast)
- High as can above front edge of bridge
- Over 3x mast diameter from masts
- Sonic anemometers are preferable
- Expected bias table (wind +-30° bow)

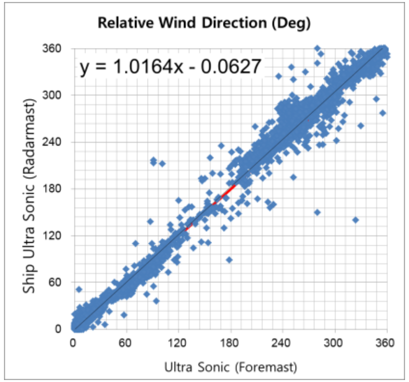
Height, z/H	Distance from front edge of bridge, x/H								
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
0.003	−20	**−76**	**−93**	**−94**	**−91**	**−89**	**−87**	**−86**	**−86**
0.1	4	−5	−34	−58	−72	−80	−85	−89	−93
0.2	3	8	8	4	−4	−15	−27	−38	−47
0.3	4	7	9	10	10	9	7	4	0
0.4	4	6	9	10	11	*11*	11	10	9
0.5	4	5	7	9	10	*11*	11	11	11
0.6	3	5	6	8	*9*	*10*	*10*	*10*	10
0.7	3	4	6	7	8	*8*	9	9	9
0.8	3	4	5	6	7	*7*	8	8	8
0.9	3	4	4	5	6	6	7	7	7
1.0	3	3	4	5	5	6	6	7	7
1.2	2	3	3	4	4	5	5	5	5
1.6	2	2	2	3	3	3	4	4	4
2.0	2	2	2	2	2	3	3	3	3
2.4	1	1	2	2	2	2	2	2	2

Limitations Of Averaging Wind Correction Method

- Case study : The characteristics of wind speed, direction and the influence of the measurement locations have been investigated
  - LNG carrier: 1 Case,
  - Tankers: 2 Case,
  - Large container: 1 Case
  - Ultrasonic anemometer installed on radar mast and foremast

Comparison of Meter Location and Filtering Process



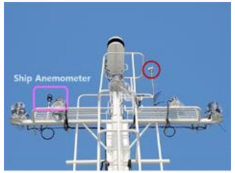


Raw Data

- #1 Ventmast -
(40.1m from Trial Condition)

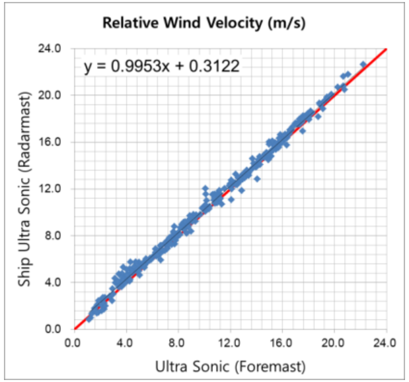
- Data Filtering -

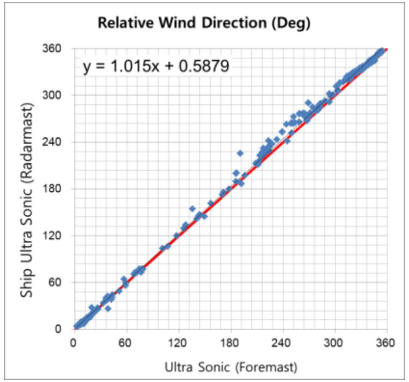
Rate of turn > 5 (deg / min)
Ship Speed < 5.0kts



- Radarmast -
(47.8m from Trial Condition)

Filtered Data





- **After filtering, the results shows influence of anemometer position seems not significant**

Difference of Wind by Averaging Process: Data from Buoy and Ship

	Difference of True Wind Velocity			Difference of True Wind Direction	
	> ±0.5 m/s	> ±1 m/s	> ±2 m/s	> ±20 deg	> ±40 deg
Geoje Buoy	**31%**	**10%**	**4%** (Max. 3.4)	**7%**	**4% (Max. 179)**
Ship - Radarmast -	78%	56%	19% (Max. 6.6)	20%	9% (Max. 139)
Ultra Sonic - Radarmast -	60%	**39%**	15% (Max. 5.5)	23%	12% (Max. 148)
Ultra Sonic - Foremast -	64%	**37%**	13% (Max. 6.2)	23%	11% (Max. 138)

- True wind speed over 1m/s difference between w/wo averaging process

- Buoy: More than 10% On board meter: More than 30%

More cases study

Based on ISO15016;2015		Relative Wind Direction (Deg)	Relative Wind Velocity (m/s)	Speed Difference (kts)	
				Anemometer Position	Vector Avg. – Each Run Value
180K LNGC	Ship: Radarmast	Base	Base	**Base**	**-0.14**
	Ultra Sonic : Radarmast	5.60	1.42↓	**0.01↓**	**-0.07**
	Ultra Sonic : Foremast	1.01	2.80↓	**0.03↓**	**-0.02**
115K COT 1st	Ship: Radarmast	Base	Base	**Base**	**-0.07**
	Ultra Sonic : Radarmast	1.22	0.93↓	**0.02↓**	**-0.03**
	Ultra Sonic : Foremast	0.72	0.66↓	**0.02↓**	**-0.05**
115K COT 2nd	Ship: Radarmast	Base	Base	**Base**	**-0.07**
	Ultra Sonic : Radarmast	0.20	0.77↓	**0.03↓**	**-0.04**
	Ultra Sonic : Foremast	2.20	0.92↓	**0.02↓**	**-0.04**
20,000TEU 2nd	Ship: Radarmast	Base	Base	**Base**	**-0.04**
	Ultra Sonic : Radarmast	8.17	0.85↑	**0.04↑**	**-0.04**
	Ultra Sonic : Foremast	6.81	0.95↑	**0.06↑**	**-0.04**

- Influence of meter position：

  Ultra Sonic-ship based meter=

  - Container: about +0.05kn
  - Other ships: about -0.02kn

- Effect of wind averaging process

  - around -0.02~-0.07kn

Limitations Of Averaging Wind Correction Method

- When wind speed is close to the design speed, and the angle between ship direction and wind direction is small, then the relative wind speed approaches zero in tailwind, which is not easy to measure accurately. This will influence the averaging accuracy over double run.
- When wind speed reaches BF5, ranging from 17-21kn, for those ships such as Oil tank, Bulk carriers, some Gas carriers, 'real' tailwind will occur, in these cases, averaging method tends to underpredict the ship speed.
- When wind speed reaches BF6, ranging from 22-27kn, for almost all commercial vessels, including container ships, averaging method tends to underpredict the ship speed.
- When absolute head wind speed is less than tailwind, averaging method tends to predict higher ship speed than without averaging.

Conclusion

- The wind average method over double run remains because of
  - Imperfection of on board wind measurements caused by disturbances of the vessel i.e the wheelhouse
  - Inaccuracies of instruments such as “cup type” anemometers.
- The wind speed correction on single run may be used in case
  - the average true wind speed from two subsequent runs is within 5% or 0.5m/s whichever is larger, or
  - the undisturbed wind speed is measured remotely by a certified instrument accurately.

Establish Guideline For CFD To Get Wind Coefficient

- New Guideline comprises two main topics:

  1.General practices for computational approach

  2.General methods of evaluation CFD based calculations

- Two rounds of improvement on the guideline in SOS

- More detail refers to the Guideline

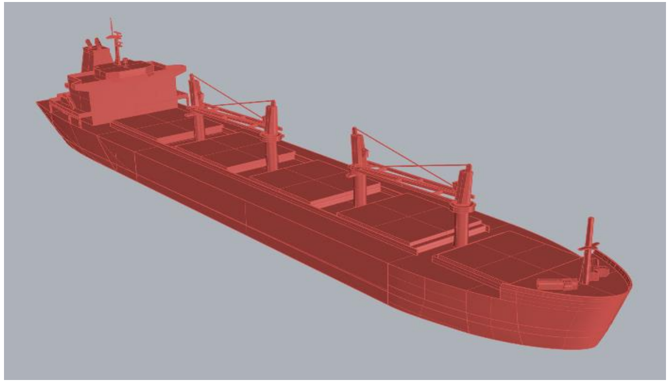
Benchmark Study For CFD To Determine Wind Resistance Coefficients

- 2 selected cases:
  - Handy Size Bulk Carrier (HSBC) – provided by CTO (SOS member)
  - Japan Bulk Carrier (JBC) – provided by NMRI (SOS member)
- 4 participants working on the HSBC
- 7 participants on the JBC case

Study on CFD computations of wind forces

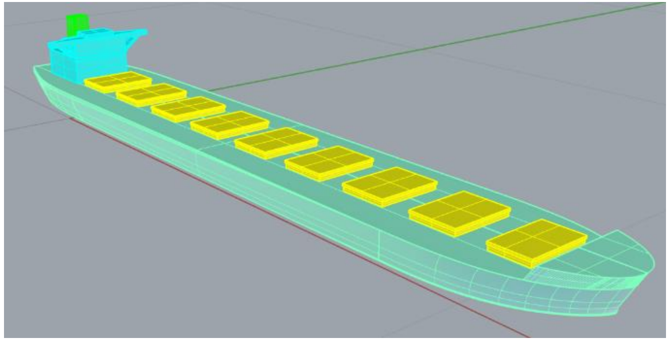
HSBC:

- Free domain size & uniform inlet velocity
- More complex geometry (cranes, realistic superstructure)



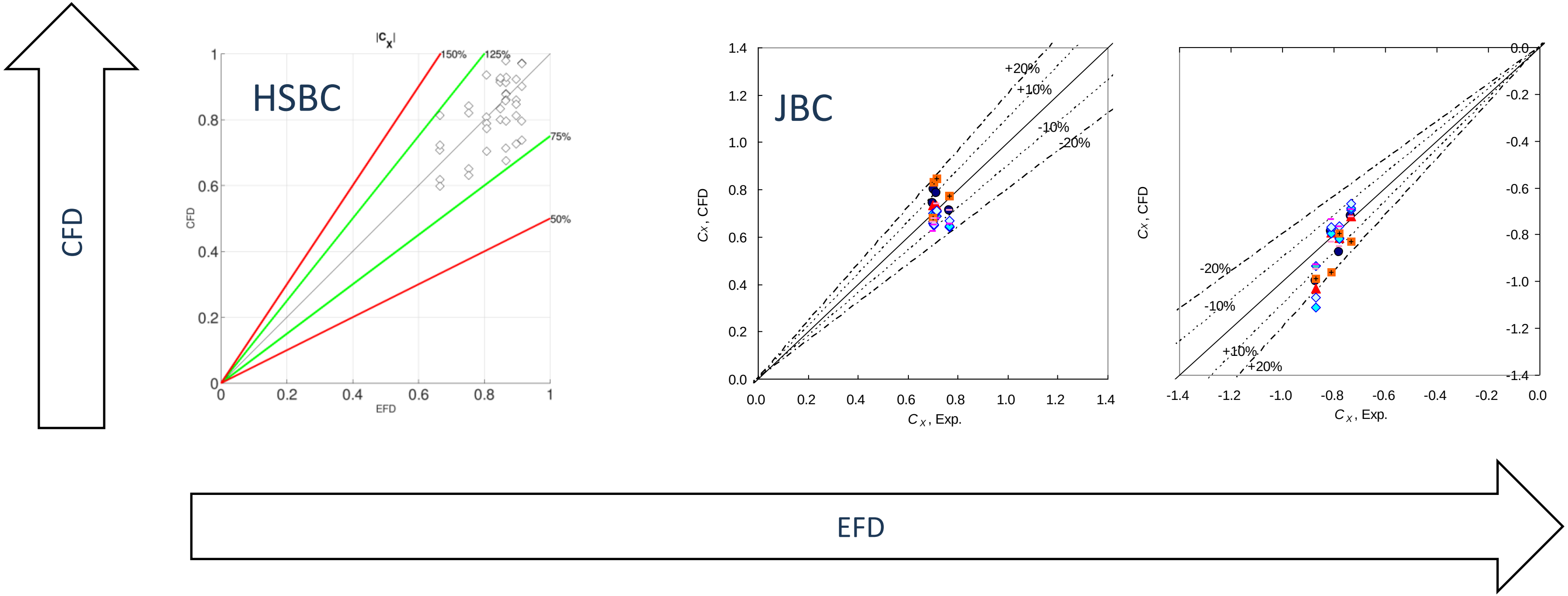
JSBC:

- Domain represents wind tunnel conditions
- Simplified geometry (box shape superstructure, block type segments)

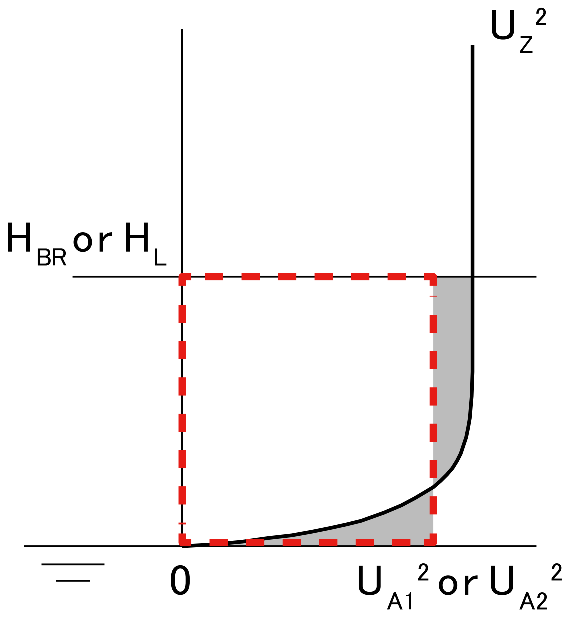


Study on CFD computations of wind forces

Results of CFD vs. Wind Tunnel Tests



Average wind velocities as representative Wind Velocities



$$U_{A1}^{2} = \frac{A_1}{H_{BR}} = \frac{1}{H_{BR}} \int_0^{H_{BR}} U(z)^2 \, dz$$

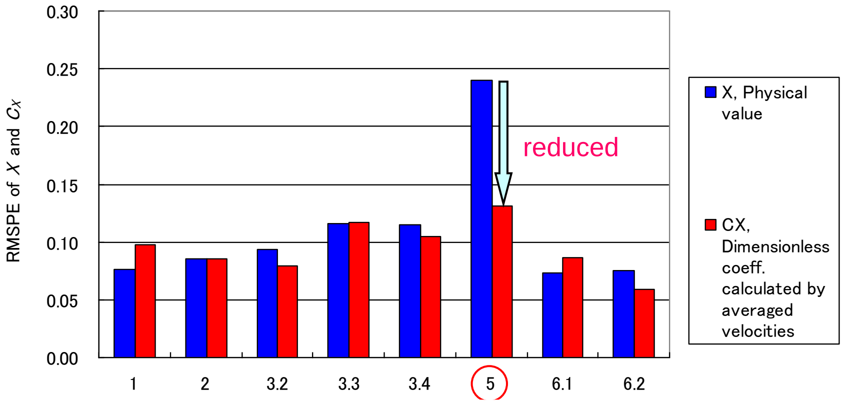
- U_{A1} is used for non-dimensionalization of C_X
- The ranges of integration are from the lower plate to the representative heights.
- H_{BR} is the height between top of the navigation bridge and sea surface.
- U(z) means a vertical distribution of the wind velocity above sea surface.

Study on CFD computations of wind forces

$$RMSPE = \sqrt{\frac{1}{n}\sum_{k=1}^{n}\left(\frac{y(CFD)_i - y(Exp)_i}{y(Exp)_i}\right)^2}$$

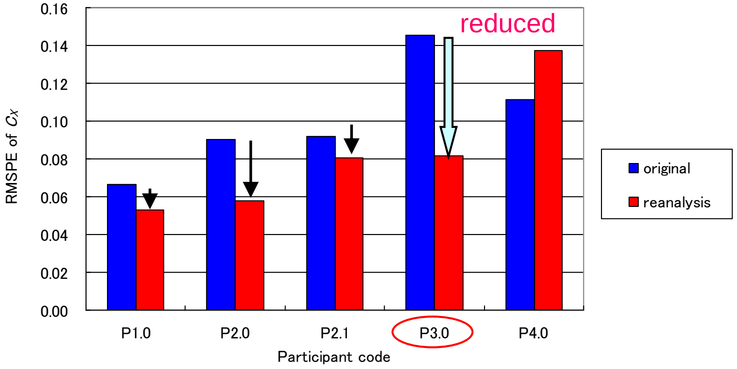
JBC

Participant code	RMSPE		
	X, Physical value	C_X, Dimensionless coeff. calculated by averaged velocities	
1	0.0759	0.0972	Thick boundary flow
2	0.0852	0.0850	Thick boundary flow
3.2	0.0938	0.0794	Thick boundary flow
3.3	0.1158	0.1174	Thick boundary flow
3.4	0.1147	0.1048	Thick boundary flow
5	0.2396	0.1311	Uniform flow
6.1	0.0730	0.0868	Thin boundary flow
6.2	0.0750	0.0592	Thin boundary flow



HSBC

Participant code	RMSPE of C_X		
	original	reanalysis	
P1.0	0.0666	0.0529	uniform flow
P2.0	0.0900	0.0577	uniform flow
P2.1	0.0919	0.0807	uniform flow
P3.0	0.1453	0.0815	boundary flow
P4.0	0.1112	0.1372	uniform flow



RMSPE of Cx remarkably reduced after using the average wind velocity

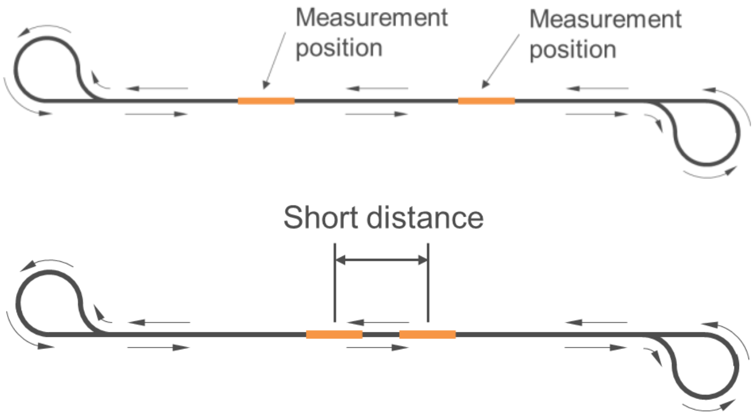
Study on CFD computations of wind forces

Conclusions

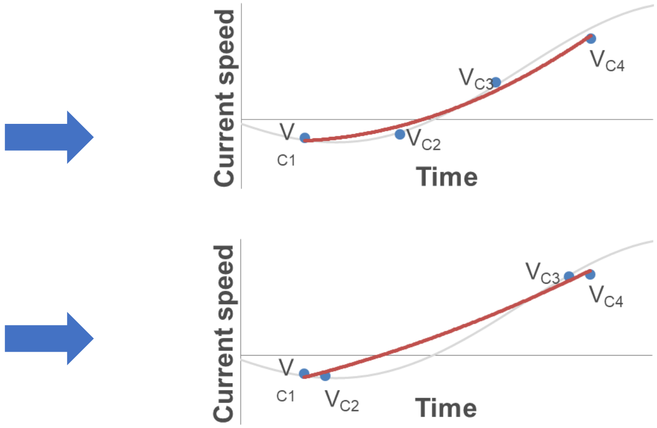
- CFD based normalized wind forces from different participants are mostly within ±20% of the experimental values, quite promising.
- The average wind velocity can contribute to obtain more comparable wind force coefficients not only in CFD but in experiment
- ITTC allows the use of CFD analyses in the wind correction of a Sea Trials Only when the corrected value of the wind force does not exceed 2% of the total power, demonstration is necessary.

Current Correction- possibility to use long track

Sufficient distance should be preserved between adjacent measurement points to generate reliable current curve.



Example of path for long track



Example of current curve

To judge how much distance is sufficient, more investigation is needed.

Requirement regarding the distance between measurement points

Current variation at measurement points should be the same as each other. In general, it is difficult to find such area.

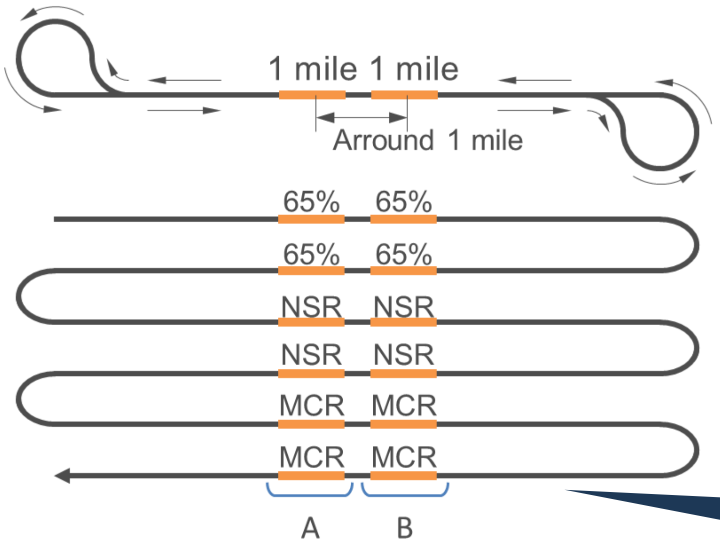
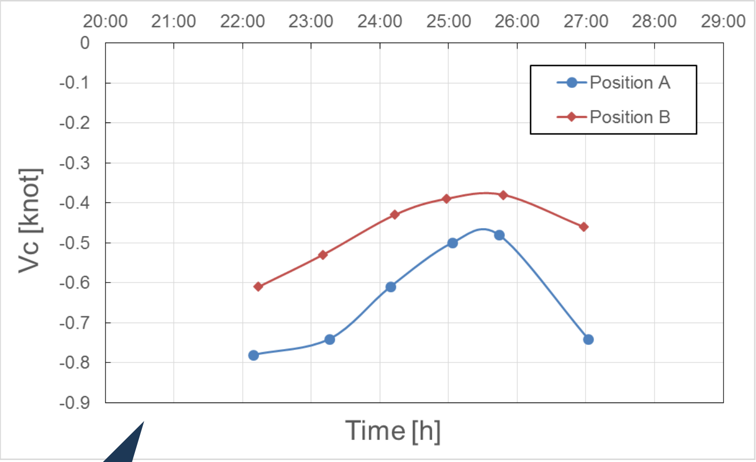


Diagram of an example of procedure of all runs



Two current curves were generated by individually analyzing the actual measurement data at each point where the distance between the two points was just 1 mile.

Regarding allowable deviation of the current variation, more investigation is necessary.

Conclusions

- Adoption of the Long track procedure is premature at this moment.

- More investigation has to be made, for example the required distance between measurement points and the acceptable deviation of current variation between measurement points.

- In addition to the above, even though adopting long track, time can not be saved so much. Long track don’t need to be applied to the trial procedure.

Power Correction- DPM

In the DPM, $\Delta\eta$ and η_{Did} can be eliminated by assuming that η_{D} vary linearly with the added resistance, as follows:

$$\frac{\Delta\eta}{\eta_{\mathrm{Did}}} = \xi_{\mathrm{P}} \frac{\Delta R}{R_{\mathrm{id}}}$$

Thus, the following quadratic equation for P_{Did} is derived:

$$P_{\mathrm{Did}} = P_{\mathrm{Dms}} - \frac{\Delta R V_{\mathrm{S}}}{\eta_{\mathrm{Did}}}\left(1 - \frac{P_{\mathrm{Dms}}}{P_{\mathrm{Did}}}\xi_{\mathrm{P}}\right)$$

And, the delivered power in ideal condition can be obtained by solving the above quadratic equation, as follows:

$$P_{\mathrm{Did}} = \frac{1}{2}\left\{P_{\mathrm{Dms}} - \frac{\Delta R V_{\mathrm{S}}}{\eta_{\mathrm{Did}}} + \sqrt{\left(P_{\mathrm{Dms}} - \frac{\Delta R V_{\mathrm{S}}}{\eta_{\mathrm{Did}}}\right)^2 + 4P_{\mathrm{Dms}}\frac{\Delta R V_{\mathrm{S}}}{\eta_{\mathrm{Did}}}\xi_P}\right\}$$

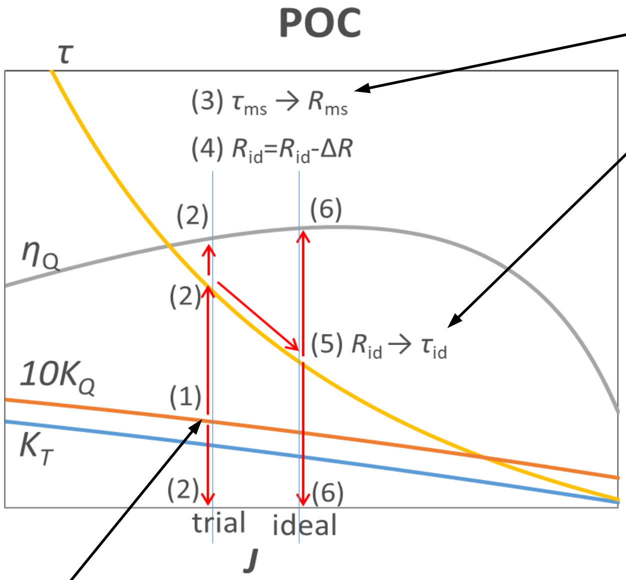
And, propeller shaft rate can be derived with the following formula using :

$$n_{\mathrm{id}} = \frac{n_{\mathrm{ms}}}{\xi_n \frac{P_{\mathrm{Dms}} - P_{\mathrm{Did}}}{P_{\mathrm{Did}}} + 1}$$

ξ_v taken away

Power Correction- EPM-Informative

In the EPM, η_{Did} and η_{Dms} can be estimated using POC and SPFs considering load variation effect, and then delivered power in ideal condition , as follows:



(1) $$K_{Q\mathrm{ms}} = \frac{P_{\mathrm{Dms}}}{2\pi\rho_S n_{\mathrm{ms}}^3 D^5} \times \eta_{\mathrm{Rms}}$$

(3) $$R_{\mathrm{ms}} = \tau_{\mathrm{ms}}(1 - t_{\mathrm{ms}})(1 - w_{\mathrm{Sms}})^2 \rho_S V_S^2 D^2$$

(5) $$\tau_{\mathrm{id}} = \frac{R_{\mathrm{id}}}{(1 - t_{\mathrm{id}})(1 - w_{\mathrm{Sid}})^2 \rho_S V_S^2 D^2}$$

Advantage of EPM -full scale wake fraction in ideal condition can be estimated.

$$1 - w_{\mathrm{Sid}} = (1 - w_{\mathrm{Mid}}) \frac{1 - w_{\mathrm{Sms}}}{1 - w_{\mathrm{Mms}}}$$

w_{Sms} : full scale wake fraction in trial condition, derived from J_{ms}

w_{Mms} : model scale wake fraction in trial condition, derived from model test

w_{Mid} : model scale wake fraction in ideal condition, derived from model test

Power Correction- PTEM

This method, proposed by Yasukawa (2019), requires Neither added resistances Nor current speed to eliminate the influence of disturbances.

P_{Did} (at $n = n_{\mathrm{id}}$) as the function of propeller shaft speed is expressed by Taylor series about $n = n_{\mathrm{ms}}$, as follows:

$$P_{\mathrm{Did}} = P_{\mathrm{Dms}} - \Delta n \frac{\partial P}{\partial n} + \Delta n^2 \frac{\partial^2 P}{\partial n^2} + O(\Delta n^3)$$

Total added resistance is estimated by the following function:

$$\Delta R = \frac{\Delta \eta P_{\mathrm{Did}}}{\xi_{\mathrm{P}} V_{\mathrm{S}}}$$

Ship's speed through the water is estimated by the following equation:

$$V_{\mathrm{S}} = \frac{P_{\mathrm{Did}} \eta_{\mathrm{Did}}}{(1 - t_{\mathrm{id}}) T_{\mathrm{id}}}$$

Δn is derived with the following equation:

$$\Delta n^2 \frac{\partial^2 P}{\partial n^2} - \Delta n \frac{\partial P}{\partial n} = \frac{\Delta \eta (1 - \xi_{\mathrm{P}})}{\Delta \eta + \xi_{\mathrm{P}} \eta_{\mathrm{Did}}} P_{\mathrm{Dms}}$$

The above ΔR, V_{S}, n_{id} and P_{Did} as well as related intermediate information, such as POCs and SPFs and so on, are derived with iterative process.

According to the analysis results with the actual trial data, scatter is smaller than that of others.

Model-Ship Correlation Factors at Different Drafts

- Focused aspects:
  - Varying relation between wave making resistance and viscous resistance components on different draughts.
  - Form factor k: In case a ship and draught dependent form factor is applied, the influence of the draught is partly incorporated; this is not the case where no specific form factor is used for the prediction.
  - Influences from submerged transoms
  - Flow separation – varying behaviour on different draughts.
  - Effect of trim in ballast cases
  - Wind resistance of model & Treatment in prediction procedure
- No Concluding Answer
- New, dedicated working group initiated

Propulsion Shaft G-Modulus

- **No new progress and following remarks are from 28PSS report**
  - Default value 82,400 Mpa remains
  - Derivation of G-modulus from tensile tests of shaft specimen results in unacceptably large variation.
  - Measured values of the actual propulsion shaft may be accepted, provided that an adequate measurement procedure and certified equipment is used by qualified test engineers.

Water Temperature Changes

		East China sea		Yellow sea	
		Temperature changing amplitude every day(℃)	Average Temperature (℃)	Temperature changing amplitude every day(℃)	Average Temperature (℃)
Surface layer	Winter	0.6	9~12	0.5	2~10
	Spring	1.3	17~23	0.8	13~17
	Summer	0.9	26~29	2.1	24~27
	Autumn	0.5	17~26	2.0	13~14
Middle layer (5m~10m)	Winter	0.4	9~11	0.4	2~10
	Spring	1.4	16~23	0.4	12~15
	Summer	0.2	20~22	2.4	18~20
	Autumn	0.2	15~23	2.4	13~14

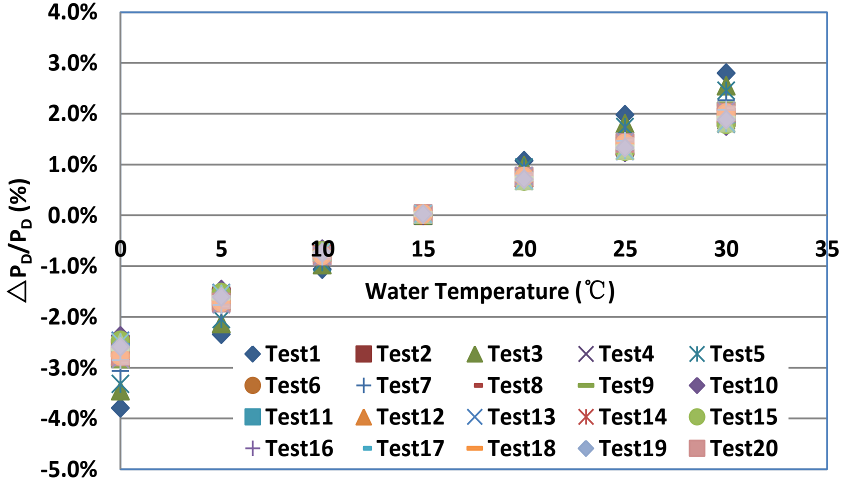
- Changes from 0 -30° in different season
- Less than 2.4° within a day

Some Examples

- Water Temperature changes about 20° for the trials of VLOC series vessel

Ship No.	Sea Trial Area	Water Temperature (℃)
1#	Yellow sea	5.5
2#	East China sea	15.0
3#	East China sea	14.0
4#	East China sea	17.5
5#	Yellow sea	19.5
6#	Yellow sea	24.4
7#	Yellow sea	25.0

- For ref. value (15℃), the speed correction is about ±0.02kn / per 2.5℃.



Correction of power for different water temperature (39000DWT B.C & 60000DWT B.C)

NOISE IN THE MEASURED DATA AND MEASUREMENT ERROR

- Uncertainty Analysis of Speed Trial

  - The uncertainty analysis of speed / power performance was carried out based on raw data in speed trials.

  - The speed-power performance was estimated on the guideline of ISO15016, and Monte Carlo simulation was used for the analysis of uncertainties.

Noise In The Measured Data And Measurement Error

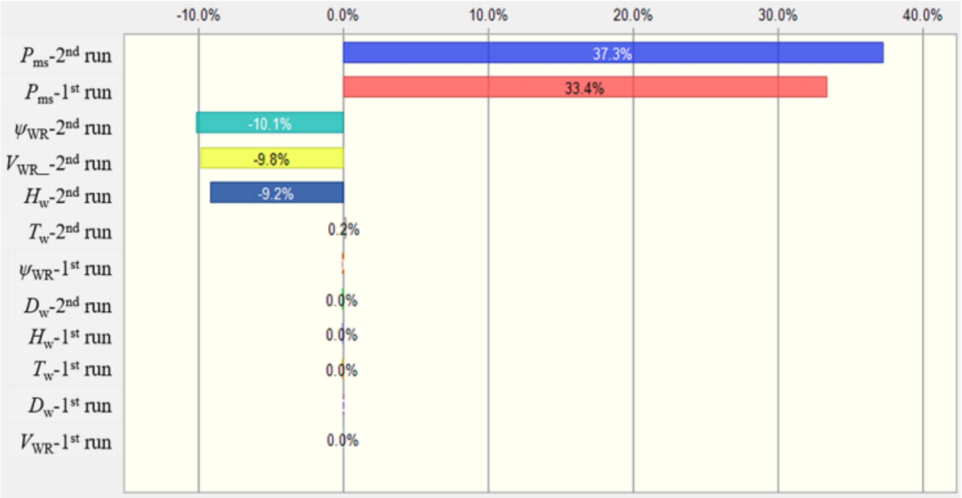


Fig. 8 Sensitivity of corrected shaft power on basic input parameters (MCR 75%)

Table 10 Uncertainty for corrected ideal power

	U (95%, K=2) (kW)	U (95%, K=2) (%)
MCR-50%	± 164	±1.2
MCR-75%	± 227	±1.2
MCR-90%	± 265	±1.2

- Dominant component : shaft power measurement about 60% of the total uncertainty.
- It is necessary to measure the shaft torque more precisely to reduce the uncertainty of the shaft power in sea trials.

Conclusion

- Expanded uncertainty of ideal power performance

  - about ±1.4% at the 95% confidence level (k=2)

- Shaft power measurement system (standard uncertainty of the shear module) was the dominant effect

  - Uncertainty in the added resistance was minor due to moderate weather conditions

Update of the procedure 7.5-04-01-01.1

Shallow Water Correction

- The committee accepted Raven method as the only method, and Lackenby method skipped
- New water depth limitations for the applicability of shallow water corrections were established
- Speed correcting replaced by corrections of delivered power.

Update of the procedure 7.5-04-01-01.1

Wave Correction

- A new wave added resistance prediction method developed and validated sufficiently in SOS

- Generally agree with model tests well and fill the blank when wave angle larger than 45°& shiplines unavailable

- Included into the sea trial procedure

Update of the procedure 7.5-04-01-01.1

Wind correction

- Limitations of wind averaging method were detected and reasons for averaging method including exceptional case for averaged single run were described
- Guidance on the location of anemometer was recommended
- The wind force coefficient database was extended by a new vessel, using the average wind velocity for non-dimensionalization , which contributes to obtain more reasonable wind force coefficients.

Main Update of the Procedure 7.5-04-01-01.1/ with 2017

No	Item	ITTC2017 version	ITTC2021 version
1	Wave correction method	STA （Within 45°from heading） NMRI （Shiplines necessary）	New method-SNNM introduced to fill the blank: when wave angle larger than 45°and shiplines unavailable. Suitable for all ship types and all wave directions
2	Shallow water correction method	Lackenby、 Raven	Only Raven method retained, and only resistance corrected
2.1	Lower limit of Shallow water	$h = \max(2\sqrt{BT},\ 2\frac{{V_S}^2}{g})$	$h = \max(2.5T,\ 2.4\frac{{V_S}^2}{g})$
2.2	Upper limit of Shallow water	$h = \max(3\sqrt{BT},\ 2.75\frac{{V_S}^2}{g})$	Cancelled to keep continuity of water depth correction
3	Wind correction method	Double run averaged	Occasions added when single run wind speed could be used
4	Additional double runs for sister ships	Current change over 0.2kn within a double run after analysis	For ‘Mean of means’ method, if after evaluation the vessel speed deviates more than 0.3 knots, compared to the first ship, then the same procedure as the first ship should be followed.

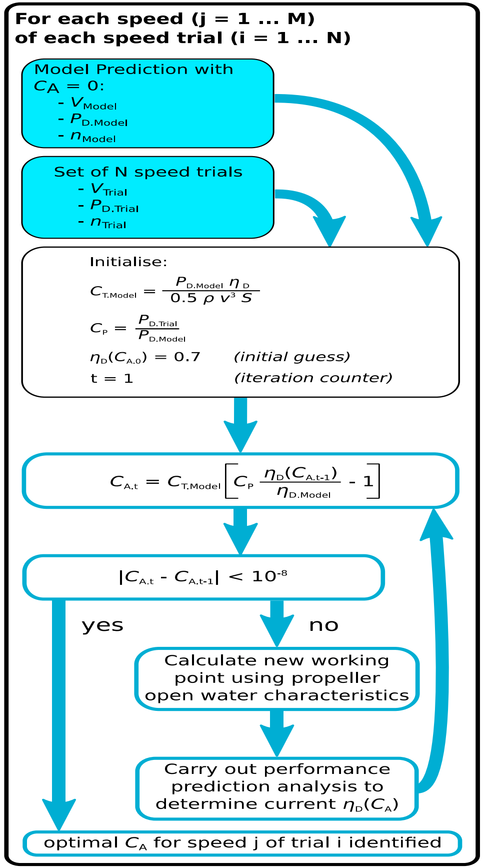
Updates to the Guideline on the Determination of Model-Ship Correlation Factors

- The guideline defines minimum requirements and general guidance for deriving correlation schemes

- Updates:
  - More detailed description of iterative approach for determination of a resistance-based correlation factor (i.e. C_A).
  - Example implementation of the procedure in Excel- format was provided to the committee members for testing
  - Required Size of Samples for a Reliable Determination of Correlation Factors:

    $$n > 50 + 8 \cdot m$$

    n: number of samples
    m: number of independent variables



Key Performance Indicators For Ships In Service

- Many reasons to monitor ship performance in service
  - Track hull and propeller fouling and coating performance
  - Voyage optimization (draught, trim, weather routing)
  - Design feedback for sea margin
  - Feedback to model basins for correlation and research
- Increasingly regulatory focus on performance monitoring
  - EEDI verified through sea-trials
  - IMO ‘short term measures’ such as proposed Carbon-intensity indices (EEXI, AER, etc.)
  - Regulatory ‘baselines’ distinct from those required for in-service monitoring
  - Absolute vs relative
- Requires trustworthy measures of in-service power and speed
  - Across all operational conditions

Key Performance Indicators For Ships In Service

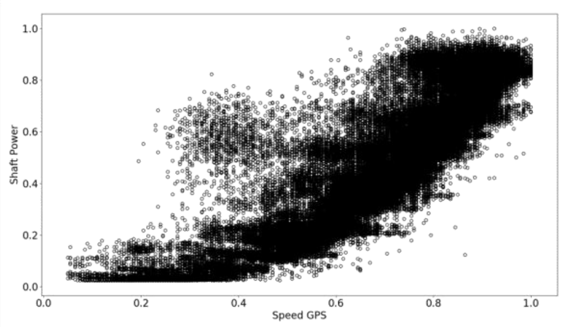
- Historically 'noon reports' were primary source of in-service data
  - Can be useful long-term with automated acquisition (remove human error)
- Increasingly replaced by 'continuous monitoring' or 'high frequency' data
- For ITTC 'noon report' data considered to have too large uncertainty

- Biggest challenge with any data is characterisation of wind and waves
  - Anemometer typically used (disturbed wind field), requires correction to true wind
  - Waves rarely measured – MetOcean hindcast data useful and reliable

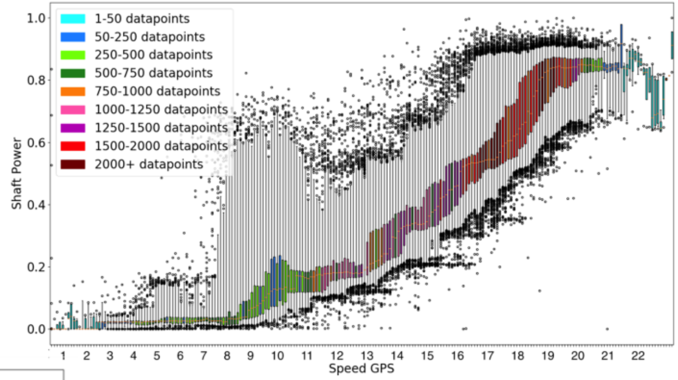
- Requirement for robust and reliable standards – ISO19030 is primary one

Key Performance Indicators

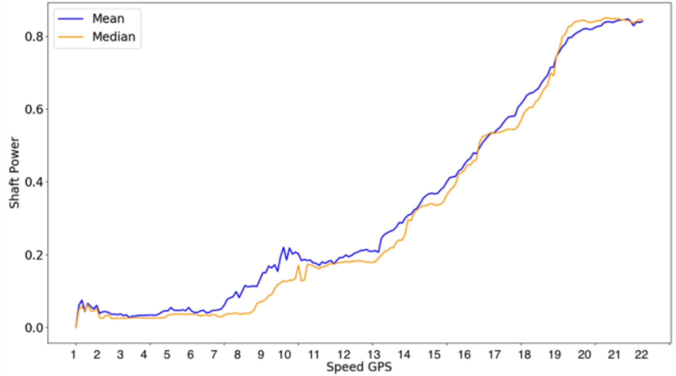
➢ Altering data presentation can provide more insight than no filtering



‘Raw’ data



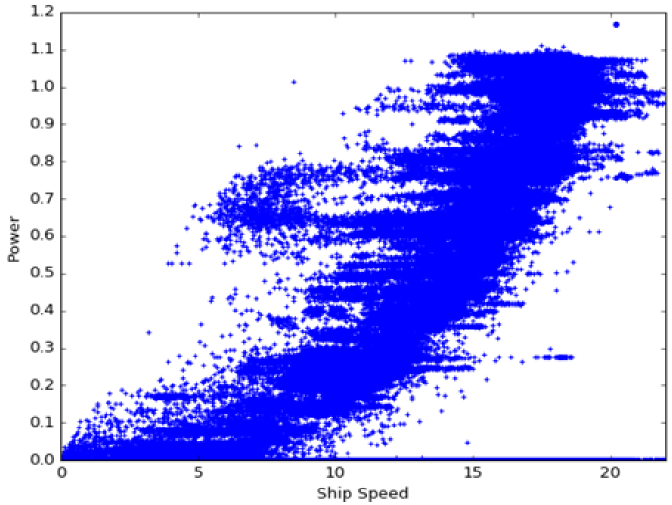
Box plot with data quantity



Resulting mean and median

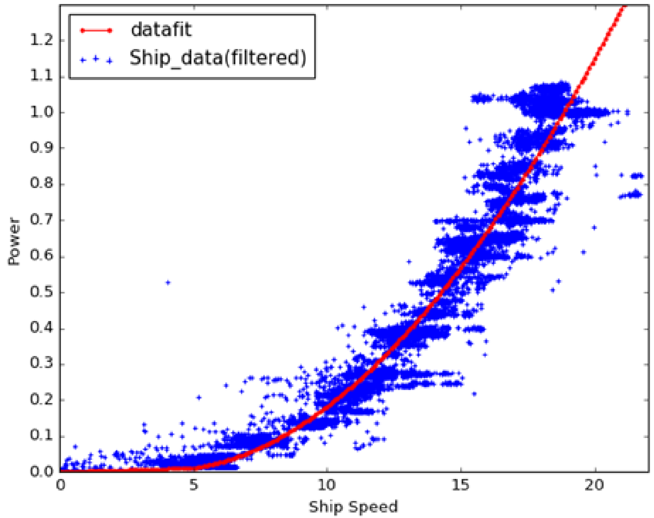
Key Performance Indicators

- ISO19030 written for hull and propeller performance monitoring
  - Filtering approach – threshold values for wind speed, wave height, draught/trim ranges
  - Derived power - speed relationship very sensitive to choice of thresholds
  - Vital to be transparent and consistent in choices



'Raw' data

Filter data for:
Wave height <x m
Wind speed < y kts



Filtered data – typically ~10% of initial

Key Performance Indicators

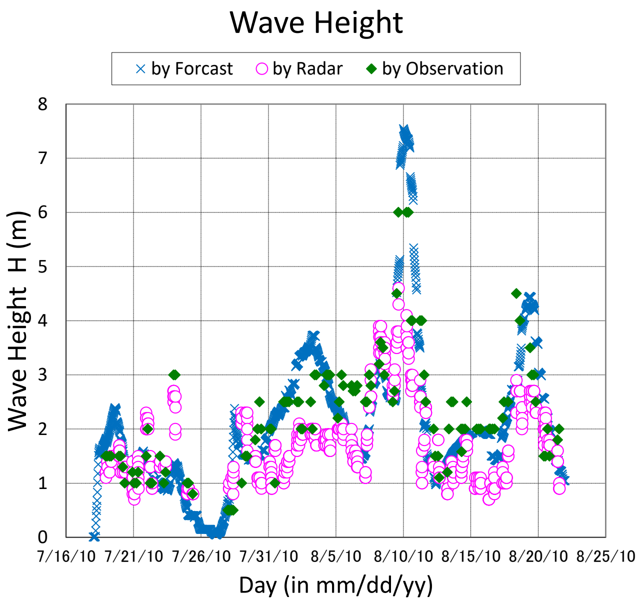
- Alternative approach is normalisation of data
  - Correct for effect of wind and waves
  - Often use methods initially derived for sea-trials analysis
  - Forms basis of methods for 'single run (in-service performance) analysis' (see later)
- Key Performance Indicators (KPIs) need to relate to purpose of analysis
- Hull and propeller fouling management
  - Common to use 'speed loss' relative to a baseline determined out of dock
  - Power increase is alternative and is more sensitive
  - Separation of hull and propeller effects challenging without thrust measurements, systems are being developed for this (see later)
- Engage with development of ISO19030 and standards for normalisation
- Uncertainties remain regarding wind/wave conditions – further investigation

More Accurate Measurement of Environmental Data

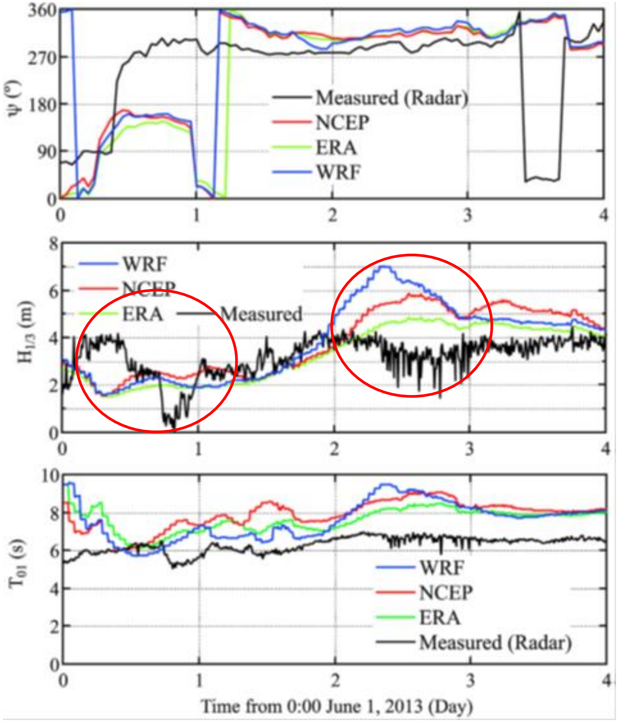
Purpose:

- Evaluation of accuracy of environmental data measurements, and comparison with forecast data.
- Waves: most difficult item to measure among environmental data.
- Availability of emerging wave-radar measurements techniques are examined.

Comparisons Of Wave Radar With Other Data



Comparison of wave-radar measurements with forecast and visually observations – clear difference



Comparison of wave-radar measurements with hindcast data- Large difference

Hindcast input wind model

WRF: Weather Research and Forecasting model

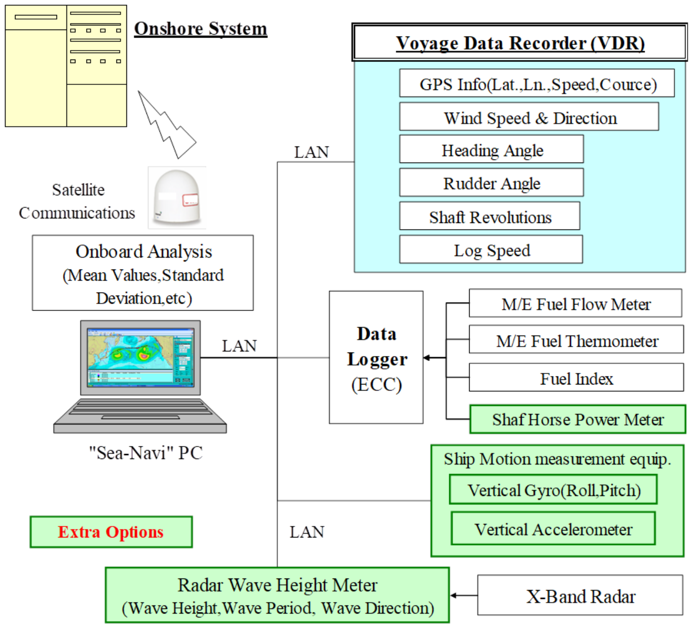
NCEP: National Centers for Environmental Prediction model

ERA: European center for medium-range weather forecasts Re-Analysis model

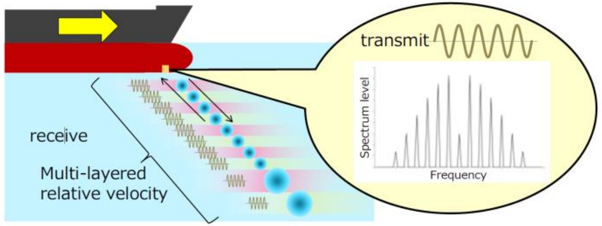
Summary

- Effectiveness of wave-radar system as an onboard wave measuring device has Not been thoroughly verified so far.
- Agreement between the wave-radar data and forecast/hindcast data is Not satisfactory.
- Comparison of measurements with a wave buoy deployed close to the ship is indispensable.

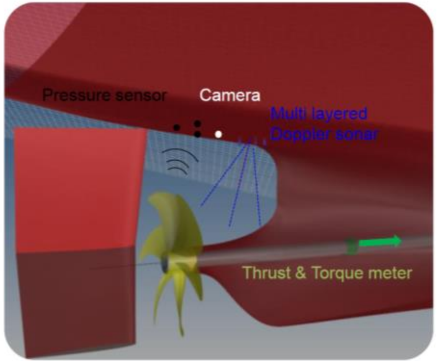
Speed-power related monitoring , including
fuel consumption, shaft torque, speed, draught, trim and rudder angle etc.

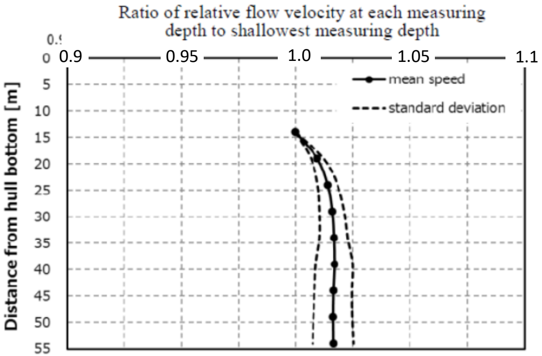


Configuration of a typical onboard monitoring system

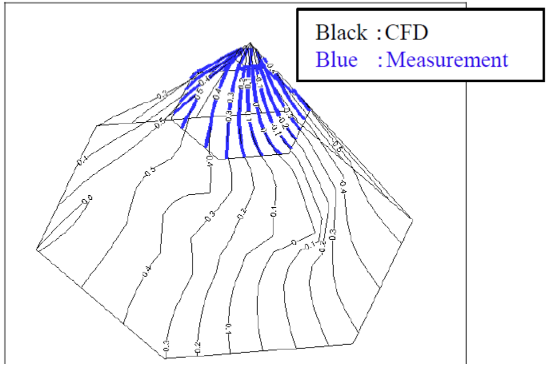


Multi-layered Doppler sonar.





Speed through water measurements. (under keel)



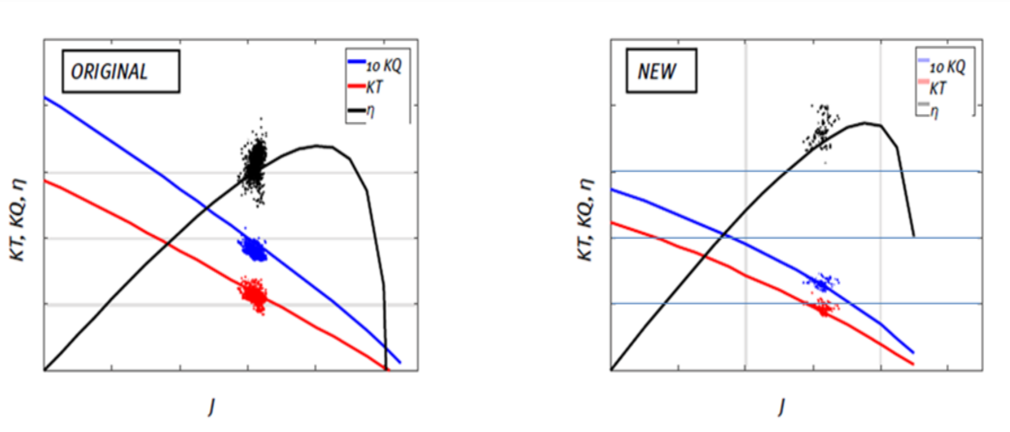
Wake flow measurements.

Summary

- Speed-power related performance monitoring has been routinely conducted on in-service ship by means of simple/robust system using normal systems for ship operation (VDR, EMS etc.).
- Improving the accuracy of speed through water measurement is indispensable for speed-power performance monitoring.

On board monitoring thrust and torque

- Observing the performance of the propeller & ship hull retrofits, it is important to measure the propeller performance from the hull resistance separately.
- Optical Propeller Thrust and Torque monitoring, is helpful to avoid unpredicted degradation of hull coating or propeller performance & separate the hull and propeller performance. Below is an example of propeller before & after modification.

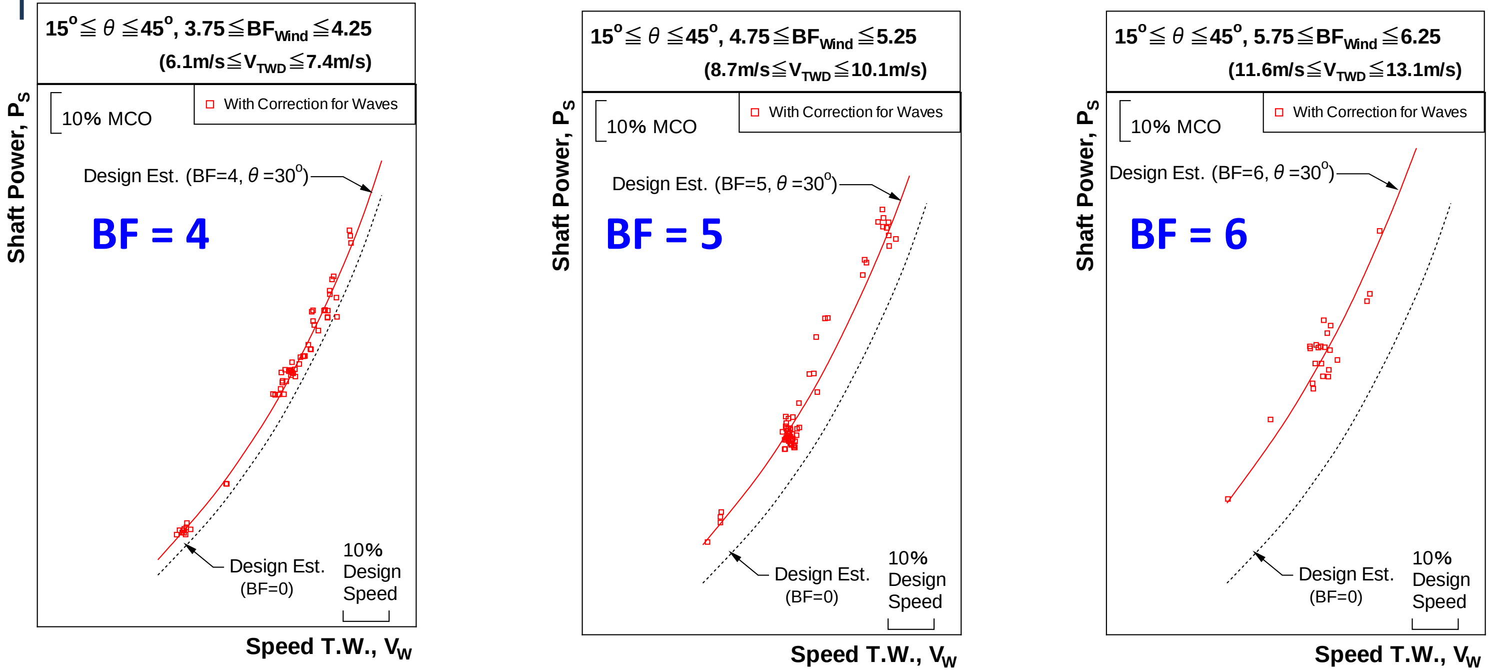


Possibilities to analyze ship performance on a single run

Background and difficulties

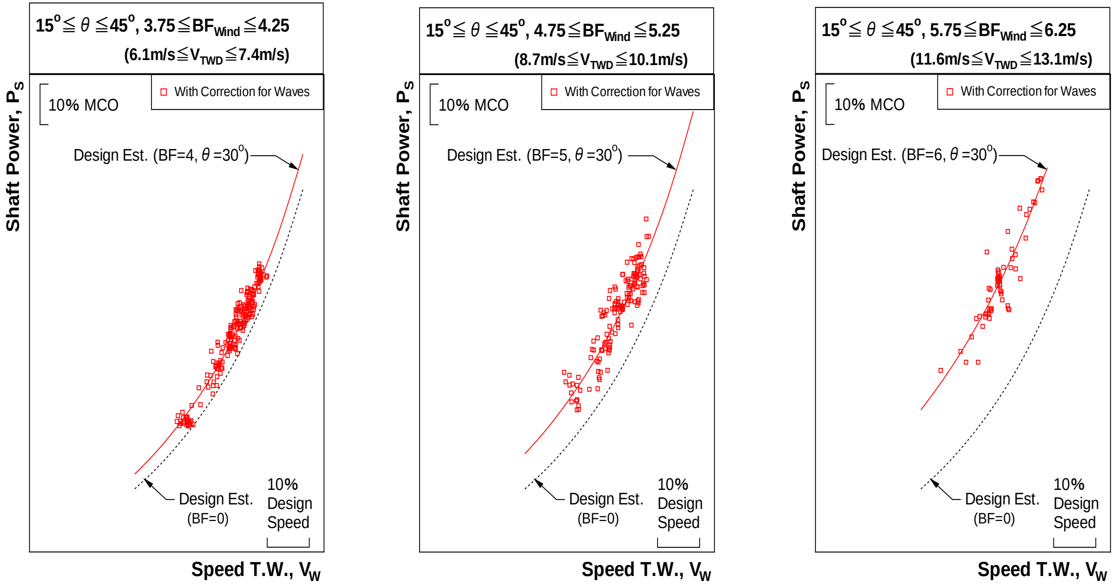
- Ship's speed/power performance evaluation in service conditions is normally conducted on a single run basis using speed through water (STW) as a reference speed.
- On-board measured STWs frequently suffer from the bias and random errors, effective correcting procedures are principal issues for accurate performance analysis
- The other issue is the correction for the encountered disturbances to the reference weather conditions.

Speed power analysis on a single run- VLCC



Corrected single-run monitoring data(Red points)
via design estimations (Red line)
Agree with each other generally well in bow waves

Speed-power analysis on a single run- PCTC



Corrected single-run monitoring data(Red points)
via design estimations (Red line)
Agree with each other quite well in bow waves

Summary

- Analysis of speed/power performance in service is worth conducting using single-run data.
- Analysis of single-run (in-service) data is useful when cope with the ship's conditions such as fully loaded conditions for dry cargo ships or rough weather conditions as an important supplement to sea-trial condition.

Applicability of Unmanned Vehicles And Devices

- Marine drones are mainly used for water quality surveys and mapping the floors of the ocean.

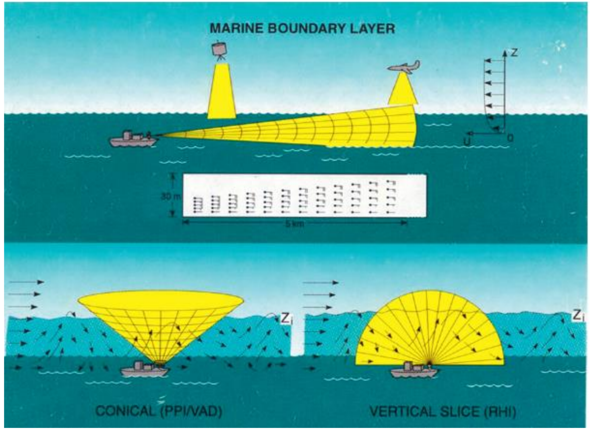
- There is little actual performance with drones getting useful information for ship operations.

- “Aquatic Drones” is one of the few examples to collect data autonomously with a multi-use platform
  - Radar for detection of ships
  - AIS system for ship tracking
  - Camera and LIDAR for distance calculation
  - GPS for positioning

Monitoring the ICT Technology

- On board ICT is often used for the structure monitoring， not for the prediction of ship performance， which needs to be continually investigated.

- LIDAR laser scanner technology is one of the few promising technologies. The vertical wind velocity distribution can be measured using a LIDAR system installed on board a ship



Conclusions And Recommendations

Main Conclusions

a) Raven method has been accepted exclusively as shallow water correction method, and upper limit of shallow water has been cancelled to avoid discontinuity and low limit redefined on the basis of study. Lackenby method has been skipped.

b) Detailed survey on the development of CFD methods for wave-added resistance shows that the deviation from model tests is in the range of 20%. Short waves tend to be affected by higher errors. Most of the comparisons are made in head wave only. Assessment of the accuracy in waves other than head waves is scarce.

Main Conclusions

c) A new full directional wave-added resistance prediction method-SNNM has been included in the sea-trial procedure after open validation in SOS extensively and intensively.

d) Limitations of averaging wind correction method investigated and discussed extensively. Averaging method has considered the influence of superstructure. However for large ships, when double run takes long time, the accuracy of averaged method decreases. To overcome this disadvantage, new testing instrument such as Lidar is proposed.

Main Conclusions

e) The guideline for derivation of correlation factors has been reviewed and updated by the committee.

f) The committee has reviewed the state of the art related to in-service performance monitoring including collection of data, analysis methods & filtering of data.

g) The speed/power sea trial procedure 7.5-04-01-01 has been further updated to reflect all research findings so far.

h) For shallow water model testing, towing tanks are normally too limited in width. Therefore results need correction for tank wall effects.

Recommendations to the Full Conference

a) Adopt the revised Procedure 7.5-04-01-01: Preparation, Conduct and Analysis of Speed/Power Trials(2021)

b) Adopt the revised Guideline 7.5-04-01-02: Guideline on the determination of model-ship correlation factors at different draughts (2021)

c) Adopt the new Guideline on the CFD-based Determination of Wind Resistance Coefficients (2021)

Recommendations For Future Work

1. Address issues related to hull and propeller surface roughness such as:

   a) Definition of roughness properties

   b) Components of roughness

   c) Measurement of roughness

   d) Effects of roughness on in-service performance including filtering and analysis methods for evaluating hull and propeller performance separately

   e) Roughness usage in performance prediction and cross effects with correlation

2. Provide technical support to ISO and IMO in further development of approaches to in-service performance monitoring (e.g. ISO19030)

Recommendations For Future Work

3. Address the following aspects of the analysis of speed/power sea trial results:

a) Initiate and conduct speed trials on commercial ships on deep and shallow water to further validate Raven method.

b) More validation on wave-added resistance methods, and recommend better method if appropriate.

c) Investigate the influence of water depth on the hull-propeller interaction (thrust de-duction, relative rotative efficiency)

d) Continue reviewing state-of-the-art of added resistance assessment by means of CFD.

e) Explore and monitor new developments in instrumentation and measurement equipment relevant for sea trials and in-service performance assessment (e.g. wind, waves, thrust, speed through water).

Recommendations For Future Work

4. Further investigate and validate draft dependency of model-ship correlation.

5. Study accuracy of CFD for shallow water applications.

6. Update the speed/power sea trial procedures 7.5-04-01-01.1 where appropriate.

7. Support ISO in updating ISO15016 in compliance with 7.5-04-01-01.1(2020).

8. Update guideline for determination of model-ship correlation factors.

9. Update guideline on CFD-based wind coefficient; in particular re-assess database of wind resistance coefficients and update it according to the new procedure for non-dimensionalising.

Thank you for your attention!