HullPIC2018, Redworth / UK

Improvement of Measuring Accuracy of Ship's Speed through Water by using MLDS (Multi-Layered Doppler Sonar)

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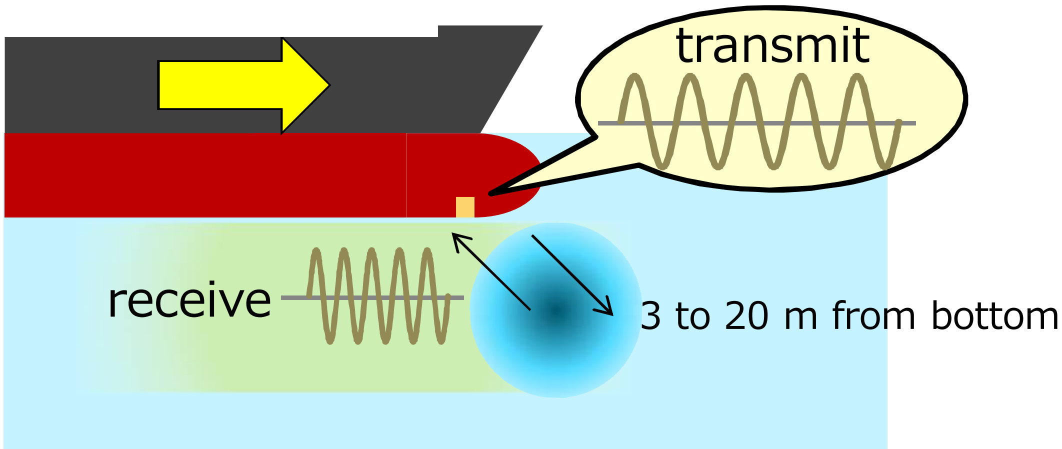
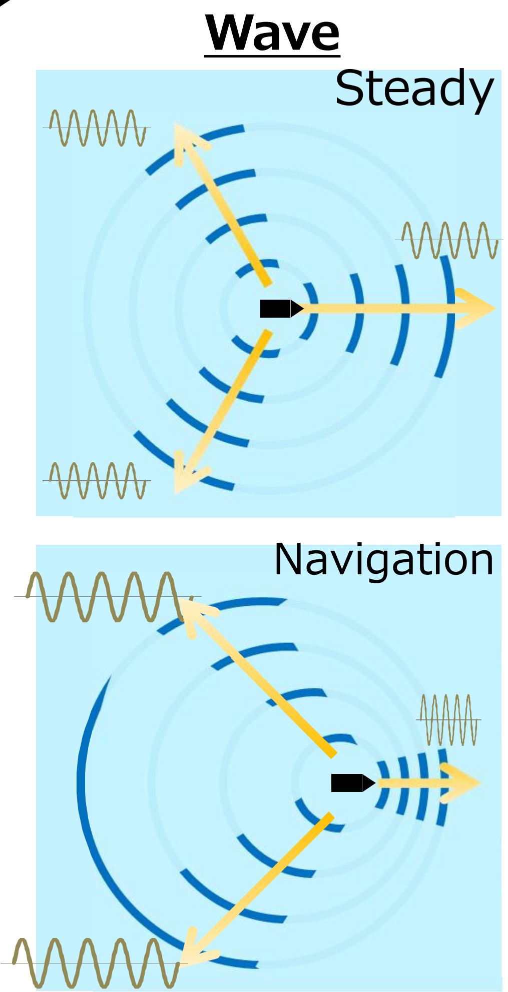
Conventional Doppler Sonar

① Transmit ultrasonic waves
② Receive reflected waves
③ Calculate relative velocity by doppler shift





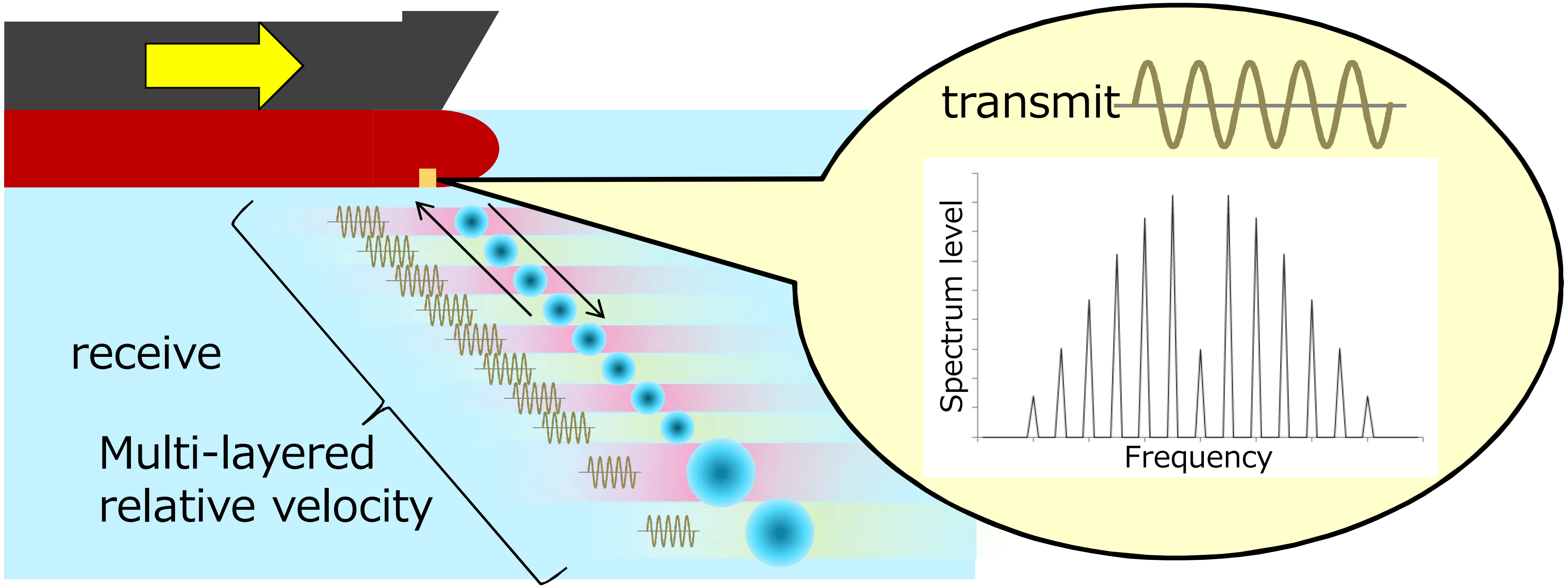
Wave length varies depends on ship's speed

MLDS (Multi-Layered Doppler Sonar)

FURUNO

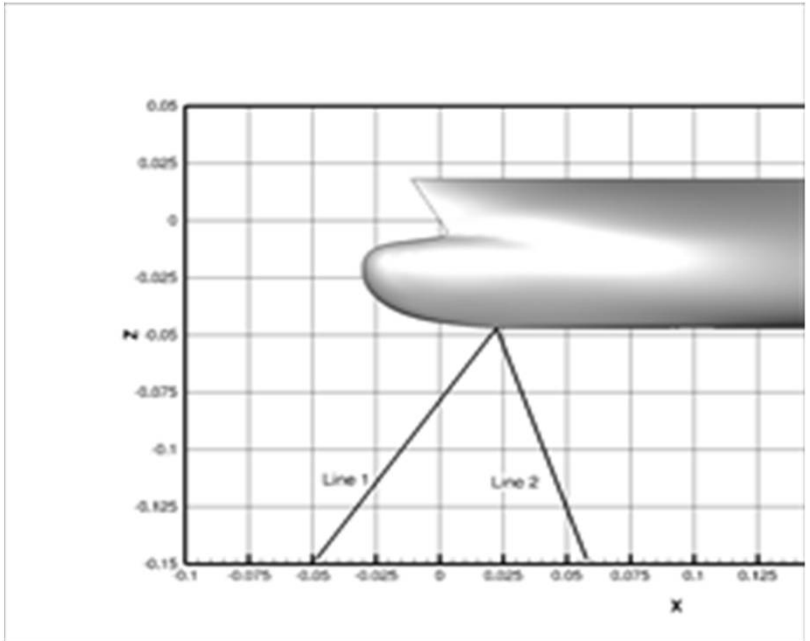
Transmitting wideband ultrasonic waves which have multiple spectral peaks

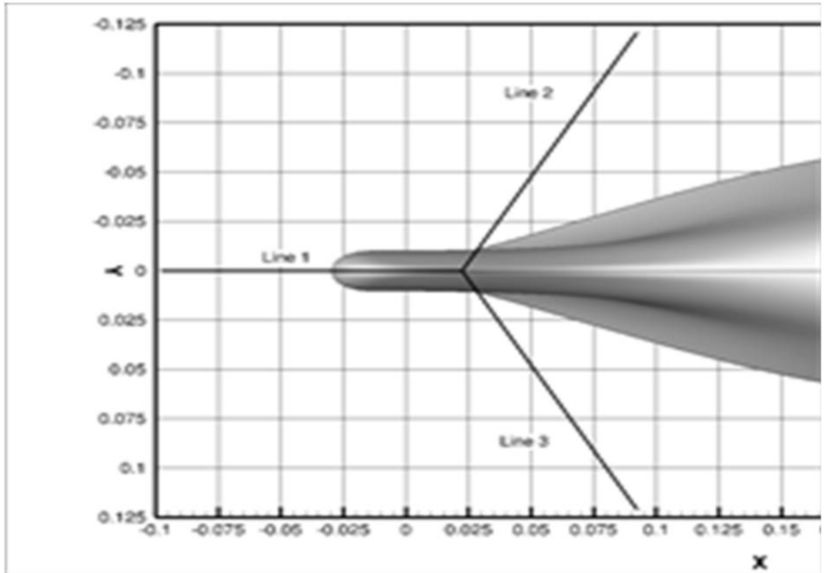
Furuno's patent



About N times amount of data can be obtained by measuring doppler shifts of each spectral peak at the same time independently. That means about N layers of relative velocity can be obtained.

Result of CFD Study



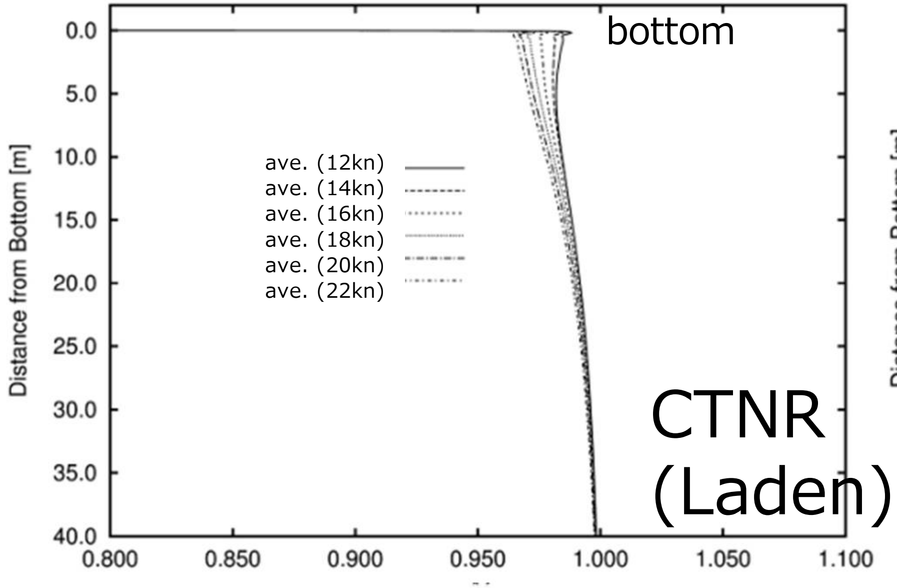


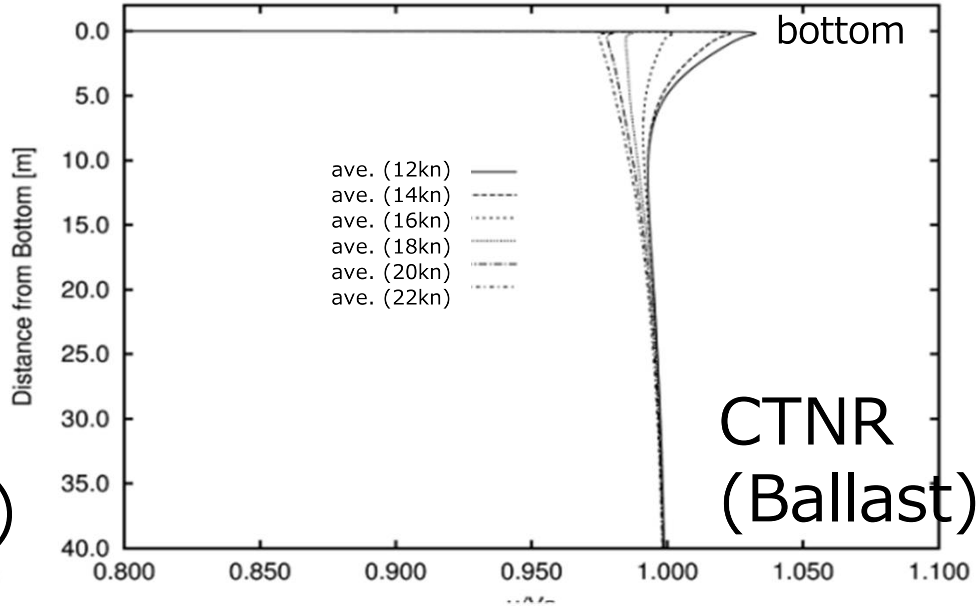
Velocity extraction lines

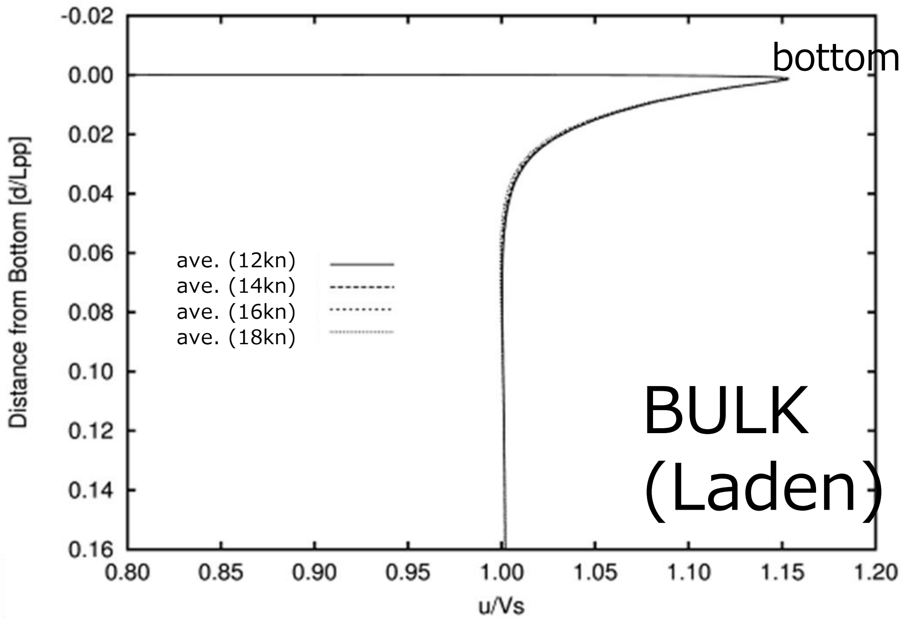
Flow fields of KRISO Container Ship (KCS), as an example of a slender ship, and Japan Bulk Carrier (JCB) as an example of a blunt ship, have been calculated by CFD.

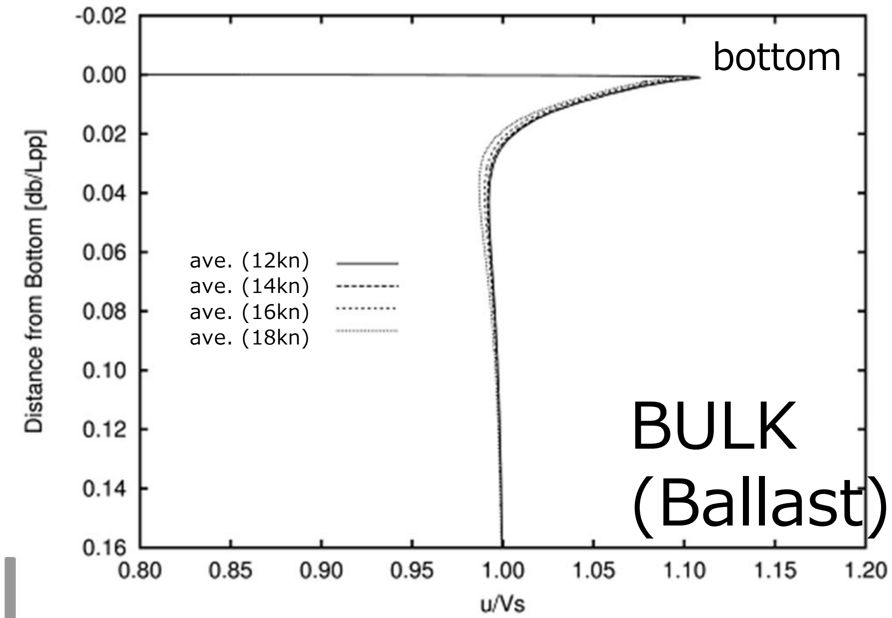
Result of CFD Study

The relative flow velocity under bow bottom varies depending on ship type, ship's speed and draft.

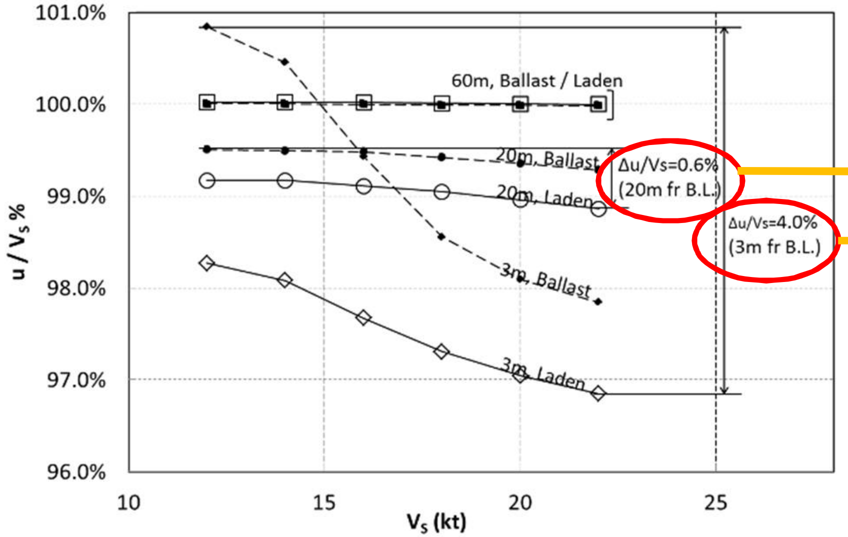


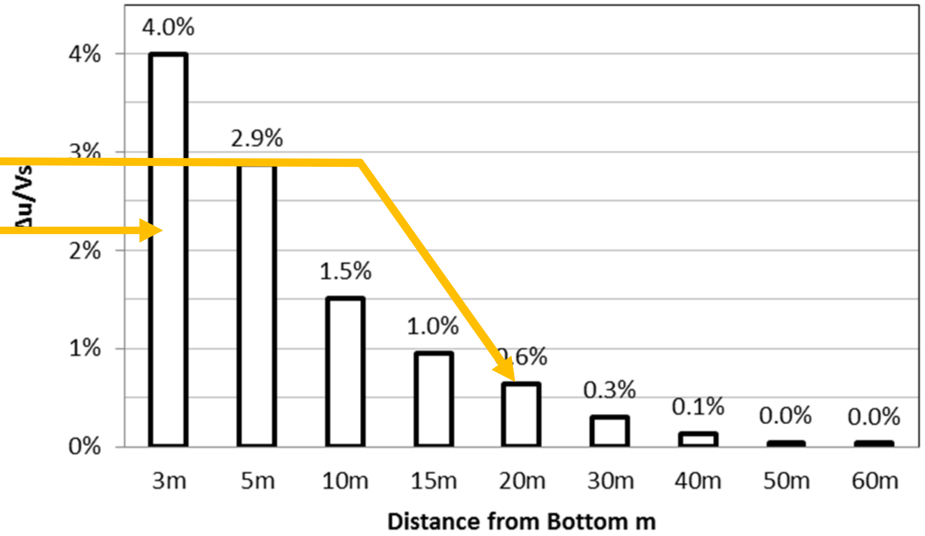






Result of CFD Study





Variations of ratio of computed relative flow velocity under bow bottom to ship's speed against ship's speed (KCS)

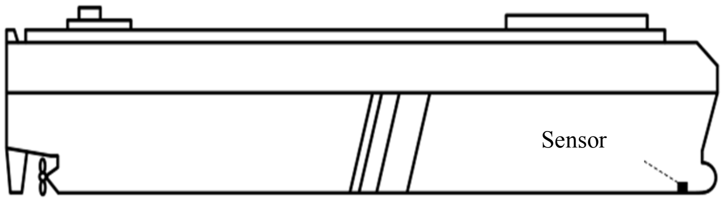
These variations could be the reason for error of ship's speed through water.

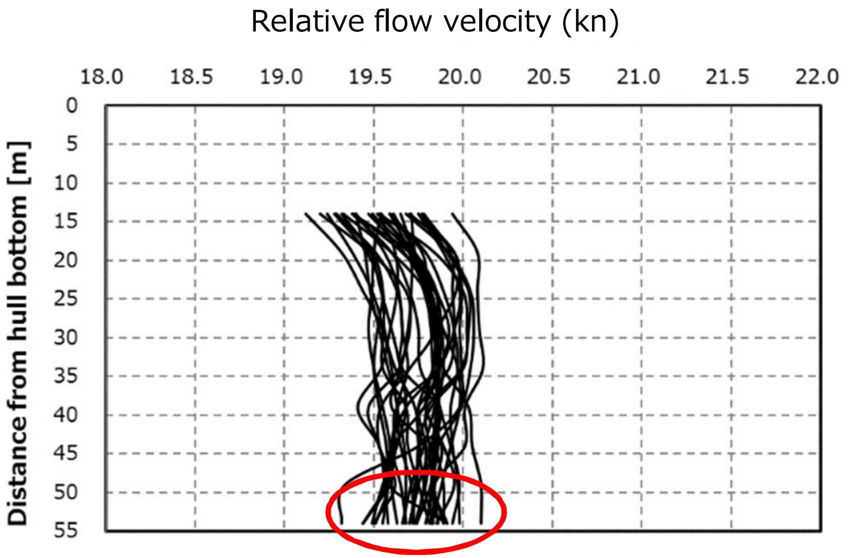
Deviations of computed relative flow velocity under bow bottom from ship's speed against distance from bottom (KCS)

The deeper the distance from ship's bow bottom, the smaller error factor for ship's speed through water.

Result of measurement on actual ships

Type	Panamax PCC
L [m]	190 m
B [m]	32.2 m
Depth [m]	34.8 m
Draft [m]	10.3 m





Initial one second measurement results taken after each time zero during 20 – 22 November 2014 (PCC)

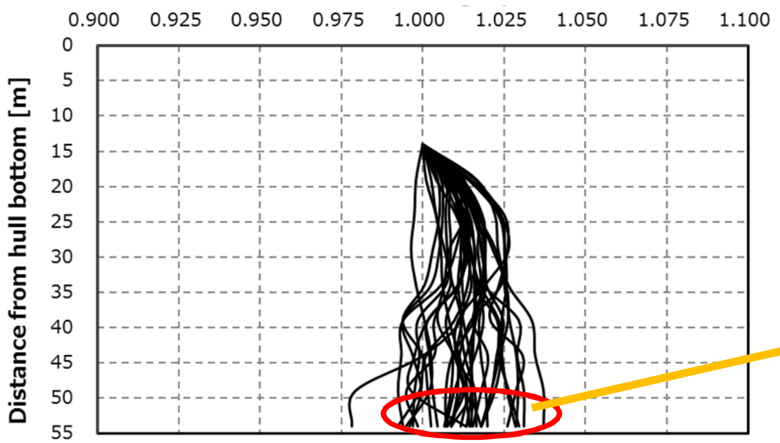
Relative flow velocity varies at each time and ship's speed even deep point.
The causes of variation are assumed to be the following three factors.

(1) Speed through water was changed actually
(2) Current of each depth was changed as time and depth
(3) Hull itself made specific flow field

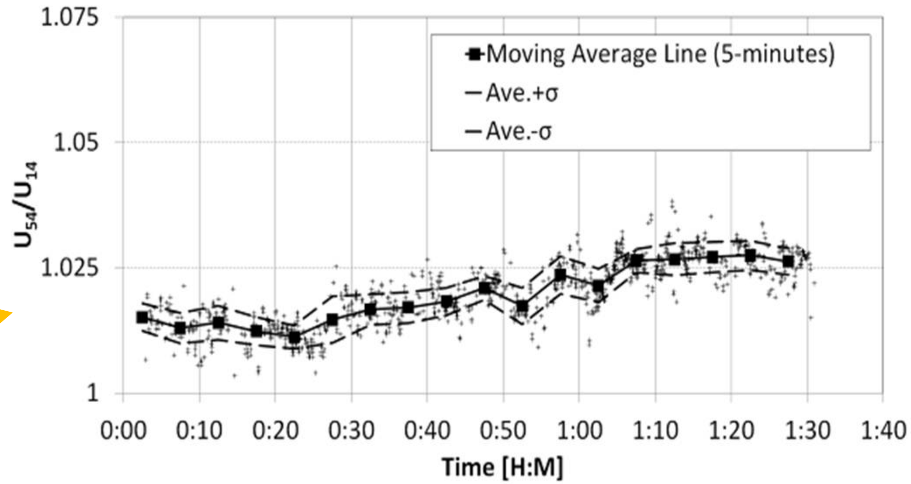
The target is to obtain tur STW (1) by using hull characteristic (3) without current effect (2).

Result of measurement on actual ships

Ratio of relative flow velocity at each measuring depth to shallowest measuring depth



Distribution of one-sec. of relative flow velocity ratio U_X/U_{14} (PCC)

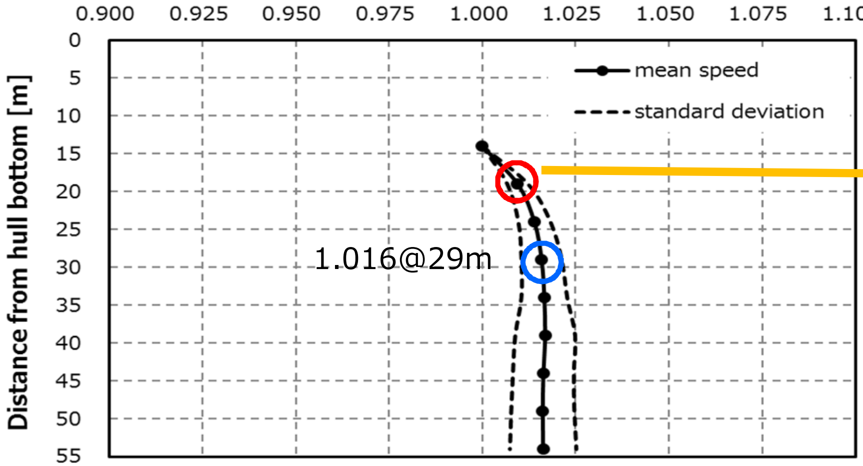


By plotting Ux/U14, it is possible to consider to be removed the effect of STW change (1) because it can be considered the hull effect (3) is same during this measurement period thanks to limited draft and ship's speed if ship itself is considered in the same layer of current as 14 meters' depth which is shallowest depth of measurement at this time.

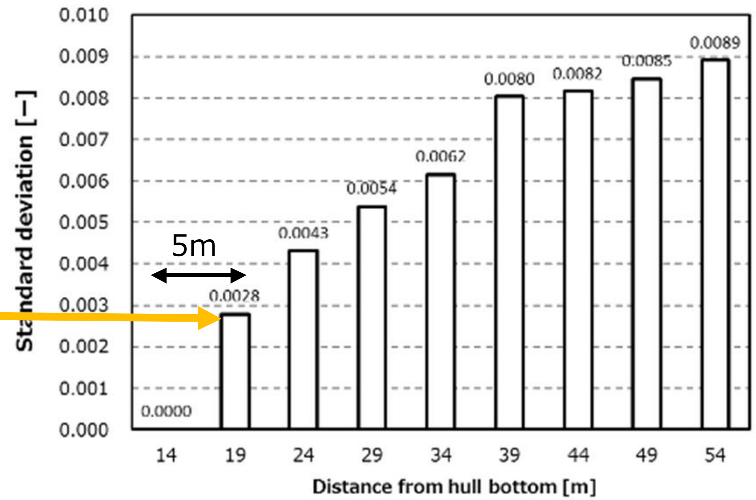
The fluctuation of relative flow velocity ratio comes from long time change of current change (2) which has 1.5% range, while the standard deviation of each time is limited, such as about 0.3%.

Result of measurement on actual ships

By averaging and filtering analysis with sufficient amount of data, hull characteristic (3) with minimum current change effect (2) is obtained.



Overall average of relative flow velocity ratio at every layer to the shallowest layer



Standard deviation of overall average of relative flow velocity ratio at every layer to the shallowest layer

1% accuracy of ship's power can be obtained.

To obtain the STW precision of 0.3%, the measuring target of shallowest depth should be within at least 5 meters from the ship's bow bottom to obtain the characteristics of (3) considering standard deviation of U19/U14 is 0.28%.

Proposed method

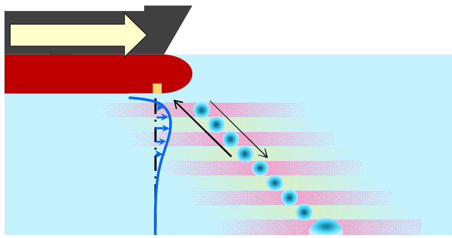
Learning phase

(Step-1) Measure the relative flow velocity distribution of each layer bottom between 2 to 40 meters under the ship's bow by MLDS and nondimensionalize by relative flow velocity in closest the hull.

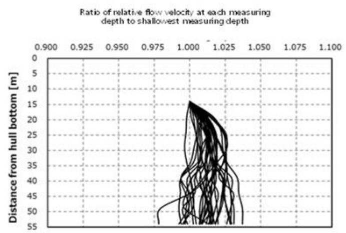
(Step-2) Collect sufficient number of data and make average analysis for each group of draft and relative flow velocity to obtain flow velocity distribution around the hull with minimal current effect.

(Step-3) Determine convergence value by increasing depth and regard this value as ratio of relative flow velocity to true ship's STW (equivalent of 1.016 under 29 meters in the case of previous slide). Collect these values for each group of draft and relative flow velocity, and create a velocity ratio chart.

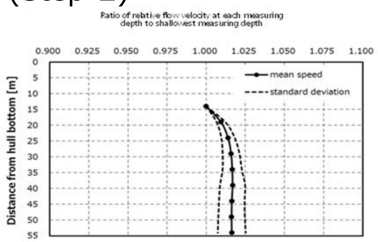
Learning phase



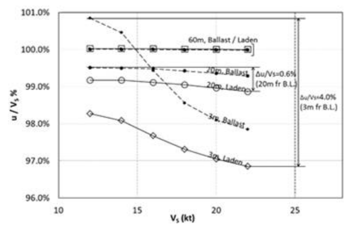
(Step-1)



(Step-2)



(Step-3)

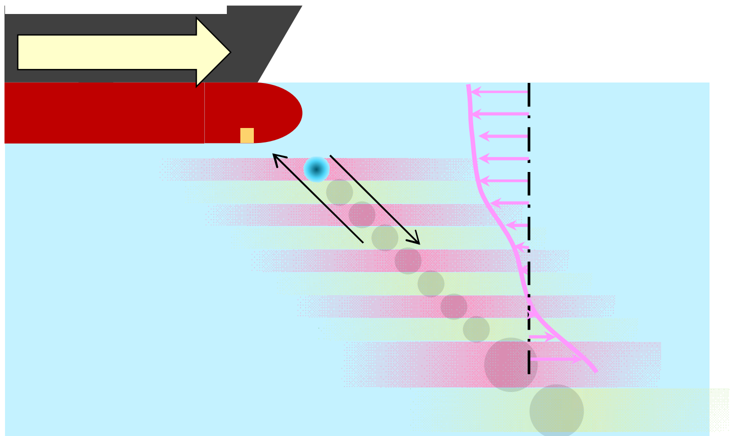


Proposed method

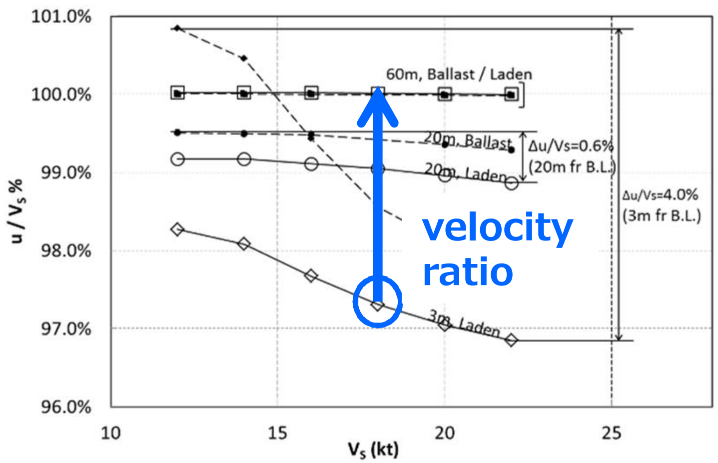
Usage phase

(Step-4) Measure relative flow velocity in closest the hull. Display the true ship’s STW by selecting appropriate velocity ratio corresponding to measurement conditions (draft and relative flow velocity) from the velocity ratio chart and multiply it by measured value of relative flow velocity in closest the hull.

Usage phase

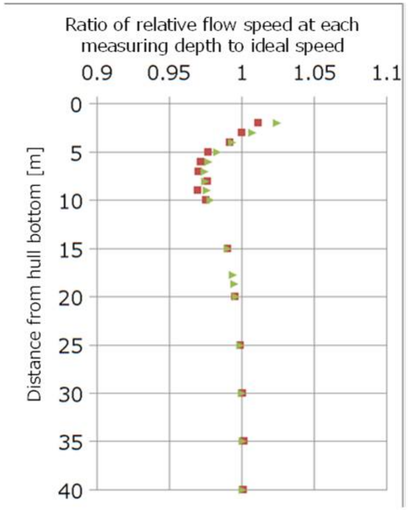


(Step-4)

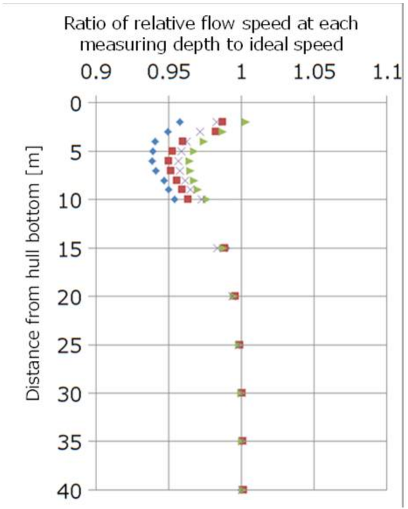


Measurement result by proposed method

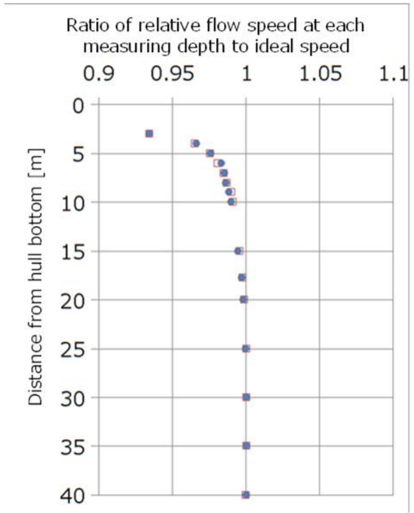
Ratio of relative flow velocity at each measuring depth to average velocity between 25 to 40 meters



Tanker (Laden)



Tanker (Ballast)

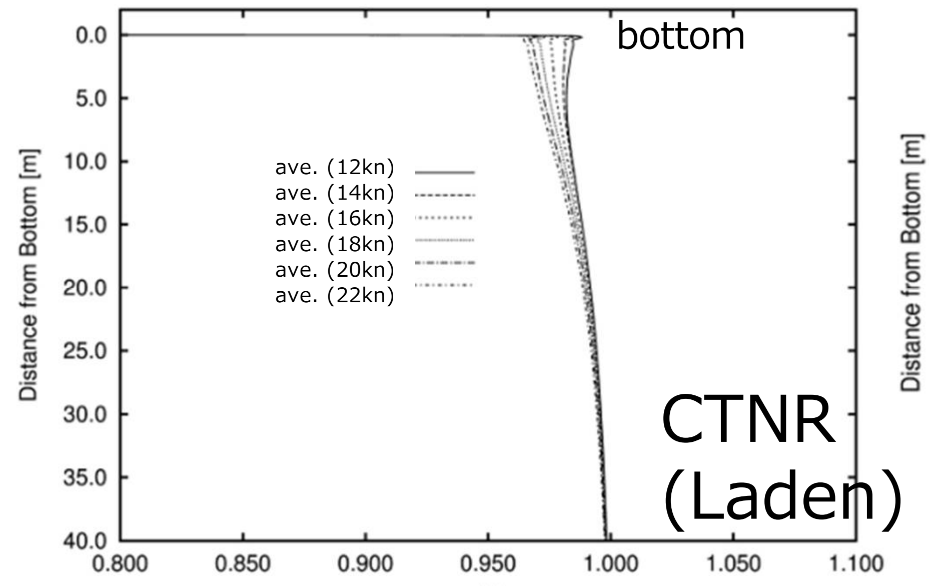


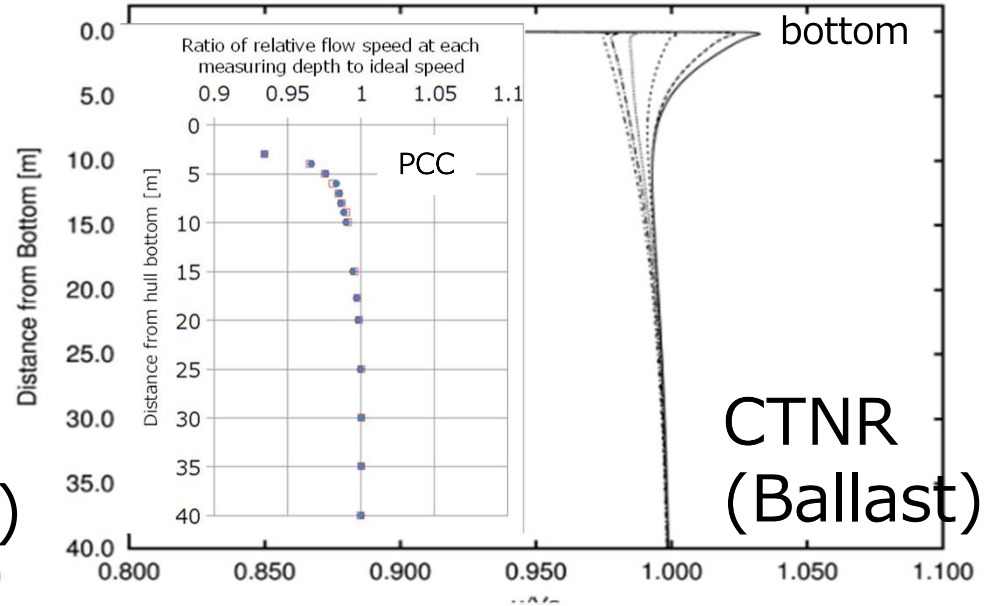
PCC

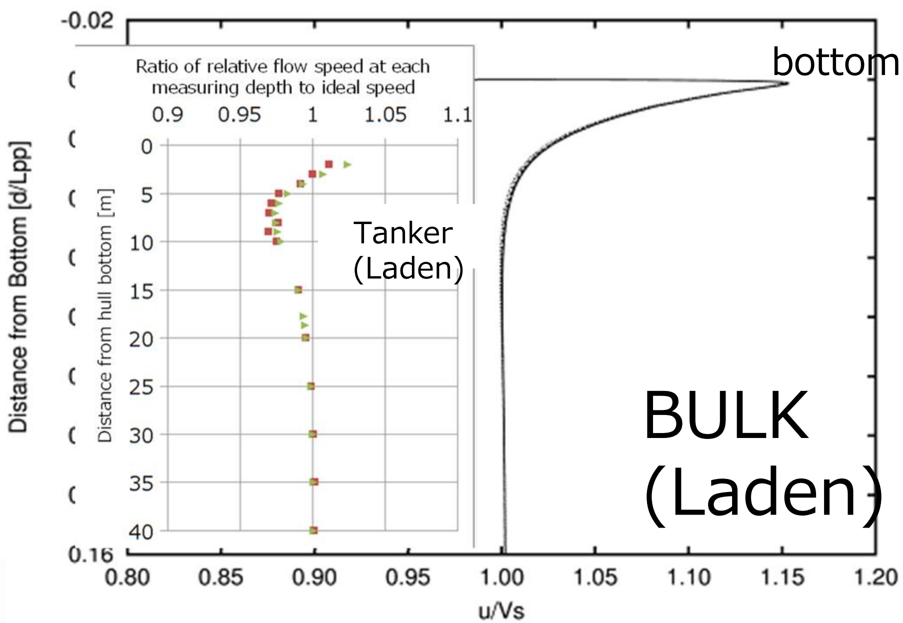
Type	Panamax PCC	Tankers
L [m]	190 m	243.8m
B [m]	32.2 m	42.0m
Depth [m]	34.8 m	21.6m
Draft [m]	10.3 m	15.0m

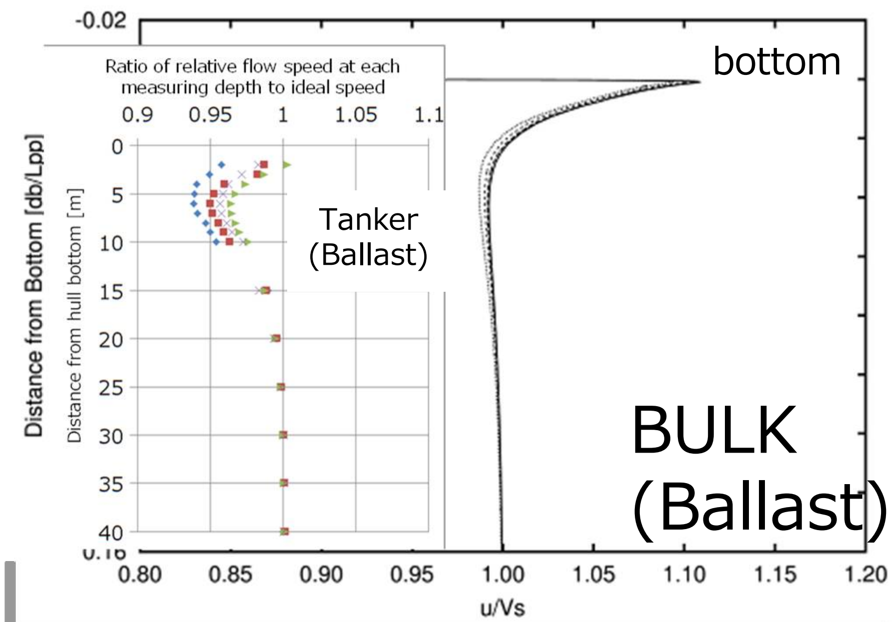
- ✓ Flow velocity distribution differs between PCC, i.e. slender ship and tankers, i.e. blunt ship, each has characteristic depends on hull form.
- ✓ Flow velocity distribution hardly changes by ship's speed under laden condition for both PCC and tankers.
- ✓ In tanker, flow velocity distribution varies according to draft.
- ✓ Flow velocity distribution changes by ship's speed under ballast condition for tankers.

Agreement to CFD









Conclusion

- ✓ The impact of current affects flow distribution under ship's bow bottom. The depth deeper, the greater the impact is. To minimize this impact the average analysis is useful by collecting sufficient number of data.

- ✓ The measuring target of shallowest depth should be within at least 5 meters from the ship's bow bottom to obtain the flow velocity surrounding the ship with 0.3% standard deviation.

- ✓ Flow distribution under the bow bottom is affected by difference in ship type, draft and speed.

Future

Following items are developing now.

- ✓ Self-learning capabilities (automation of Step1~3) for making flow velocity chart
- ✓ Function to display the true ship's speed through water (Step 4)