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GM Loss and Stability Analyzes on MV. Pacific 88 During The Surabaya Port Accident

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Abstract**—** iNews on February 2, 2026 at 04.00 a.m, an accident occurred on the MV. Pacific 88 when it was on the starboard side alongside at Surabaya Port which caused the death of one stevedoring worker. Built in 1992, has a LOA of 88,4m with a LBP of 15,0m and a NT of 1,532 m3. The ship suddenly heels to the starboard side, the cargo on deck shifted and containers fell into the sea. The purpose of this case study is to analyze, understand the causes of ship accidents during loading and unloading from the science of ship stability by calculating the gravity metacentric height-GM value. This case study uses a qualitative descriptive method, processes secondary data, formulates, interprets formulas in numerical values theoretically to provide solutions and analyzes the causes of the KM. Pacific 88 ship accident without answering hypothetical variables. Internal factors such as shifting cargo weight, on deck loads, and ballast-free surface water conditions as well as shifting the 'g' point at the end top of the crane are factors causing the ship to heel due to errors in stability calculations and loading planning which affect the GM value moving upwards due to loading and unloading activities.

*Keywords***—***container cargo weight; ballast water; metacentric height; ship stability*

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I. INTRODUCTION

Stability is a major safety concern during cargo-handling operations, particularly on vessels that carry containers on deck and use their own cranes. As loading or unloading progresses, the ship's stability condition may change because of shifts in cargo distribution, suspended loads, ballast arrangements, or liquid movements in partially filled tanks. When these changes are not properly monitored, the ship may lose part of its stability margin and develop a significant heels. Maritime accident data according to the Indonesian Maritime Information Center (IMIC) in 2026 recorded 61 maritime accidents, meaning that maritime accidents are certain to continue to occur and remain an interesting topic of discussion every year in the maritime industry, although it is known that there has been a decrease in data in the last three years from 2023 to 2025 based on information accessed from the KNKT website. Why this incident continues to be a trend for study, analyzed because almost 80-90% of global trade still relies on sea transportation and human error is still one of the factors causing work accidents.

On 2 February 2026, MV. Pacific 88 reportedly heeled heavily to starboard while berthed at Jamrud Selatan Pier, Tanjung Perak Port, Surabaya, during cargo-handling operations. Several containers fell overboard, and one port worker lost his life in the incident (ANTARA, 2026). Although public reports provide a general description of the event, they do not contain the technical records needed to determine the vessel's actual stability condition at the time, such as the approved stability booklet, loading plan, tank sounding records, container Verified Gross Mass (VGM) data, and crane operating condition. This Indonesian-flagged general cargo ship was built in 1992 with an overall length of 88.4m and an overall width of 15.0m with a net cargo volume of 1.532 metric tons.This incident is relevant for technical examination because the vessel developed a heel while it was alongside and engaged in cargo handling. In such a condition, stability may be affected by changing operational loads, even in the absence of significant wave-induced motion. Because the final investigation findings are not yet available in the data used for this study, the analysis does not attempt to establish the definitive cause of the accident. Instead, it examines stability-related scenarios that may help explain how the reported heels could have developed during cargo handling. Accordingly, this study aims to: (1) identify stability-related mechanisms that may be associated with the reported starboard heels of MV. Pacific 88 during cargo-handling operations; (2) evaluate, through a reconstructed stability scenario, how cargo distribution, suspended-load effects, and possible free surface corrections may influence the vessel's effective GM and righting capability; and (3) draw operational implications for loading planning, ballast management, and stability monitoring during container-handling operations.

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Available reports indicate that the vessel heeled during cargo-handling operations and that containers subsequently fell overboard. From a ship-stability perspective, several factors need to be examined, including the transverse and vertical distribution of container weights, the effect of a suspended load handled by the ship's crane, the condition of ballast and consumable-liquid tanks, and the free surface correction associated with partially filled tanks. In this study, these

factors are treated as possible technical contributors rather than proven causes of the incident. Cargo handling and stability management form part of the broader obligation to maintain ship safety and seaworthiness. For the purpose of this study, the most relevant regulatory requirements are those concerning ship stability and verified container weight, because both provide the technical basis for assessing the vessel's loading condition. For a vessel alongside during cargo handling, the stability margin may be influenced by several interacting conditions, including the loading sequence, the vertical and transverse position of cargo weights, the movement of a crane-suspended container, and the free surface effect of liquid tanks. Therefore, the heeling event of MV. Pacific 88 should be examined through an integrated stability assessment rather than attributed in advance to a single operational factor. A reconstructed loading condition should account for free surface correction whenever slack tanks are present. Liquid movement in a partially filled tank produces a virtual rise in the ship's centre of gravity and reduces effective GM. In evaluating whether the reconstructed condition meets the required stability standard, this study refers to the International Code on Intact Stability, 2008 (2008 IS Code), adopted through IMO Resolution MSC.267(85), which specifies an initial transverse metacentric height criterion of $GM_0 \geq 0{,}15$ m for the relevant cargo-ship assessment, together with the applicable righting-lever criteria (IMO, 2008).The stability issue considered in this case is initial transverse stability during a moored cargo-handling operation. Metacentric height (GM) indicates the vessel's initial stability margin, while the righting arm (GZ) reflects its ability to return toward the upright position after heeling. During lifting operations, a suspended container is treated as acting at the point of suspension. If that point is high above the deck and positioned away from the vessel's centreline, the operation may reduce effective GM and create a transverse heeling moment (Derrett & Barrass, 2006).

The journal also explains that the stability of the ship can be simply seen from the three points above. Including the righting moment depicted by GZ. M or metacenter, a virtual point like a swinging pendulum that at a small angle of tilt the initial M does not change but at a large angle of tilt the angle of inclination > 15º occurs a shift. G or gravity, a virtual point that is supported works downwards to increase the ship's draft. B or buoyancy, a virtual point that is supported works upwards to float the ship. KG is the distance between point K (keel) and point G (gravity). GZ is the uprighting arm in positive stability called the righting moment uprighting arm and in negative initial stability the angel of loll is called the capsaizing moment follower arm. Previous studies on container-ship stability have mainly focused on planned loading conditions. For example, Ladosa, Trimulyono, and Samuel (2025) evaluated the stability of a 25,000 DWT container ship on the Surabaya–Kobe route under seven combinations of cargo loading and tank conditions using stability calculations and Maxsurf Stability.Their study shows how cargo and tank arrangements influence compliance with stability criteria. However, it does not examine an actual casualty in which a vessel developed a heels during cargo-handling operations. Center of bouyancy always moves to the heeled side to be centered in ½ to under water volume. The formula as follows:

$$KM = KG + GM \tag{1}$$
$$KM = KB + BM \tag{2}$$
$$KG = KB + BG \tag{3}$$
$$KG = KM - GM \tag{4}$$
$$GM = KM - KG \tag{5}$$

The buoyancy formula in Figure 2 explains that the downward pressure is depicted by point G and the fulcrum of the upward pressure is depicted by point B (buoyancy). Therefore, to calculate the GM value, the formula GM = KM-KB can be used. In the stability booklet-static curve table, by looking at the average draft of KM and KB values, the formula KB = 1/2 x draft is more general and practical. Rachman et al. (2014) entitled Identification of Ship Transverse Stability Lines Through Tilting Experiments Using Arduino-Based Delphi. The journal explains that the precision value depends on the block coefficient and the actual transverse shape of the ship's stern (rectangular plate, V-shaped, and U-shaped). Meanwhile, the formulation of the KM = KB-BM value is explained by KB (height of buoyancy from the keel).

The location of the KB point from the keel changes due to changes in the magnitude of the ship's wet heels or the ship's tilt. Young, & Kemp. (2001) and Rubianto. (1996), the following equation can be used to find the KB point value: for a flat-bottom vessel, KB = 0.50 x draft, V-bottom vessel, KB = 0.67 x draft, and U-bottom vessel, KB = 0.53 x draft, where 'd' is the vessel's draft. The height of the KB point can be obtained using a metacentric diagram or hydrostatic curve for each given draft height (Wakidjo, 1972). The BM value is obtained using the formula: BM = I/V, where I = moment inertia of the waterplane area, V = volume displacement.

One factor that needs particular attention in this case is the suspended-load effect during crane operation. Once a container is lifted clear of its original support, its weight is considered to act at the crane suspension point. This produces a virtual rise in G and reduces effective GM. When the crane is operated away from the ship's centreline, the suspended load also creates a transverse heeling moment. On a vessel with a limited stability margin, this condition may become more critical when combined with deck-cargo distribution and free surface effects. If seen in the image, point G is located at the center point of the ship's midship line, point G moves upward to G1 and the formulation forms a triangle with a calculated angle of ship tilt. As a result of the movement of point G upwards to G1 as seen in figure 3, this is what makes the temporary hypothesis that the KM.Pacific 88 ship tilted to the right during the loading and unloading process and other container cargo fell into the sea, because the GM value decreased, point G coincided with point M making the arm GZ = 0 or maybe even point G was negative passing point M or called the initial stability of the ship's angel of loll into a negative stability condition, a continuation moment occurred instead of a straightening moment that was working, also reinforced by the stowage plan, poor ballast water management.

II. METHOD

This study used a descriptive case-study approach combined with a scenario-based technical analysis of ship stability. It examines the reported heeling of MV. Pacific 88 during cargo-handling operations at Tanjung Perak Port on 2 February 2026. Since the study relies on secondary information, the analysis is intended to identify relevant stability mechanisms rather than establish the final cause of the accident. Incident data were obtained from four publicly available news reports: Kompas.id, CNN Indonesia, DetikJatim, and the official iNews YouTube news report. These reports were reviewed to identify the reported location, cargo-handling activity, direction of heels, containers falling overboard, and fatality. Statements attributed in the news reports to port or police authorities were treated as secondary reported information, unless the authors possess separate official documents that can be cited directly. Utilizes document analysis methods from previous studies on ship accident reports issued by the National Transportation Safety Committee (KNKT). The reported incident was examined using technical references on ship stability and relevant regulations. Standard stability relationships were used to discuss changes in KG and GM, while maritime professional knowledge supported the interpretation of the reconstructed scenario. Such interpretation was not treated as direct evidence of causation.The collected information was classified into two categories: reported facts and analytical assumptions. Reported facts comprised the vessel's cargo-handling activity, reported starboard heels, loss of containers, and fatality. Analytical assumptions comprised the reconstructed loading condition, the KM value used in the illustrative calculation, suspended-load effect, and possible free surface effect.

The analysis was conducted in two stages. First, the reported facts of the incident were identified from the selected sources. Second, these facts were examined through a reconstructed stability scenario focusing on cargo distribution, suspended-load effect during crane operation, and possible free surface effect in liquid tanks.

1. The explain the ship's virtual points operating under positive, negative, and neutral stability, which relate to the final GM formula obtained during the loading and unloading process. There is a force acting both downward and upward, in this case study focusing on the ship's tilted position, the uprighting arm GZ = 0. If it reaches point M beyond point M or GZ = negative (-), the uprighting arm is no longer the uprighting arm but becomes a forward arm, as formulated in Figure 1.The estimated GM was interpreted in relation to initial transverse stability. A positive GM indicates an initial restoring tendency, while a reduced GM indicates a lower stability margin. This interpretation was applied to the reconstructed scenario and not presented as the vessel's verified stability condition during the incident.

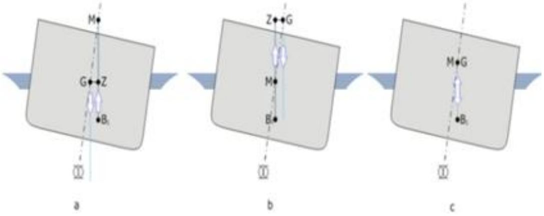

Figure 1. Positive, Negative & Neutral Stability

2. The determine the ship's buoyancy using the formulas :

   KG = 1/2 x depth (6)

   KB = 0,53 x draft (7)

   based on the shape of the stern. Given that the MV. Pacific 88 has a U-shaped hull, a simple formula for calculating the GM value requires knowing the KG, KB, and BM values, as described above.

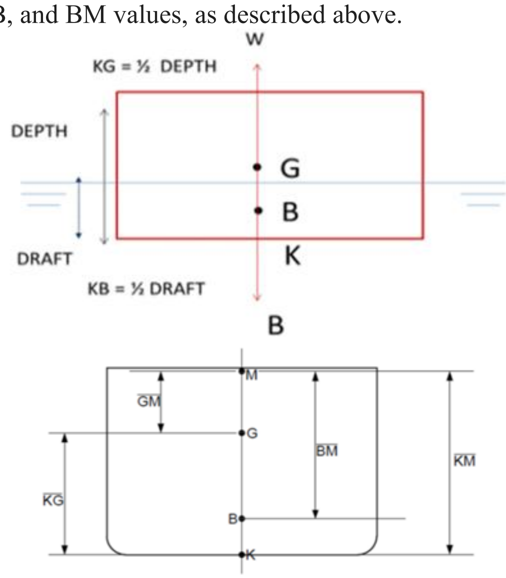

Figure 2. Low of Flotation

3. The analysis also considered the suspended-load effect. While a container is lifted by the ship's crane, its weight is treated as acting at the suspension point. This condition may raise the effective centre of gravity and create a heeling moment when the crane operates away from the vessel's centreline. Figure 3.

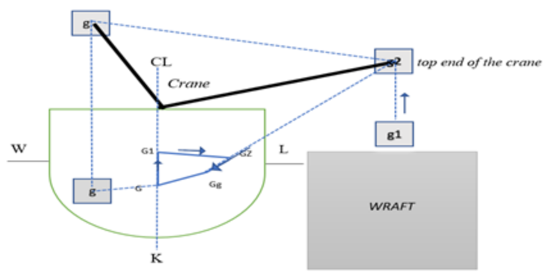

Figure 3. Shifting point g1 to g2 of the end top of the ship's crane

4. The formulate FINAL GM = KM - FINAL KG, before arriving at the GM value, the KG value is obtained using the formulation KG = Σ Moment/Σ Weight, while the KM value is obtained from the average ship's draft using the stability booklet or hydrostatic curve or the formulation can be obtained in the first step, to get an idea of the GM value that moves up as seen in the formulation in figure 5 and simple calculations in table 1 for the initial GM moment calculation against the keel.

   The possible free surface effect of partially filled ballast, fuel, or freshwater tanks was considered conceptually. Since tank sounding records and tank geometry were not available in the analysed data, no vessel-specific free surface correction was calculated. This study is based on secondary reports and an illustrative stability scenario. It does not use the vessel's approved stability booklet, actual stowage plan, tank sounding records, VGM documents, crane-operation records, or final investigation report. Therefore, the analysis identifies possible stability-related mechanisms but does not determine the definitive cause of the accident.

III. Results and Discussion

Problem. A ship's GM value can be calculated before loading, known as the empty ship GM, or the GM value after loading. The available information confirms that the heelsing occurred during cargo-handling operations; however, it does not provide the actual loading plan, tank condition, or approved stability data at the time of the incident. Therefore, the discussion below interprets cargo arrangement, suspended-load effect, and ballast condition as technically relevant mechanisms to be examined, rather than as confirmed causes of the casualty.If the ship is on a voyage, information about the cargo to be loaded and unloaded is obtained from the owner or charterer via fax-Inmarsat. In the initial condition or called GM empty ship or GM during the loading and unloading process or after loading all these activities are influenced by the loading and unloading planning and ballast water conditions, it is possible that at that time the condition of the MV.Pacific 88 ship had positive stability with a small GM value after carrying out container loading activities onto the ship. By the ship's side, it is possible that the monitoring activities for the initial stability - the initial GM value of the ship until the loading process took place were not monitored properly. Other things include one of the excessive container capacity weights and the condition of the ballast water which is also suspected of not being monitored properly by the decision maker, namely the ship's officers.

The first problem analysis is on the stowage plan-by plan or cargo planning. According to (Istopo, 2003) in the book entitled Kapal dan Muatanya, it is stated in one of the principles that includes 'protecting the ship', it is explained that a merchant ship officer (chief mate) must be able to carry out handling, arrangement and calculation of cargo to maintain the stability of the ship by having the correct final value of the ship's GM. Fulfillment of 'protecting the ship' above is done by arranging and arranging the cargo in the hold and on deck which is outlined in the cargo planning from the initial stage of the stowage plan-by plan until the completion of the final loading of the stowage plan-by plan. The cargo is divided transversely, vertically and longitudinally by calculating the weight, type of cargo, nature and dimensions, with the aim of preventing cargo concentration at the bottom which results in the ship being stift and tender cargo concentration focused on the ship is usually called on deck. It can be said in this case study that one of the causes of the tilt of the MV.Pacific 88 ship is the handling, the cargo arrangement outlined in the stowage plan-by-plan has not fulfilled the loading principle, namely 'protecting the ship' along with its explanation.

The second problem analysis in this respect, the crane operation should be discussed as a suspended-load condition: while a container is suspended, its weight is considered to act at the point of suspension. This may increase the effective vertical position of G and, where the crane operates off the centreline, introduce a heeling moment. In the present case, this mechanism is technically relevant, although it cannot be quantified without the lifted weight and crane outreach at the time of the incident. Darrett & Barrass (2006) in his book explains that when the MV. Pacific 88 ship crane lifts the container load from the pier, the formulation of the point g on the container load will move towards the end point of the crane as seen in Figure 3. If the first analysis of the principle of protecting the ship is not fulfilled, it can be explained that at the time of the incident the GM value of the MV.Pacific 88 ship also shows a decreasing value. If seen from the triangle in figure 3 the shift of point G moves upwards to G1 on the ship's center line meaning that the container load being lifted, especially if it is predicted that the load capacity lifted by the ship's crane exceeds the container load capacity limit (heavy load), the diagonal point g1 automatically moves towards 'g2' at the end of the ship's crane. This illustrates the acceleration of the movement of point G to the condition G = M with GZ = 0 or the point exceeding point M which is called negative stability or GZ is no longer a supporting arm but a supporting arm. In this condition, because the KM.Pacific 88 ship is in the berthing pool so that the forces acting from outside cannot affect the conditions at the time of the incident, this can be proven that the ship did not capsize but remained in a right-leaning condition.

The third problem analysis is the condition of the ballast water on the MV.Pacific 88 ship has a large free surface, it is estimated that the ballast water that supports the weight of the ship in the composition of the ship's stability calculation is lighter than the amount of cargo that has been loaded on board. So it is estimated that the arrangement of ballast water filling so that the ship's stability remains positive with the right GM value is delayed. Because in addition to the process of loading and unloading containers seen in the conditions of the Km.Pacific 88 ship incident which caused the ship to tilt, ballast water filling is a factor to increase the GM value so that the ship has the right GM value after the stability calculation is carried out.

The fourth problem analysis is the lashing or fastening factor, locking (twist lock, turnbuckles, bridge fitting) of the container load so that it does not move, shift when the ship sails, which was found not to have been implemented. To clarify the assumption above from figure 4 it can be seen that the loading has not been completed, it can be seen by the arrow in the figure below, in fact the container load has shifted to the right, 30 fell into the sea and the container lashing tool was not found in the figure. Lashing of container cargo was not the main factor causing the MV. Pacific 88 to tilt at the dock, as the cargo lashing procedure is generally carried out when container loading is almost complete or is carried out in the hold of a ship that has already been loaded.

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Solution to the first problem of cargo planning (stowage plan-by plan) is overcome by the ship's officer (first mate) starting the creation of a tentative stowage plan-by plan up to the final stowage plan-by plan document. The contents include information on the name of the ship, voyage, front and rear draft, trim, number of 20ft and 40ft containers, refeer containers, container positions according to tier, row, bay, container code, container weight and capacity of each hold. This final stowage plan document is signed by the first mate and acknowledged by the captain, then this document is distributed to the watch officer and TKBM foreman. This data is supporting data needed in calculating the final GM value of the KM.Pacific 88 ship so that the stability of the ship is maintained and remains seaworthy. In the Indonesian regulatory context, the relevance of container-weight information to stowage planning should be referred to Regulation of the Minister of Transportation of the Republic of Indonesia Number PM 25 of 2022 concerning Container Seaworthiness and Verified Gross Mass, which replaced PM 53 of 2018. This requirement is also aligned with the SOLAS VGM framework, under which verified gross mass must be available to the master or representative and the terminal representative sufficiently in advance for preparation of the ship stowage plan. The Verified Gross Mass (VGM) document or certificate must be signed by the Shipper or Third Party and submitted to the Captain and Port Business Entity or Port Operator and local Harbor Master to be used as a Ship Stowage Plan.

Stowage plan-By plan can be done manually or using applications, currently almost all ships have used applications in making loading calculation plans and the results of the stability information displayed are faster, more detailed and very accurate. The image above is simple information on container loading planning that is similar to the type of ship MV. Pacific 88. This is a recommended solution for making loading plans before loading is carried out on the ship. From there, the information data on ballast water, draft, displacement, trim, cargo weight, container location, container type and others that describe the stability of the MV. Pacific 88 ship, including the impact of ship stability if the planner makes changes to the above data using the application, manually it can also be seen in the example of the initial GM calculation of the moment on the keel in table 1.

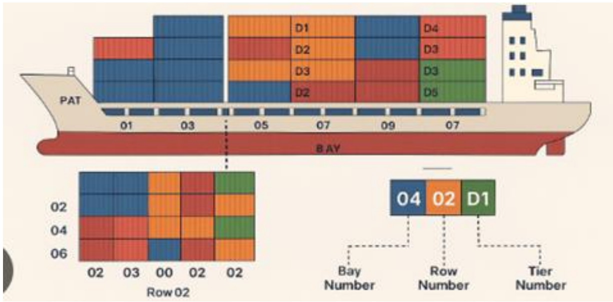

Figure 4. Stowage Plan-By Plan Container Ship's

Solution to the second problem in this respect, the crane operation should be discussed as a suspended-load condition: while a container is suspended, its weight is considered to act at the point of suspension. This may increase the effective vertical position of G and, where the crane operates off the centreline, introduce a heeling moment. In the present case, this mechanism is technically relevant, although it cannot be quantified without the lifted weight and crane outreach at the time of the incident. So when the container is about to be loaded, the ship's officer already knows the existing GM value as well as the change in the GM value if the container cargo is to be loaded. By knowing the existing GM value, there will be efforts to prevent the shift in the GM point from shrinking before the container cargo is loaded, by regulating the water ballast. An alternative qualitative approach to overcome the second problem refers to the Regulation of the Minister of Transportation of the Republic of Indonesia Number PM 44 of 2021 concerning Ship Stability, in Article 13 paragraph 2 (g) and (F). The initial metacentric height (GM) is not less than 0.15 m (zero point one five meters), and the weather criteria are in accordance with the provisions of the (International Code on Intact Stability/IS Code) 2008 and its amendments.

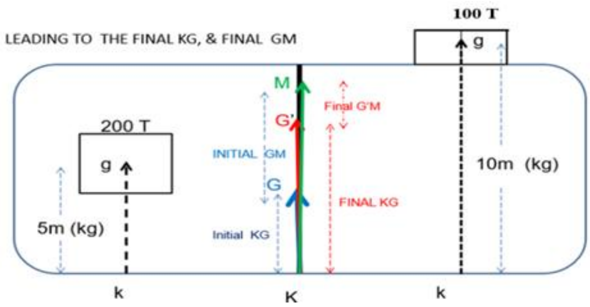

Figure 5. Leading to Final KG & GM

TABEL.1
ILLUSTRATIVE CALCULATION OF KG AND GM BASED ON THE RECONSTRUCTED STABILITY SCENARIO

Items	Tonnage (+ loading and - unloading)	KG (meter)	Moment about Keel. Tonnage x KG
Displacement	+8000	7.5	+60000
Constant	+150	6.5	+975
Ballast	+100	6.1	+610
Diesel Fuel	+150	6.1	+975
Fresh Water	-30	6.3	-189
Total	8370		62371

Source: Author (2026)

$$\text{Final KG} = \frac{\Sigma \text{ Momen}}{\Sigma \text{ Berat}}$$

$$\text{Final KG} = \frac{62371}{8370}$$

Final KG = 7.5 meter.

The estimated GM of 1.05 m is higher than the minimum initial GM criterion of 0.15 m stated in the 2008 IS Code. However, the code assesses stability through more than the minimum GM criterion alone; the applicable righting-lever criteria and free surface correction must also be considered. Accordingly, the illustrative GM value in Table 1 cannot by itself demonstrate that the vessel satisfied the required stability condition during the incident. The formula used is Mean Draft = Forward Draft + Aft Draft / 2. If the KM value in the stability booklet table is 8.50 meters, the initial GM of the KM.Pacific 88 can be calculated as follows: Using the assumed KM value of 8.50 m, the estimated GM is calculated as GM = KM − KG = 8.50 − 7.45 = 1.05 meter. The initial GM value of 1.05 meter for the MV.Pacific 88 is explained as follows: According to the International Code of Intact Stability Part A - Mandatory Criteria, 2008, the minimum GMMo, in accordance with the general regulations for cargo ships (General Cargo Ships) in the 2008 IS Code, the initial metacentric height (GMo) must not be less than 0.15 meters. The GM value of 0.15 m is the absolute minimum limit. The detailed criteria of the 2028 International Code of Intact Stability regarding the properties of the stabilizer lever curve are as follows:

1. The area under the stabilizer lever curve (GZ curve) must not be less than 0.055 meter-radians up to a heel angle of <p = 30° and not less than 0.09 meter-radians up to a heel angle of <p = 40° or a flood angle of <pr if this angle is less than 40°. Furthermore, the area under the stabilizer lever curve (GZ curve) between heel angles of 30° and 40° or between 30° and <pr if this angle is less than 40° must not be less than 0.03 meter-radians.
2. The stabilizer lever GZ must be at least 0.2 m at heel angles equal to or greater than 30°.
3. Maximum heeling must occur at a heel angle of not less than 25°. If this is not feasible, alternative criteria, based on an equivalent level of safety, may be applied with the approval of the Administration.
4. The initial metacentric height of the GMo must not be less than 0.15 m.

Severe wind and rolling criterion (weather criterion) . The ability ofa ship to withstand the combined effects of beam wind and rolling shall be demonstrated, with reference to figure 2.3.1 as follows:

1. The ship is subjected to a steady wind pressure acting perpendicular to the ship's centreline which results in a steady wind heeling lever (*lw1*).
2. From the resultant angle of equilibrium ($\varphi 0$), the ship is assumed to roll owing to wave action to an angle of roll ($\varphi 1$) to windward. The angle of heel under action of steady wind (φ0) should not exceed 16° or 80% of the angle of deck edge immersion, whichever is less.
3. The ship is then subjected to a gust wind pressure which results in a gust wind heeling lever *(lw2)*.
4. And under these circumstances, area b shall be equal to or greater than area a, as indicated in figure 2.3.1 below:

In actual operation, container ships often require significantly higher GM values to meet the GZ curve area criteria, especially under full load conditions. Historically, the MV. Pacific 88 was known as a general cargo ship and was later converted to a container ship after meeting the requirements for its class. This calculated GM represents an illustrative reconstructed scenario and should not be interpreted as the verified stability condition of MV. Pacific 88 at the time of the incident. To make it easier to understand, see the image below.

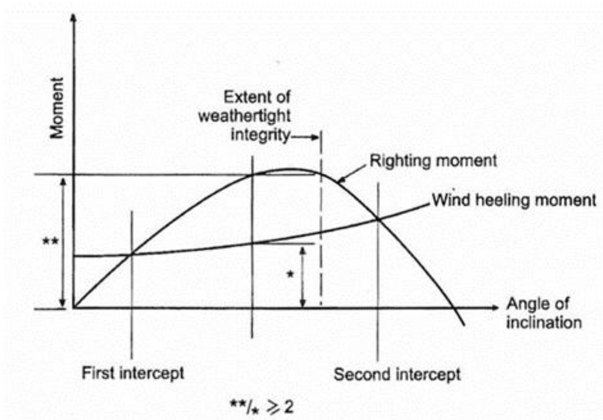

Figure 5. Righting Moment and Wind Heeling Moment Curves

Solution to the third problem this point is important because the GM criterion in the 2008 IS Code is applied after correction for free surface effects. Since the present study does not contain tank sounding records or tank geometry, free surface effect should be retained as a possible reducing factor in the stability margin, rather than reported as a calculated condition of KM. Pacific 88.The measurement of the tanks above provides information on how many tons of ballast water, fuel and fresh water weigh before loading begins, so that the free surface of the tank can be calculated and when the ballast water will be filled or discharged to maintain the GM value at the right value. An alternative qualitative approach to solving the third problem is that ballast water functions to add weight at the bottom, ballast lowers the center of gravity, thereby increasing the safe distance between the center of gravity and the center of buoyancy in ship stability in accordance with the International Maritime Organization Convention Ballast Water Management (BMW) in 2004.

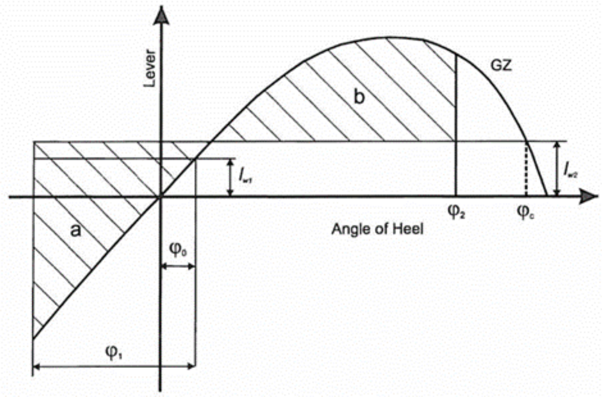

Figure 6. Severe Wind and Rolling

Solution to the fourth problem is the lashing factor or container fastening is overcome by carrying out port duty officer with full responsibility, meaning always coordinating with the foreman, planner, watch mate and first mate when the lashing can be carried out while still prioritizing the safety of the land crew and the ship's crew who assist in completing the lashing, this is because the work can be done in parts where the hold has been loaded. To be known with the modern system of loading and unloading containers from before the ship arrives, the ship pier and the ship departs neatly arranged on time according to the predetermined schedule. Installation of lashing that does not comply with lashing procedures can cause various problems, such as endangering the safety of the ship, damage to the cargo, or the cargo can fall into the sea. An alternative qualitative approach to overcome the fourth problem is guided by the Shipping Law of the Republic of Indonesia Number 17 of 2008, a seaworthy ship is a condition of a ship that meets the requirements for ship safety, prevention of water pollution from ships, manning, loading lines, loading, crew welfare and passenger health, legal status of the ship, safety management and prevention of pollution from ships and ship security management for sailing in certain waters. Lashing is a condition that is called seaworthy which has an impact on the stability of the ship according to the regulations above.

Overall, the analysis suggests that cargo distribution, suspended-load effect, and possible free surface effect are the most relevant stability mechanisms for interpreting the reported heels of MV. Pacific 88. This finding complements previous stability studies conducted under planned loading conditions by extending the discussion to a reported casualty during cargo handling. The practical implication is that stability monitoring should not be limited to the final stowage condition, but should also consider temporary lifting conditions, verified container weights, and slack-tank effects during loading and unloading.

Figure 6. Lashing Container not Installed

IV CONCLUSION

In the case study of the MV. Pacific 88, which experienced a heels to starboard while berthing at the Jamrud Selatan pier in Tanjung Perak Port, Surabaya, academically, it can be concluded that the heels of the MV. Pacific 88 was caused by : The stability analysis of the MV. Pacific 88, which resulted in an initial GM value and a GM value during the container loading process, failed to be properly implemented, resulting in the GM value decreasing to GMo and not being monitored. A proper analysis was not conducted in the stowage plan-by-plan preparation in accordance with regulations, resulting in the shift from the container's 'g' point to 'g1' at the end of the crane, particularly for containers with larger capacities, not being monitored. A calculation analysis of the shift in GM values due to the impact of ballast water and free surface was not performed, resulting in unmonitored GM values.

While the lashing that was not carried out on the container cargo that resulted in the shift of the container cargo to starboard was not the main factor in this case, more the direct impact of the ship's tilt so that the container cargo shifted to starboard.

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