The Effect of Trim on Stability and Seakeeping of Tanker, Container, and Bulk Carrier

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Abstract. Stability and seakeeping are important factor that must be owned by a ship because it related to the safety of the ship, meanwhile the trim also affecting the ship operation. The study has a purpose to find out the impact of the trim to the stability and seaworthiness of the ship. The analysis is carried out on 3 types of ships, namely tankers, containers, and bulk carriers. A.N. Krylov method is using to calculate the stability, whereas the seakeeping is analysed by strip theory. Both of the results for stability and seakeeping are calculated by Maxsurf Software. Stability and seakeeping analysis was carried out when the ship is in even keel condition, trim by bow, and trim by stern in maximum and extreme condition. The results shows that the trim by stern of the ship can increased the ship stability rate by 0.5~5.4%. While the effect of trim on ship motions varies due to the differences characteristics of each ship. The results shows due to the trim impact by values of RAO's, which some of ship motions have increased meanwhile for some ship motion have decreased of ship motion condition.

1. Introduction
In the ship operation, trim is one of the most important factor, due to change of the trim can affects the ship’s stability and seakeeping. Two types of trim that are applied to a ship, namely trim by bow and trim by stern. Trim by bow will be decreased resistance of ship, meanwhile the high performance of ship stability and seakeeping can be affected more safety for the crew and ship. Purposes of the study to fine correlation trim, stability, and seakeeping.

Achieving a good trim condition can be done by calculating various trim angle and observing which one have the less power required for the ship to perform at a desired state [1]. Right achieving trim on a ship will improve efficiency in ship and finally will reduce fuel consumption [10].

The shape of a ship hull is also a huge factor in determining ships stability and seakeeping performance, also can be affected the ship resistance factors. Meanwhile the ratio more higher between draft and breadth of ship, the stability will be increased [4].

A conclusion can be drawn based from all the studies mentioned on the effects of trim optimization using only a few data model for the study. In order to calculate the effects of trim optimization on stability and seakeeping improvement and contrasting to all the research mentioned, this study using three types of ship namely tanker, container, and bulk carrier, which particularly use three samples for tanker and container ship, and two samples for bulk carrier ship. To calculate the ship stability use A.N
Krylov method, while the seakeeping calculation use strip theory. In the calculation of stability and seakeeping are using Maxsurf Software.

2. Methods
The steps to determining the best trim condition was calculated by three types of ship with various trim. This paper uses lines plans and General Arrangement drawing from ships that are currently operating as the sample, the lines plans then are redrawn on Maxsurf Software and will be used to set the load case on each ships accordingly on ship capacity. Principal Dimensions of each ships are shown in Table 1, Table 2 and Table 3 with TS stands for Tanker Ship, CS for Container Ship and BCS as Bulk Carrier Ship. An example of the original lines plan and General Arrangement source and those that were redrawn are shown in figure 1, figure 2 and figure 3.

Table 1. Principal Dimensions and Data for Tanker Ships

| Parameter                        | Value  | Unit |
|----------------------------------|--------|------|
|                                  | TS-1   | TS-2 | TS-3 |
| Length Between Perpendicular (L_{BP}) | 84.50  | 149.50 | 233.00 |
| Breadth (B)                      | 15.40  | 27.70 | 42.00  |
| Height (H)                       | 7.30   | 12.00 | 22.20  |
| Draught (d)                      | 5.00   | 7.00  | 15.45  |
| Service Speed (Vs)               | 11.00  | 13.00 | 15.70  |

Table 2. Principal Dimensions and Data for Container Ships

| Parameter                        | Value  | Unit |
|----------------------------------|--------|------|
|                                  | CS-1   | CS-2 | CS-3 |
| Length Between Perpendicular (L_{BP}) | 69.20  | 92.00 | 112.80 |
| Breadth (B)                      | 17.20  | 23.50 | 18.20  |
| Height (H)                       | 4.90   | 10.00 | 8.20   |
| Draught (d)                      | 3.50   | 6.50  | 6.20   |
| Service Speed (Vs)               | 12.00  | 11.25 | 12.00  |

Table 3. Principal Dimensions and Data for Bulk Carrier Ships

| Parameter                        | Value  | Unit |
|----------------------------------|--------|------|
|                                  | BCS-1  | BCS-2 |
| Length Between Perpendicular (L_{BP}) | 182.00 | 217.00 |
| Breadth (B)                      | 32.26  | 32.26 |
| Height (H)                       | 17.20  | 19.60 |
| Draught (d)                      | 12.49  | 14.20 |
| Service Speed (Vs)               | 14.70  | 14.50 |
After all the redrawing process has been done on Maxsurf, the next process is to use the general arrangement to locate all the ship tanks that will be used on calculation by Maxsurf Software. All the tanks loading condition then will be set according to IMO A.749(18) – “(Code on Intact Stability for All Types of Ship Covered by IMO Instrument)” Chapter 3.5.1.2 about Loading Conditions for Cargo Ship. The example of redrawn tanks on Maxsurf Will be shown on figure 3.

The amount of trim variety that were used to determine the best trim and to analyze seakeeping performance are five for each ship (trim by bow and trim by stern) while using the ship operating speed
for the seakeeping analysis. After analyzing each stability and seakeeping performance each respectively with the stated trim variations, the best trim condition that have positive impact on stability and performance on the each ship can be determined.

2.1. Trim Variations

Definition of trim is the differences between draft by bow (TF) and by stern (TA) of ship. Trim conditions is described by the equation below.

\[ \text{Trim} = T_A - T_F \]  

(1)

The calculation of trim is defined by the distance between LCB and LCG of the ship. The formula for calculation of trim as follows.

\[ \text{Trim} = \frac{(LCB - LCG) L_{BP}}{G_{ML}} \]  

(2)

The Variations of trim are limited by maximum value of the distances between LCB - LCG equals 1% Lpp on each trim by bow and trim by stern, with the formula as follows [9][12].

\[ \text{Trim Max} = \frac{1\% L_{BP}^2}{G_{ML}} \]  

(3)

Where; LCB: Longitudinal Center of Buoyancy (m); LCG: Longitudinal Center of Gravity (m); L_{BP}: Length Between Perpendicular (m); G_{ML}: Distance Between Center of Gravity to its Metacenter (m).

2.2. Ship Stability

To calculate the stability used each ship load case conditions which IMO Stability Criterion A.749 (18) Ch.3 become standard calculate, that will be shown on Table 4, and table 5 will show the seakeeping criterion [4].

Table 4. IMO Stability Criterion

| Code          | Criteria                                      | Value  | units |
|---------------|-----------------------------------------------|--------|-------|
| A.749(18) Ch3 | 3.1.2.1: Area 0 to 30                         | 3,1513 | m.deg |
| A.749(18) Ch3 | 3.1.2.1: Area 0 to 40                         | 5,1566 | m.deg |
| A.749(18) Ch3 | 3.1.2.1: Area 30 to 40                        | 1,7189 | m.deg |
| A.749(18) Ch3 | 3.1.2.1: Max GZ at 30 or greater              | 0,200  | m     |
| A.749(18) Ch3 | 3.1.2.1: Angle of maximum GZ                  | 0,350  | deg   |

Ship stability calculation method that is used in this paper is done by using A.N Krylof method with the help of Maxsurf software using the previously set loading condition following IMO standard and applying the following equation [7][8].

\[ F_b = g\Delta = \rho g \nabla \]  

(4)

Static stability (GZ) arms are calculated by.

\[ GZ = y_{B\phi} \cos \phi + Z_{B\phi} - K_g \sin \phi \]  

(5)

Where \( y_{B\phi}, Z_{B\phi} \) is the coordinate of the center buoyancy. To calculate the righting moment (RM) all of the heel angle can be calculated by formula.

\[ MR = g\Delta GZ \]  

(6)

Where \( F_b \) is buoyancy (KN); \( g \) is gravity (m/s²); \( \Delta \) is displacement of ship (Ton); \( \rho \) is density sea water (Ton/m³).
2.3. Seakeeping
Calculation and analysis on seakeeping in this paper with the help of Maxsurf was done using the Strip Theory Method to analyze each ship seakeeping performance. The process of determining if a certain trim condition have positive or negative impact on the ship is done by observing the RAO value of each of respective ship movement which are heaving, pitching and rolling. There are to calculate heaving, pitching and rolling by with the formula follow.

Strip Theory is a method used on Maxsurf to calculate and predict heaving, pitching and rolling, and other ship movement. There are 5 steps done in Strip Theory to calculate and predict ship movement which follows [13].

Gerakan heaving dihitung dengan menggunakan rumus yang diberikan oleh Bhattacharyya (Bhattacharyya, 1978) dalam Persamaan 1.

\[ a \ddot{\omega} + b \dot{\omega} + c \omega = F_0 \cos \omega_e t \]  

(7)

Where \( a \) is true mass (mass of ship plus added mass); \( \ddot{\omega} \) is \( \frac{d^2 \omega}{dt^2} \) is vertical acceleration; \( b \) is dumping constant; \( \dot{\omega} \) is speed or \( \frac{dz}{dt} \); \( c \) is restoring constant; \( z \) is shift point of KG; \( F_0 \) is amplitude from encountering force, \( \omega_e \) is encounter frequency; and \( t \) is time.

Pitching. Gerakan pitching dihitung dengan menggunakan Persamaan 2.

\[ a \dddot{\theta} + b \ddot{\theta} + c \theta = M_0 \cos \omega_e t \]  

(8)

Where \( a \) is the true mass from moment inertia; \( \dddot{\theta} \) is \( \frac{d^3 \theta}{dt^3} \) is angular acceleration for piching; \( b \) is damping moment coefficient; \( \theta \) is angular shift; and \( F_0 \cos \omega_e t \) is outdoor moment.

Rolling. Gerakan rolling dihitung dengan menggunakan persamaan 3.

\[ a \dddot{\phi} + b \ddot{\phi} + c \phi = M_0 \cos \omega_e t \]  

(9)

Where \( a \) is the true mass from moment inertia; \( \dddot{\phi} \) is \( \frac{d^3 \phi}{dt^3} \) is angular acceleration for rolling; \( b \) is damping moment coefficient; \( \phi \) is angular shift; and \( F_0 \cos \omega_e t \) is outdoor moment.

The calculation of seakeeping that has been carried out using the above equation, the results refer to standard in table 5.

| Table 5. Seakeeping Criterion (Tello 2010) |
|------------------------------------------|
| **Criterion**                           | **Maximum Value** |
| Roll                                     | 6 deg             |
| Pitch                                    | 3 deg             |
| Lateral Acceleration (at working deck AP & FP) | 0,1 g             |
| Vertical acceleration (at working AP & FP)   | 0,2 g             |

2.4. JONSWAP Wave Spectrum
JONSWAP Wave Spectrum is the wave specification that used in the seakeeping calculation, calculation then is done with the with the help of Maxsurf using the value provided by the application and setting the angle of wave encounter to 90° in order to be able to be able to observe all the ship movement. The equation that is used in this calculation is as follow [3]:

\[ S(\omega) = \frac{ag^2}{\omega^5} \exp \left[ -\beta \frac{\omega_P^4}{\omega^4} \right] \gamma^\alpha \]  

(10)
Constants that connect with wind speed and fetch length. Typical values in the north of the north sea are in the range of 0.0081-0.01. $\omega$ is wave frequency and $\omega_p$ is peak frequency wave.

3. Results and Discussions

The calculation for ship stability and seakeeping analysis have been calculated respectively, while each of the calculation, firstly considering the even keel condition and after that the trim of ship is determined by trim conditions using the equation 3. The result of the Maximum trim for each ship conditions as shows in Table 6.

Table 6. Maximum Trim for Each Ships

| Parameter | Value (m) |
|-----------|-----------|
| TS-1 | 0.65 | 0.52 | 0.99 | 0.41 | 0.81 | 0.77 | 1.56 | 1.73 |
| TS-2 | 0.842 | 1.05 | 1.69 | 1.85 | 1.82 | 1.65 | 1.35 | 0.97 | 0.54 | 0.09 |
| TS-3 | 1.988 | 1.14 | 1.96 | 2.18 | 2.15 | 2.00 | 1.70 | 1.27 | 0.76 | 0.22 |

The calculation of stability and seakeeping analysis of ship in every condition has been determined by Maxsurf Software. For stability analysis, the GZ value output will be drawn as curves and compared with all the others load case condition to determine the optimal trim condition on each ship. Meanwhile for the seakeeping analysis, the RAO output for heaving, pitching and rolling of each ship on every trim condition that have been determined will be observed to see if the trim have positive or negative impact on the ship movement.

3.1. Trim Optimization for Ship Stability

Result of using trim variations (trim by stern and trim by bow) to modify stability performance on each ship gave out two impact on which one have positive impact on the ship stability and the other one have negative impact on the ship stability. From the comparison of ship stability performance based on GZ value comparison while in even keel condition vs. trim by bow vs. trim by stern[2], trim by stern results in positive impact on ship stability while trim by bow results otherwise.

Table 7. GZ Value of TS-2, TS-2, and TS-3

| Angle | 0° | 10° | 20° | 30° | 40° | 50° | 60° | 70° | 80° | 90° |
|-------|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Trim (m) | **TS - 1** | **TS - 2** | **TS - 3** |
| 0.65 | 0.00 | 0.52 | 1.00 | 1.20 | 1.24 | 1.15 | 0.96 | 0.70 | 0.41 | 0.10 |
| 0 | 0.00 | 0.51 | 1.00 | 1.20 | 1.24 | 1.15 | 0.95 | 0.70 | 0.41 | 0.10 |
| -0.65 | 0.00 | 0.51 | 0.99 | 1.19 | 1.23 | 1.14 | 0.95 | 0.70 | 0.40 | 0.09 |
| 0.842 | 0.00 | 1.05 | 1.69 | 1.85 | 1.82 | 1.65 | 1.36 | 0.98 | 0.55 | 0.10 |
| 0 | 0.00 | 1.05 | 1.69 | 1.85 | 1.82 | 1.65 | 1.35 | 0.98 | 0.55 | 0.10 |
| -0.842 | 0.00 | 1.05 | 1.69 | 1.85 | 1.81 | 1.64 | 1.35 | 0.97 | 0.54 | 0.09 |
| 1.988 | 0.00 | 1.14 | 1.96 | 2.18 | 2.15 | 2.00 | 1.70 | 1.27 | 0.76 | 0.22 |
| 0 | 0.00 | 1.13 | 1.97 | 2.18 | 2.14 | 1.98 | 1.69 | 1.26 | 0.75 | 0.21 |
| -1.988 | 0.00 | 1.13 | 1.95 | 2.16 | 2.13 | 1.97 | 1.67 | 1.25 | 0.74 | 0.20 |
Table 8. Stability Criteria of TS-2, TS-2, and TS-3

| Code | Criteria | Standar | TS-1 | TS-2 | TS-3 |
|------|----------|---------|------|------|------|
| A.749 (18) Ch3 - Design Criteria | Max GZ at 30 or greater | ≥ 0,2 m | 1.239 | 1.853 | 2.177 |
| | Angle of maximum GZ | ≥ 25 deg | 40° | 30° | 30° |
| Applicable to All Ship | Initial GMt | ≥ 0,150 m | 2.87 | 5.886 | 6.299 |

Figure 4. GZ Curve of TS-2, TS-2, and TS-3

From table 7 to table 8, the stability improvement rate when the ship is on trim by stern are ranging from 0,4% up to 5% which is on TS-2. While the condition of trim by stern on all the tanker ship overall have a positive impact on the ship stability, trim by bow on the other hand, have negative impact on overall ship stability. Trim by bow impact on the tanker ship is reducing the ship performance stability from 0,7% and up to 3% which is on TS-2.

Table 9. GZ Value of CS-2, CS-2, and CS-3

| Angle | 0° | 10° | 20° | 30° | 40° | 50° | 60° | 70° | 80° | 90° |
|------|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Trim (m) | CS-1 | | | | | | | | | |
| 0.415 | 0.00 | 1.92 | 3.52 | 4.09 | 4.23 | 4.15 | 3.90 | 3.52 | 3.01 | 2.42 |
| 0 | 0.00 | 1.91 | 3.52 | 4.09 | 4.23 | 4.15 | 3.90 | 3.52 | 3.01 | 2.42 |
| -0.415 | 0.00 | 1.91 | 3.51 | 4.09 | 4.23 | 4.15 | 3.90 | 3.51 | 3.01 | 2.41 |
| Trim (m) | CS-2 | | | | | | | | | |
| 0.807 | 0.00 | 2.03 | 4.13 | 5.93 | 6.74 | 7.01 | 6.92 | 6.56 | 5.96 | 5.17 |
| 0 | 0.00 | 2.02 | 4.11 | 5.91 | 6.73 | 7.00 | 6.92 | 6.56 | 5.96 | 5.17 |
| -0.807 | 0.00 | 2.01 | 4.08 | 5.88 | 6.71 | 6.99 | 6.91 | 6.55 | 5.95 | 5.16 |
| Trim (m) | CS-3 | | | | | | | | | |
| 0.774 | 0.00 | 1.25 | 2.07 | 2.72 | 3.25 | 3.68 | 3.99 | 4.18 | 4.23 | 4.15 |
| 0 | 0.00 | 1.26 | 2.07 | 2.72 | 3.25 | 3.68 | 3.99 | 4.17 | 4.23 | 4.14 |
| -0.774 | 0.00 | 1.24 | 2.07 | 2.72 | 3.25 | 3.67 | 3.99 | 4.17 | 4.22 | 4.14 |
Table 10. Stability Criteria of CS-2, CS-2, and CS-3

| Code | Criteria | CS-1 | CS-2 | CS-3 |
|------|----------|------|------|------|
| A.749 (18) Ch3 - Design Criteria | Max GZ at 30 or greater | ≥ 0.2 m | 4.231 | 7.003 | 4.225 |
| Applicable to All Ship | Angle of maximum GZ | ≥ 25 deg | 40° | 50° | 80° |
| | Initial GMt | ≥ 0.150 m | 11.386 | 11.998 | 8.163 |

Figure 5. GZ Curve of CS-2, CS-2, and CS-3

From table 9 to table 10, the stability improvement rate when the ship is on trim by stern are ranging from 0.1% up to 5.72% which is on CS-3. While the condition of trim by stern on all the container ship overall have a positive impact on the ship stability, trim by bow on the other hand, have negative impact on overall ship stability. Trim by bow impact on the container ship is reducing the ship performance stability from 0.08% and up to 4.48% which is on CS-3.

Table 11. GZ Value of BCR-1 and BCR-2

| Trim (m) | 0° | 10° | 20° | 30° | 40° | 50° | 60° | 70° | 80° | 90° |
|----------|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| BCR-1    |    |     |     |     |     |     |     |     |     |     |
| 1.562    | 1.77 | 0.14 | 0.98 | 0.14 | 0.98 | 0.14 | 0.98 | 0.14 | 0.98 | 0.14 |
| 0        | 2.47 | 0.11 | 1.76 | 0.07 | 1.76 | 0.07 | 1.76 | 0.07 | 1.76 | 0.07 |
| -1.562   | 1.73 | 0.10 | 1.75 | 0.09 | 1.75 | 0.09 | 1.75 | 0.09 | 1.75 | 0.09 |

| Trim (m) | 0° | 10° | 20° | 30° | 40° | 50° | 60° | 70° | 80° | 90° |
|----------|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| BCR-2    |    |     |     |     |     |     |     |     |     |     |
| 1.733    | 2.87 | 1.35 | 2.16 | 1.35 | 2.16 | 1.35 | 2.16 | 1.35 | 2.16 | 1.35 |
| 0        | 2.86 | 1.34 | 2.15 | 1.34 | 2.15 | 1.34 | 2.15 | 1.34 | 2.15 | 1.34 |
| 1.733    | 2.84 | 1.33 | 2.13 | 1.33 | 2.13 | 1.33 | 2.13 | 1.33 | 2.13 | 1.33 |
Table 12. Stability Criteria of BCR-1 and BCR-2

| Code | Criteria                          | Standard | BCR-1 | BCR-2 |
|------|-----------------------------------|----------|-------|-------|
| A.749 (18) Ch3 - Design Criteria | Max GZ at 30 or greater           | ≥ 0.2 m  | 3.126 | 3.726 |
|      | Angle of maximum GZ               | ≥ 25 deg | 40    | 50    |
|      | Applicable to All Ship            | Initial GMt | ≥ 0.150 m | 4.697 | 4.659 |

Figure 6. GZ Curve of BCR-1 and BCR-2

From table 11 to table 12, the stability improvement rate when the ship is on trim by stern are ranging from 0.7% up to 4.25% which is on BCS-3. While the condition of trim by stern on all the Bulk Carrier ship overall have a positive impact on the ship stability, trim by bow on the other hand, have negative impact on overall ship stability. Trim by bow impact on the Bulk Carrier ship is reducing the ship performance stability from 1.3% and up to 7.56% which is on BCS-3.

While having the even keel and trim calculation been done on all the condition that have been determined, all the result of the stability calculation of all the ship are still in passing grade range of the IMO Stability Criterion A.749(18) Ch.3 that is shown on Table 4. And after all the calculation here’s all the optimal trim from within the established range of trim that has been determined of all the ships in this paper.

Table 13. Optimal Trim within the Established Range of Trim

| Parameter                  | Value (m) |
|----------------------------|-----------|
| Maximum Optimal Trim (m)   | TS-1      | TS-2      | TS-3      | CS-1      | CS-2      | CS-3      | BCS-1     | BCS-2     |
|                            | -0.650    | -0.842    | -1.988    | 0.415     | -0.800    | -0.774    | -1.562    | -1.733    |

3.2. Trim Optimization for Ship Seakeeping Performance

The optimization of ship seakeeping performance analysis is done with the help of Maxsurf Software by using variety of limited trim condition to see the impact of trim on a ship seakeeping performance compared to when the ship is on even keel condition. In addition to the trim condition, calculation for the seakeeping analysis on Maxsurf Software is done by using Strip Theory method that was shown on Equation 3, while using JONSWAP as the wave spectrum which is mentioned on Equation 4 with 90 degree as the wave encounter radius. The maximum amplitude output from Maxsurf Software of ship movement that were calculated with the strip theory method which are heaving, pitching and rolling then to be compared with other trim condition, including even keel.
### Tabel 14. Maximum Ship Motion RAO of TS-1, TS-2, TS-3

| RAO   | TS - 1 | TS - 2 | TS - 3 |
|-------|--------|--------|--------|
|       | Max Heave | Max Roll | Max Pitch | Max Heave | Max Roll | Max Pitch | Max Heave | Max Roll | Max Pitch |
| Trim 1 m by stern (m) | 1.574 | 6.629 | 0.498 | 1.507 | 6.67 | 0.484 | 1.442 | 6.554 | 0.512 |
| Even Keel (m) | 1.464 | 6.342 | 0.521 | 1.475 | 6.685 | 0.489 | 1.554 | 6.68 | 0.505 |
| Trim 1 m by bow (m) | 1.441 | 6.487 | 0.56 | 1.428 | 6.409 | 0.506 | 1.34 | 6.288 | 0.52 |

#### Figure 7. RAO at Even Keel Condition TS-1, TS-2, and TS-3

### Tabel 15. Maximum Ship Motion RAO of CS-1, CS-2, CS-3

| RAO   | CS-1 | CS-2 | CS-3 |
|-------|------|------|------|
|       | Max Heave | Max Roll | Max Pitch | Max Heave | Max Roll | Max Pitch | Max Heave | Max Roll | Max Pitch |
| Trim 1 m by stern (m) | 1.221 | 6.544 | 0.611 | 0.999 | 6.617 | 0.622 | 1.795 | 6.583 | 0.425 |
| Even Keel (m) | 1.164 | 6.542 | 0.623 | 0.991 | 6.607 | 0.636 | 1.841 | 6.674 | 0.427 |
| Trim 1 m by bow (m) | 1.161 | 6.551 | 0.627 | 0.992 | 6.681 | 0.653 | 1.725 | 6.664 | 0.435 |
From the calculation that has been done and as the table 16 to table 24 shown, the highest amplitude on each movement on every ship varies and does not have any consistent or particular pattern, with the amplitude of the roll surpassing the maximum seakeeping criterion that were shown on Table 5 [11]. This is caused by the different initial condition of all the ship have alongside with their criteria, but on the side of the trim impact on ship movement, the pitching movement was able to be mitigated by trim by stern, while trim by bow is mitigating the heave movement.
4. Conclusion
From the three types of ships that were used on this study namely tanker, container and bulk carrier. The resulting of the maximum trim for each ship conditions for tanker TS-1: 0.65 m, TS-2: 0.84 m, and TS-3: 1.99 m. meanwhile for container CS-1: 0.41 m, CS-2: 0.81 m, and CS-3: 0.77 m. Bulk carrier BCS-1: 1.56 m and BCS-2: 1.73 m. The result stability calculation shows, all the ships passes of IMO criterion and trim by stern on ships can increase the level of ship stability by 0.5% ~ 5.4%. The results shows due to the trim impact by values of RAO's, which some of ship motions have increased meanwhile for some ship motion have decreased of ship motion condition.

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