Risk Assessment Fishing Vessel Based for the Intact Ship Stability

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Abstract. Application of safety assessment and risk analysis using a risk-based approach for ship stability in ship operations at sea. However, there are currently no specific criteria and computational methods for risk assessment of ship stability. Based on the stability requirements for fishing activities at sea, the ship stability criteria will be explained in detail in this study. Calculation of stability used to obtain the GZ enforcement arm is carried out with the help of software for the shaking period using the International Maritime Organization (IMO) formula. Next, how to calculate parameters and determine certain coefficients for risk assessment of ship stability, and how to redraw the stability curve. Finally, proposed method is applied to ship model with comments and recommendations for monitoring to provide and overview. The study result indicate that the five loading conditions that occur on the ship have good stability by the criteria set by the International Maritime Organization (IMO). The value of GMt in each condition includes condition 1 and so on, 0.48; 0.48; 0.47; 0.46; 0.43. The results are presented in the form of F-N. Finally the sensitivity of the model is evaluated along with the assessment of associated uncertainties. The FN graph represents acceptable areas and unacceptable areas. Based on the results of data processing, the highest GM at GM Load-case 5 0.638 meters is in the Acceptable area. While Load-case 1 to Load-case 4 GM values sequentially Load-case 1: 0.487 meters; Load-case 2: 0.488 meters; Load-case 3: 0.47 meters; Load-case 4: 0.468 meters; is in an unacceptable area Unacceptable.

1. Introduction
Ship stability is essential for every ship that sails at sea. The instability of the ship due to extreme waves is often a factor for the ship to capsize. So that the consequences of these events can be fatal to the loss of the ship and crew [10-9]. Ship stability is the most basic requirement considered by shipping architects in designing a ship [2-7]. The purpose of studying ship stability is to provide an overview of the ship's behavior during sea shipping activities with the geometric characteristics of the sea and ship operations to achieve cost-effective and safe operations. The International Maritime Organization (IMO) in the late sixties and early seventies of the last century has made a criterion for ship stability. These criteria are used to this day by several ship design experts as a reference. However, the existing criteria design and essentially consist of the critical values of several stability parameters. The development of ships is now more modern both in its features and in the form of design. Of course, references related to the safety and stability of these ships are needed. Ship accident
scenarios based on the International Maritime Organization (IMO) there are several identifications of major ship stability accidents such as\[12\]:

- Loss of ship's return arm;
- The ship loses main engine power;
- The ship has problems with the maneuvering system, and;
- The ship has problems with the acceleration system.

The scenario proposed by IMO still does not provide all the possible causes of the ship's major significant loss of stability\[1\]. There needs to be another approach that can provide a detailed description of the ship's stability. The study carried out is based on a previous in-depth analysis of phenomena associated with the behavior of ships on waves. Such an approach makes it easier to develop different scenarios. The development of methods for assessing the safety of ships, carried out not only physical, but also the operational characteristics of the ship are also taken into account. Well-known methods, which take into account the elements mentioned above are methods based on risk analysis and assessment, such as those based on Safety Cases [13], widely used in the offshore industry – or else called Formal Safety Assessments [8-5], used in the shipbuilding industry to create new rules\[1\]. There is also the Risk-Based Design methodology [6], which is increasingly being used to design ships in unfavorable conditions.

2. Experiment Model
2.1 Ship Stability Criteria
The danger posed by sea power is the most danger for a loss of stability accident (LOSA) and keeping the ship in position. The stability criteria currently part of the IS Code include consideration of sea power in the form of weather criteria, originally adopted by Resolution A.562 (14) [1]. The ship's ability to withstand the combined effects of wind and rolling shall be demonstrated for each standard condition: loading, concerning the following drawings:

a. The ship experiences a constant wind pressure which acts perpendicular to the ship's centerline resulting in stable wind heeling Hw1.

b. The ship is rolling in waves around the inclination angle of 0 due to the steady wind. The rolling amplitude is equal to 1 to the windward side. The steady wind angle should not be greater than 16° or 80% of the main deck immersion angle.

c. In this situation the ship experiences a dynamic wind-heeling moment Hw2.

d. The area of b must be equal to or greater than the area of a (Fig. 1).

The IMO Stability Code includes simple weather criteria based on experience with ship construction and hull parameters. So the application of risk analysis is likely better for criteria development. The stability criteria are based on the requirements of the International Maritime Organization (IMO), Intact Stability for all types of the ship covered by instrument resolution A.749 (18), namely\[1\]:

a. The area under the return arm curve (GZ curve) to an angle of 30° is not less than 0.055 m.rad or 3.151 m.degrees;

b. The area under the return arm curve (GZ curve) to 40° angle or downflooding angle (θf) if the angle is less than 40°, is not less than 0.090 m.rad or 5.157 m.degrees. The downflooding angle (θf) is the angle of sway at which openings in the hull, superstructure or deckhouse which cannot be watertight closed are immersed. In applications, small openings through which leaks can pass are not considered open;

c. The area under the return arm curve (GZ curve) between an angle of 30° and an angle of 40° or between an angle of 30° and a downflooding angle (θf) if the angle is less than 40°, is not less than 0.030 m.rad or 1.719 m.degrees;

d. GZ return arm at an angle of sway equal to or more than 30° at least 0.20 m;

e. Maximum return arm occurs at a swing of more than 30° but not less than 25°;

f. The initial metacenter height of GM0 is not less than 0.15 m.
In Figure 1, the weather criteria must meet that area ba. The angle in the figure is defined as follows:
φ₀ : Swing angle at steady wind conditions: 16° or 80% sinking deck angle, the smallest is taken, it is recommended to the maximum;
φ₁ : Angle of rotation (roll) the direction from which the wind blows due to wave conditions;
φ₂ : Minimum from φᵢ, 50°, φₑ;
φᵢ : The angle of sway at which openings in the hull, superstructure or deckhouse, which cannot be closed watertight, sink;
φₑ : The angle at the second intersection of the wind heeling lever (lw2) of the stability arm curve (GZ).

Simulation-Based Approach to Ship Safety and Stability can be used to determine the ship's stability system. LOSA analysis shows that the causes of ship accidents can be related to functional, operational, externally generated causes or cargo related aspects [4].

2.2 Hazard Identification and Capsizing Scenarios
Hazard identification and rating procedures are the first step to continuing risk analysis. Concerning stability, hazard identification can be achieved using: standard methods involving evaluation of available data in the context of functions and systems relevant to the type of ship and its mode of operation. Hazard identification is based on analysis of historical data on reverse accidents, statistical analysis of causes of accidents available from various sources, detailed description of reverse accidents, analysis of multiple accidents using other methodologies or analysis by expert groups etc. The expert group only considered the first level of danger following sea power’s reverse scenario [4]. The influential external consequences include: wave movement; wind; crash; sinking; transfer of load on board; adding or subtracting weight etc [3].

2.3 Example
The object of this research uses a traditional 4 GT fishing boat from the fishing community of Bengkalis Regency, Riau Province, Indonesia. This traditional fishing boat operates around the Bengkalis Strait and reaches the Malacca Strait. Traditional fishing boats are still widely used by the Bengkalis fishing community. The fishing gear used is a net. The target fish caught are surface fish. The size of the ship includes an overall length of 11.50 meters; the length of each vertical line is 9.30 meters; 2.3 meters wide; boat height 1.2 meters; the water-laden height of 0.55 meters. The general shape of the ship's design can be seen in fig 2. Based on the calculation of the estimated weight, the weight and center of gravity of the ship are empty. Empty ship weight 3.02 Tons; center of gravity against AP (0th frame) 2.78 meters; center of gravity to the baseline 0.55 meters.
3. Results and Discussion

3.1 Ship Model Design

The first step in designing a ship with software is modeling the ship into the maxsurf program. Maxsurf education program was in this research. The ship is composed of a single hull. The fishing boat has one main engine on board with a capacity of 33 HP. The engine is located on the stern of the ship on the inside. The capacity of the 4 GT passenger ship is four crew. The ship is propelled by one propeller with dimensions of 19 inches. From the data on the methodology the ship body modeling is made with the help of maxsurf software figure 2:

![Figure 2. Bengkalis Traditional Fishing Boat Hull Model](image)

Loading conditions for stability analysis refer to IMO resolution A.749(18) Ch3 - Design criteria applicable to all ships for fishing vessels, namely [1]:

a. The ship is on a whole load of departure, with a full load of fuel with three oil containers, a crew of 2 people and carrying complete net equipment. The value of the ship's GZ is 0.26 at a sway angle of 49.1 degrees.

| Criteria                              | Value    | Units | Actual   | Status | Margin % |
|---------------------------------------|----------|-------|----------|--------|----------|
| Area 0 to 30                          | 3.1513   | m.deg | 3.4972   | Pass   | +10.97   |
| Area 0 to 40                          | 5.1566   | m.deg | 5.8431   | Pass   | +13.31   |
| Area 30 to 40                         | 1.7189   | m.deg | 2.3460   | Pass   | +36.48   |
| Max GZ at 30 or greater               | 0.200    | m     | 0.260    | Pass   | +30.00   |
| Angle of maximum GZ                   | 25.0     | deg   | 49.1     | Pass   | +96.36   |
| Initial GMT                           | 0.150    | m     | 0.487    | Pass   | +224.67  |
| Turn: angle of equilibrium            | 10.00    | deg   | 0.0      | Pass   | +100.00  |

![Figure 3. Bengkalis Traditional Fishing Boat Model](image)
b. Ship in sailing condition, with 80% fuel load, several the crew carrying complete netting equipment, and 0% catch. The GZ value in the second loadcase is 0.58 with a sway angle of 50 degrees.

Table 2. Recapitulation of the analysis of the stability of the loadcase 2

| Criteria                      | Value  | Units | Actual  | Status | Margin % |
|-------------------------------|--------|-------|---------|--------|----------|
| Area 0 to 30                  | 3.1513 | m.deg | 3.4839  | Pass   | +10.55   |
| Area 0 to 40                  | 5.1566 | m.deg | 5.8115  | Pass   | +12.70   |
| Area 30 to 40                 | 1.7189 | m.deg | 2.3276  | Pass   | +35.41   |
| Max GZ at 30 or greater       | 0.200  | m     | 0.258   | Pass   | +29.00   |
| Angle of maximum GZ           | 25.0   | deg   | 50.0    | Pass   | +100.00  |
| Initial GMt                   | 0.150  | m     | 0.488   | Pass   | +225.33  |
| Turn: angle of equilibrium    | 10.0   | deg   | 0.0     | Pass   | +100.00  |

c. Ships at full load return home, with 50% fuel load, the of crew and carrying full netting equipment, and 100% catch. The GZ value is at 0.249 with a tilt angle of 47.3 degrees.

Table 3. Recapitulation of the analysis of the stability of the loadcase 3

| Criteria                      | Value  | Units | Actual  | Status | Margin % |
|-------------------------------|--------|-------|---------|--------|----------|
| Area 0 to 30                  | 3.1513 | m.deg | 3.3849  | Pass   | +7.41    |
| Area 0 to 40                  | 5.1566 | m.deg | 5.6616  | Pass   | +9.79    |
| Area 30 to 40                 | 1.7189 | m.deg | 2.2767  | Pass   | +32.45   |
| Max GZ at 30 or greater       | 0.200  | m     | 0.249   | Pass   | +24.50   |
| Angle of maximum GZ           | 25.0   | deg   | 47.3    | Pass   | +89.09   |
| Initial GMt                   | 0.150  | m     | 0.470   | Pass   | +213.33  |
| Turn: angle of equilibrium    | 10.0   | deg   | 0.0     | Pass   | +100.00  |

d. The ship is fully loaded and returned home, with a fuel load of 10%, the number of crew members and carrying complete net equipment, and carrying 100% of the catch. The GZ value is at 0.247 with a tilt angle of 48.2 degrees.

Table 4. Recapitulation of the analysis of the stability of the loadcase 4

| Criteria                      | Value  | Units | Actual  | Status | Margin % |
|-------------------------------|--------|-------|---------|--------|----------|
| Area 0 to 30                  | 3.1513 | m.deg | 3.3641  | Pass   | +6.75    |
| Area 0 to 40                  | 5.1566 | m.deg | 5.6125  | Pass   | +8.84    |
| Area 30 to 40                 | 1.7189 | m.deg | 2.2485  | Pass   | +30.81   |
| Max GZ at 30 or greater       | 0.200  | m     | 0.247   | Pass   | +23.50   |
| Angle of maximum GZ           | 25.0   | deg   | 48.20   | Pass   | +92.73   |
| Initial GMt                   | 0.150  | m     | 0.468   | Pass   | +212.00  |
| Turn: angle of equilibrium    | 10.0   | deg   | 0.0     | Pass   | +100.00  |
e. The ship is in a condition without passengers but crew, without nets and without fuel. The GZ value in loadcase 5 is 0.289 with a sway angle of 57.3 degrees.

**Table 5. Recapitulation of the analysis of the stability of the loadcase 5**

| Criteria                     | Value     | Units   | Actual       | Status | Margin % |
|------------------------------|-----------|---------|--------------|--------|----------|
| Area 0 to 30                 | 3.1513    | m.deg   | 3.9764       | Pass   | +26.18   |
| Area 0 to 40                 | 5.1566    | m.deg   | 6.2275       | Pass   | +20.77   |
| Area 30 to 40                | 17.189    | m.deg   | 2.2511       | Pass   | +30.96   |
| Max GZ at 30 or greater      | 0.200     | m       | 0.289        | Pass   | +44.50   |
| Angle of maximum GZ          | 25.0      | deg     | 57.3         | Pass   | +129.09  |
| Initial GMt                  | 0.150     | m       | 0.638        | Pass   | +325.33  |
| Turn: angle of equilibrium   | 10.0      | deg     | 0.0          | Pass   | +100.00  |

Limiting KG is one type of analysis at HydromaxPro that will calculate the limiting value of KG on the ship design that has been made.

![](draft_amidship_limit_kg.png)

**Figure 4: Maximum KG Bengkalis Traditional Fishing Boat Model**

IMO has issued minimum stability criteria for various types of ships and these criteria have been used in the ship design phase and calculations in the stability book. Staff at sea and personnel ashore engaged in marine operations usually know the minimum allowable height for a GM and only use this to measure ship stability. However, this is only a single criterion, and meeting this criterion alone is not sufficient to ensure the required stability. There are equally important, or even more important, factors that must be considered for the head to have positive stability while sailing. In the Club's experience these limitations are not fully understood or accounted for.

Using the ship stability data, a static stability curve can be created and from this the dynamic stability of the ship can be determined. Dynamic stability is the ship's ability to withstand or avoid external heeling forces and this stability is directly proportional to the area under the static stability curve. So if the ship has high dynamic stability, the ship can withstand external forces well.
Figure 5. Minimum GM curve Bengkalis Traditional Fishing Boat Model

Each FN curve in Figure 6 corresponds to one loadcase load condition. The higher the GM, the fewer accidents there are. Loading condition coded LC1: 0.487; LC2: 0.488; LC3: 0.47; LC4: 0.468; LC5: 0.638. When viewed from the calculation results, LC 5 has: the highest GM[11]. These conditions meet the current stability requirements by a large margin. The division of the area shown [7] is divided into three areas. The first acceptable area is an acceptable area, the second area is an area that is still acceptable, and the third is an unacceptable area. By the condition loadcase 5 is in the ALARP area. Besides loadcase 5 is in an unsafe area. Also, the FN chart confirms this as follows:

Figure 6. FN curve with ALARP region curve Bengkalis Traditional Fishing Boat Model
In the engineer’s experience, it should be necessary to check the loading conditions, i.e., to verify if the conditions are realistic. In the case of a situation where it is not known that the ship is in a tilted condition, it is not possible to verify the estimated load. If the previous steps did not give relevant results, it would be necessary to change the hull shape.

There are advantages and disadvantages of risk analysis when used to assess the stability of ship safety for all conditions. The great advantage of a risk analysis method that it may be applied in new or even innovative cases that cannot be compared with data drawn from previous cases. In the process of designing modern ships, it is possible to use test models or computer simulations. Such an approach allows more accurate prediction of ship models than using simple empirical formulas based on experience. It is possible to use risk analysis in the evaluation of loading scenarios. However, such an analysis is impractical. Much better results are obtained by applying a holistic approach using multiple scenarios. Risk analysis can provide an overall view of the causes and consequences of accidents, and assess the impact of Risk Control [11].

Disadvantages of risk analysis include high costs, particularly those associated with time-consuming trials. In addition, not only the financial side but also a matter of time and personnel. In order to carry out a detailed risk analysis, it is necessary to gather a group of experts who are experts in risk assessment. The vessel’s lack of a good probability model makes it more difficult for the analysis to accurately. Current technological developments statistics can be used in the probability of this accident.

4. Conclusion
The results of the stability risk assessment using the traditional fishing boat model on the island of Bengkalis obtained several conclusions. The first conclusion is the value of ship stability is calculated based on the help of software with IMO standards A.749(18) Ch3 - Design criteria applicable to all ships with scenario 5 Loadcase is acceptable. The details are as follows for LC 1 The value of the ship's GZ is 0.26 at an angle of 49.1 degrees. Results of LC 2 The GZ value is at 0.58 with a sway angle of 50 degrees. Load-case 3 The GZ value is 0.249 for a tilt angle of 47.3 degrees. on Load-case 4 has a GZ value of 0.247 with a sway angle of 48.2 degrees. load-case 5 GZ value of 0.289 the angle of sway is at 57.3 degree.

The assessment results are seen from the results of the fatality number and the GM and KG values. The highest GM value indicates that the stability risk is acceptable. The FN graph represents acceptable areas and unacceptable areas. Based on the results of data processing, the highest GM at GM LC 5 0.638 meters is in the Acceptable area. While LC1 to LC4 GM values sequentially LC1: 0.487; LC2: 0.488; LC3: 0.47; LC4: 0.468; is in an unacceptable area Unacceptable.

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