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A Proposed Design Technique for Recycling of Very Large Container Ship

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ABSTRACT

Ship recycling is a significant industry controlled by a few countries that violates local and international laws, putting public health, safety, and the environment at risk. The European Union Ship Recycling Regulations and the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships have created new ship recycling regulations that may be expensive and difficult to implement. The high cost of ship recycling by conventional means lowers industry profits. The best options have been the subject of numerous studies in recent years, but no one has yet discovered the ideal answer, which has led researchers to devote their efforts in that direction. By employing the MAXSURF program to simulate the cutting process on a 400 m container ship as a case study, the stability of each block following cutting is examined. The results show that implementing this new approach early in the design phase could enhance the recycling process when the ship is retired. Also, it is proposed a modified ship recycling process through a new block diagram to show the recycling process concerning stakeholders. Applying this concept will solve the research problem, which concerns shipowners switching from a standard shipbreaking yard to a substandard one. Ultimately, the shipbreaking yard's capabilities will be less than the ship designer's requirements for his ship recycling plan.

Keywords: Ship Recycling, Ship Recycling Plan, Standard Shipbreaking Yard, Substandard Shipbreaking Yard.

1. INTRODUCTION

After the Second World War, the shipbreaking business was founded and operated until 1980 mostly in industrialized nations such as Germany, Italy, the United Kingdom, the United States, and Scandinavia. The ship recycling business has recently expanded to five more nations: Bangladesh, China, Pakistan, India, and Turkey. This is because the latter gives a better price for scrap tons than the former. A vital component of maritime commerce and finance is also the shipbreaking sector. In times of stagnation, ship scrapping provides ship owners with income. When there is an excess of ships available in the market for shipments, the disposition of ships determines how the percentage of the trade fleet and assists in balancing the supply and demand for ships used in marine transportation by removing outdated vessels from the market [1]. Ship recycling using conventional techniques can be economical. The most ecologically responsible choice is ship recycling using traditional processes, even if they may only offer slight financial advantages. Also, because recycled materials do not provide income, coral reefs have the least economic advantage of all [2]. This is because of the way that a significant part (60% to 80%) of the heaviness of a ship is steel. When the demand for scrap steel is great and there is a high supply of obsolete ships, the offer price will rise. These factors are combined in the disposal market with a huge inventory of old ships and low demand for scrap steel [3]. Shipbreaking is the most efficient way to get rid of outdated ships because it is perceived to promote the sustainable and economic development of society, as the International Maritime Organization (IMO) has acknowledged through the publication of the Hong Kong Convention and the European Union recycling laws [3]. Furthermore, as a result of the IMO's adoption, the ship recycling industry will employ hundreds of thousands of trained, semi-skilled, and unskilled workers in developing countries like Bangladesh, China, India, and Pakistan [2, 5]. Additionally, millions of tons of scrap are salvaged from ships each year through recycling, including different types of machinery, equipment, and other fittings for use as spares when the ship's life ends [6], [7], [8], [9].

The price of obsolete ships is influenced by many factors both locally and nationally, including labour wages and the type of recycling method used (beaching, slipway, alongside, dry dock), as well as the intended use of the demand for scrap steel (melting or re-rolling) and other recyclable items (used machinery, furniture, etc.) [4]. Many ship owners are unaware of green shipbreaking yards since they do not provide a satisfactory value for scrap tons when compared to other yards that do not meet their standards. The value gap between these yards is basically because of the additional expense of maintaining high health, safety, and environment (HSE) principles and the interest in reusing offices and labour force government assistance needed for green ship recycling yards [5]. For a ship recycling yard to be profitable, the total cost of the cycle should be less than the wages. Thus, the green ship recycling yards are unable to match the price that the inferior yards using conventional disposal methods are willing to provide. Just as the value gap between the two yards is reduced or even closed, they may become more significant. The issues that the shipbreaking industry faces have been linked to safety, health, and environmental concerns [10]. Variables affecting green ship recycling were also looked into to prevent pollution from shipbreaking [11]. In addition, the questionnaire was created and distributed by managers, scientists, and workers in the ship recycling sector. In addition, a 2017 investigation detailed the challenges that recycling facilities, governments, and ship owners confront when attempting to recycle obsolete ships in an environmentally friendly way [12]. Furthermore, an analysis was conducted using information obtained from a review of the literature, an examination of pertinent papers, semi-structured interviews with chosen Norwegian industry participants, websites and non-governmental organizations, documents, and interviews.

shipbreaking involves ship scrapping, which is a major source of maritime pollution [13]. This comprises harmful substances that, if released into the environment or the general public's health, might be extremely dangerous. An assessment and analysis were conducted with a focus on the 2009 Hong Kong International Convention on the Safe and Environmentally Sound Recycling of Ships, which addresses the regulation's history, framework, and implementation [14]. The 2009 Hong Kong Convention establishes guidelines for the marine recycling sector by outlining the responsibilities of the flag states, parties, and recycling facilities that fall under its authority, as well as the administration and enforcement procedures for shipbreaking. The article discusses ship recycling in detail and will eventually have an impact on how the whole community ultimately accepts this Convention.

The challenges of implementing into practice the 2009 Hong Kong International Convention and EU Regulation 1257/2013 were investigated [15]. The EU Regulation 1257/2013 and the Hong Kong Convention on ship recycling are argued to represent a retreat in ship recycling regulation, despite their acknowledged benefits. Despite [16] their research on the consequences of registering ships in various nations immediately before recycling their vessels creates a way around strict national and international regulations. The safe, easy-to-recycle and ecologically friendly ships' design is essential to facilitating safe and environmentally sound ship recycling and raising the standard for recycling facilities. The idea of "design-for-recycling" ought to be implemented for ship designs to be improved.

The author's strategy was implemented in 2024 by the suggested calculation procedure that would be taken into account in all structural plans and details throughout the new ship's design phase, facilitating the green shipbreaking process [17]. This study, however, addresses the information about the ship's records that will be kept on board to be helpful to the shipowner and the ship's breaking yard at the end of the ship's life, even as early as the design phase. This could be derived from some unique data, such as lightweight distribution, ship’s lines, general arrangement plan, tank arrangement, ship’s stability manual, loading manual, offset table and capacity plan. A suggested method for dismantling the demolished ship can be carried out to speed up the ship scrapping process, which will be used by the shipbuilding yard or the shipbreaking yard that complies with regulations, by knowing the subsequent information from the ship's documentation. Consequently, the shipbreaking process should be considered throughout the design phase since the methods utilized for shipbreaking affect the maritime environment. Furthermore, the health and safety of those working in this industry as well as the crew members who work on board ships are impacted by shipbreaking. Lastly, because scrap is crucial to the steel sector, it has an impact on steel factories. Lastly, the goal of this article is to formalize the process of scrapping under international conventions and rules. Through the involvement of multiple entities, such as the ship owner, classification societies, shipbuilding yard, flag state control, port state control, and the International Maritime Organization, and placing the shipbreaking process in the design spiral, it will be possible to eliminate substandard shipbreaking yards that do not comply with international conventions. Providing a secure, environmentally friendly method of ship scrapping is the second objective.

2. SHIP RECYCLING ACTIVITIES CONCERNING STAKEHOLDERS

The following block diagram, as seen in Figure 1, covers the processes and activities related to ship recycling and the extent to which they interfere with the parties involved [18].

The Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships, 2009, which was ratified on May 15, 2009, established the following requirements. Ship recycling facilities and ships over 500 GT are subject to these regulations.

(1) Ship requirements

- On recently built ships, avoid using asbestos, ozone-depleting substances, hazardous paints, and polychlorinated biphenyls (PCBs).
- the presence of an inventory of hazardous materials (IHM) with the location, kind, name, and volume of the hazardous materials listed.
- Periodic inspection by appropriate flag nation agency or recognized organization.

(2) Ship recycling facility requirements

- Supplement of the document for authorization of ship recycling facility (DASR) by the competent authority or recognized organization of the recycling nation.
- Periodic inspection of sound operation and management to mitigate environmental pollution and industrial accidents.

(3) Requirements for the ship recycling process:

- The ship recycler shall provide the ship recycling plan (SRP) based on information provided by the ship owner, and the ship owner shall finalize the inventory of the hazardous list.
- The ship recycling nation approves the SRP
- The flag nation conducts the final inspection (confirming the authorized SRP and ensuring the IHM complies with the ship's real condition).
- The International Certificate of Recycling Readiness (ICRR) is issued.
- Recycling
- Notation of completion of recycling to the Flag Nation and Recycling Yard Nation.

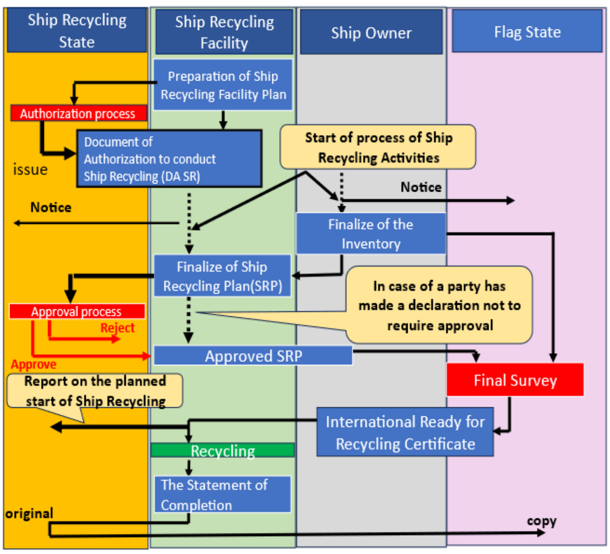

Figure 1: Ship recycling process under convention [18].

The ship recycling procedure that complies with the Convention's standards is displayed below. The ship recycling process is shown in Figure 1 through a block diagram according to the Hong Kong Convention and it is explained in the following paragraphs. The interaction of stakeholders in the ship recycling process based on HKC will be clarified through this block diagram. All of the following procedures are performed at the end of the ship’s life before commencing the recycling process. Moreover, the ship recycling facility prepares the ship recycling facility plan, which must be approved by the state of the ship recycling yard, and then the state issues a document of authorization to conduct ship recycling (DASR). Further, the shipowner begins the activities of the ship recycling process by notifying both the ship recycling state and the flag state. Additionally, the shipowner conducts a final review of the inventory of hazardous materials (IHM) and sends it to the ship recycling facility, then the ship recycling facility will review the ship recycling plan based on IHM, and then the ship recycling facility approves this plan from the ship recycling state. Furthermore, the ship recycling facility sends the approved plan with a review of IHM to the flag state to conduct a final survey. Then, the flag state issues an international ready-for-recycling certificate, and the certificate is sent to the ship recycling facility, which in turn carries out the recycling process and prepares a report to the ship recycling state. Finally, the ship recycling facility prepares a statement of completion and sends the original copy to the ship recycling state and a copy to the flag state.

3. PROPOSED MODIFIED SHIP RECYCLING ACTIVITIES

Because noncompliant shipyards are unable to do the scrapping due to limitations in their capabilities, ship owners will not be able to escape to those shipyards. As a result of the author's proposal to set up the scrapping procedure under the Hong Kong Convention, shipowners will be forced to scrap their vessels in shipyards that abide by that convention.

The author's proposal is presented through a more recent proposed block diagram, as shown in Figure 2, to clarify the researcher's point of view through modifications that must be carried out. This was done by researching international conventions and regulations related to ship recycling as well as concepts of ship design. From the end-of-life scrapping period to the early design stage is the new plan for ship recycling. Moreover, the ship designer is dedicated to preparing the ship recycling plan rather than the ship recycling facilities.

Furthermore, it is proposed to move the classification society's approval of the ship recycling plan and identification of hazardous materials from the end-of-life scrapping time to the early design stage. In conclusion, the ship owners will be unable to flee to the substandard ship recycling yards after this update is implemented via the new block diagram. The next paragraphs explain the proposed ship recycling process, which is shown in Figure 2 using the updated suggested block design as per HKC.

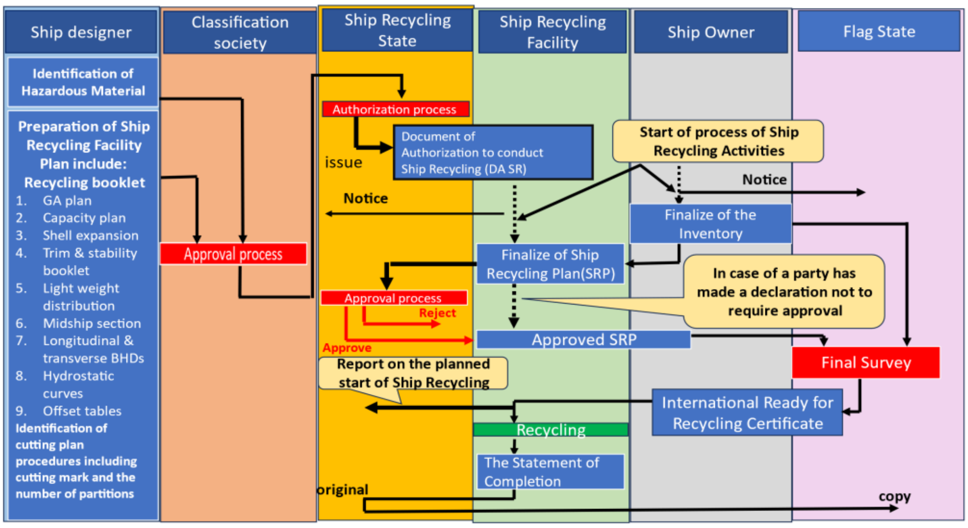

Figure 2: A new proposed block diagram

The relationships, between the several stakeholders participating in the HKC-based ship recycling process, are clarified by this new proposed block diagram. When a ship reaches the end of its useful life, all of the following are done before the recycling process begins. First, following Appendix 1 of the Hong Kong convention, it is suggested that the ship designer create a ship recycling plan and identify any hazardous materials. This plan needs to be approved by the classification society. Following that, the state responsible for ship recycling initiates the authorization procedure and issues a document of authorization to carry out ship recycling (DASR).

Furthermore, the ship owner notifies the flag state and the ship recycling state to begin the recycling procedure. Additionally, the shipowner completes the final review of the inventory of hazardous materials (IHM) and submits it to the ship recycling facility, which examines and approves the ship recycling plan based on the IHM.

Additionally, the approved plan and an IHM review are sent by the ship recycling facility to the flag state for a final survey. After that, the flag state issues an international ready-for-recycling certificate, which is then forwarded to the ship recycling facility, which completes the recycling process and reports back to the ship recycling state. To close the ship's registry, the ship recycling facility then drafts a statement of completion and mails the original to the ship recycling state and a duplicate to the flag state.

4. CASE STUDY

A carefully chosen case study simulates the process of chopping the ship into blocks for recycling to demonstrate the applicability of the suggested strategy. The ship is a container ship 400 meters in length called "BARZAN". The particulars are shown in Table 1. The ship is owned by United Arab Shipping Company S.A.G. Figure 3, the general arrangement shows that the ship has 14 bulkheads dividing it into 15 compartments, namely the after peak, hold no. 10, engine room, holds no. 9 to 5, fuel tanks, holds no. 4 to 1, bow thruster room and the fore peak.

Table 1: BARZAN General Particulars

Parameters	Value
Type	Container Ship
Ship's name	BARZAN
Length Overall	400 m
Breadth	58.6 m
Depth at midship	30.6 m
Summer draught	16.024 m
Displacement	257,947 t
Lightweight	57,100 t

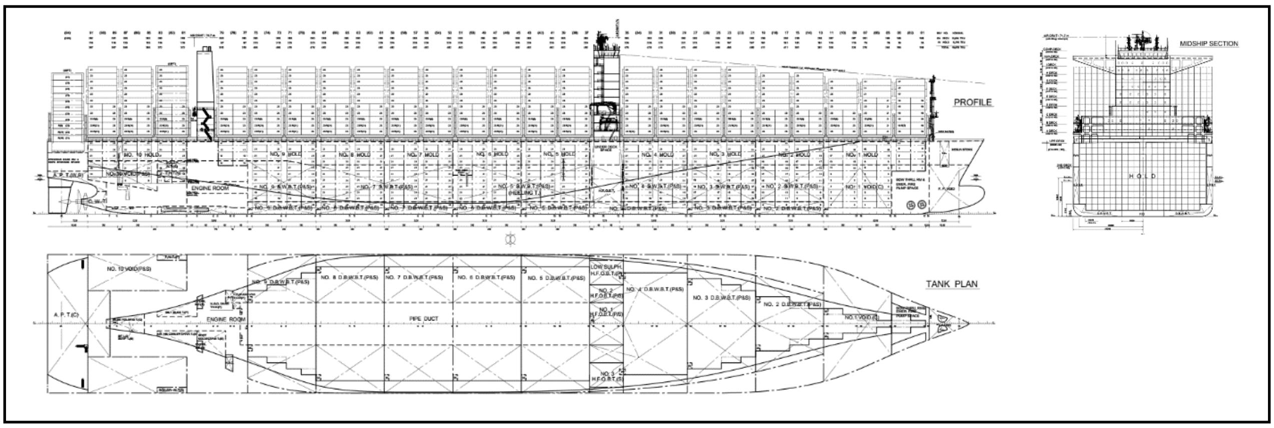

Figure 3: BARZAN General Arrangement

The ship is divided into 5 blocks, where the cutting locations are shown in m from after perpendicular:

- 109.5 m (between FR 68 &69)
- 167.9 m (between FR 89 & 90)
- 226.3 m (between FR 109 & 110)
- 297.2 m (between FR 140 & 141)

The same process can be performed on other ship types as well at the design stage. Stability is calculated for each block to ensure that it will remain afloat and comply with IMO criteria. Figure 4 shows the Lightweight distribution.

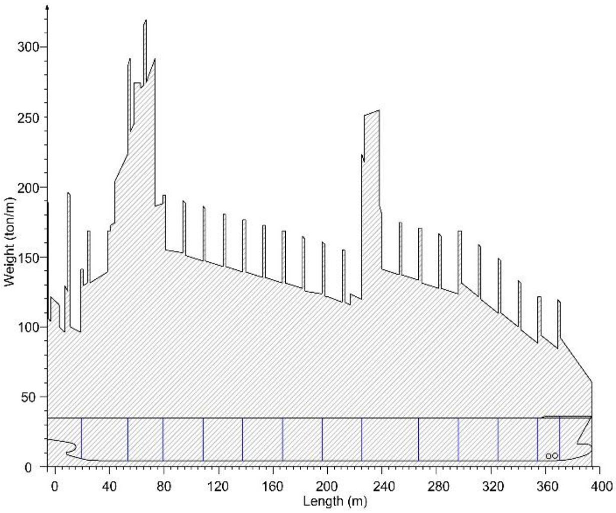

Figure 4: Lightweight Distribution

The cutting process is illustrated in the following steps:

1. The ship is to be divided into blocks, where each one is considered an independent floating unit. Every ship has several watertight bulkheads that divide the ship into several watertight compartments. The concept is to add additional bulkheads adjacent to already existing bulkheads. This creates a narrow void between the two bulkheads. In this case study the void is taken at the next frame space which is 1 meter long. The void exists directly under the hatch, in a location which is not initially occupied by containers. So, this new proposed design doesn't reduce cargo capacity or hinder cargo handling. To ensure the extent of the impact of the relative increase in lightweight, the weight of the added bulkheads was calculated to find the percentage of the increase in lightweight. In this way, the weight of the added bulkheads is determined to be 1364.5 tons, representing 2.4% of the ship's lightweight, 57100 tons. So, increasing the ship's weight will affect the ship's draft, leading to an increase in the draft by 6 cm, which requires the designer to take this increase into account to calculate the freeboard calculations at the early design stage. Existing and additional bulkheads are shown in Figures 5 and 6.

Cutting takes place at the new void between compartments under the hatch, as shown in Figure 7. This location doesn't affect the hull's structural integrity or the block's buoyancy and stability after cutting.

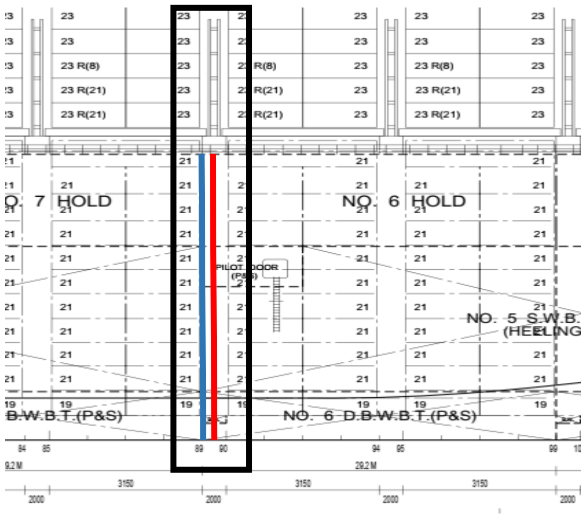

Figure 5: Existing Bulkheads (Blue) and Additional bulkheads (Red)

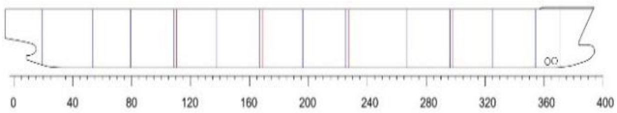

Figure 6: Existing Bulkheads (Blue) and Additional bulkheads (Red**)**

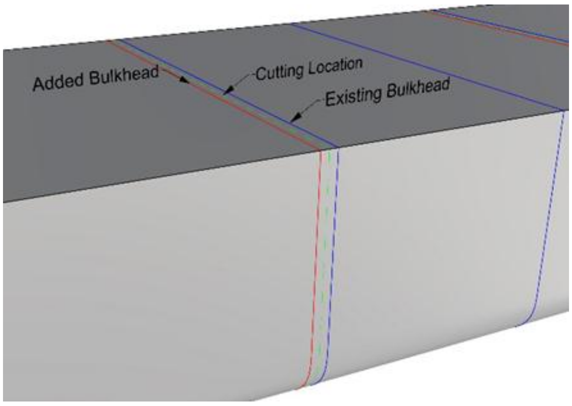

Figure 7**:** Cutting Location

Also, according to the resolution MSC.l58(78) adopted on 20 May 2004 for the amendments to the technical provisions for means of inspection access [19], the passageways forming sections of a permanent means of access, where fitted, shall have a minimum clear width of 600 mm. Therefore, implementing the proposal of adding bulkheads in this location at the early design stage will facilitate the shipbreaking process safely and environmentally friendly. In addition, it is required to determine the compartments where cutting takes place to determine the location of additional bulkheads at the design stage. The number of compartments is plus one the number of doubled bulkheads. Consequently, Equation can be used to represent the maximum number of blocks that can be created.

$$\textit{No. of Blocks} = \textit{No. of Doubled Bulkheads} + 1 \qquad (1)$$

When cutting occurs, the void between compartments is assumed to be damaged and open to the sea. Each block should have at least one intact compartment; and one or two damaged half-compartments. The other half-compartment belongs to the preceding or following block. The number of the ship's damaged compartments (voids) must be less than the number of intact compartments that remain.

2. The weight and centroids of each block are calculated using the lightweight distribution. The weight of the machinery and outfit to be removed is to be deducted from the block weight. Machinery includes the main engine(s), Gen-sets, pumps, compressors, and other auxiliary. Outfitting includes hatch covers, cranes, mooring winches, bridge, navigational equipment and other fittings.
3. The MAXSURF Modeler Module is used to develop a 3D model of the ship. The model is then divided into blocks, as in step 1, and each block can be treated as an independent unit.
4. Using the MAXSURF Stability Module, intact stability calculation is performed for each block, where the open half-compartments (void) are considered damaged. However, the void is already very narrow (0.5 meters in length). Hydrostatics Curves are obtained for the specified condition as well as the Statical Stability (GZ-θ) Curve.
5. Drafts and trim are checked to determine if the towing condition is safe by maintaining as near as possible even keel condition. Results of GZ-θ are calculated to ensure the safety of the block. The results are checked according to IMO stability Criteria used for all ships.

The following criteria apply:

- The area under the GZ curve should not be less than 0.055 m.rad up to $\theta = 30°$.
- The area under the GZ curve should not be less than 0.09 m.rad up to $\theta = 40°$.
- The area under the GZ curve should not be less than 0.03 m.rad between $\theta = 30°$ and $\theta = 40°$.
- The right arm should be at least 0.2 m at an angle of heel equal to or greater than 30°.
- The maximum righting arm should occur at an angle $\theta > 30°$.
- The initial metacentric height GM should not be less than 0.15 m.

6. In case one or more block(s) didn't meet IMO criteria, measures are to be taken. These measures include changing the locations of bulkheads, changing the cutting locations, reducing the number of blocks or using water and solid ballast. In this case study, water ballast is used in both blocks no.1 and 5, where the cargo hold is flooded up to the desired level.

Some points need to be considered in selecting the location of additional bulkheads and cutting locations. Cutting could take place at almost any compartment between the forward engine room bulkhead and collision bulkhead. This means any compartment except the fore peak, aft peak and engine room. Cutting could take place at any location within the voids, but it is most convenient to consider the mid-length for most blocks. For most ships, the shape of the forward section (length of entrance) and aft section (length of run) is far from being uniform, unlike the parallel middle body. In both cases, the center of buoyancy is extremely shifted to one end of the length. The center of weight is not necessarily similar. The unbalance will lead to extreme trim or even ship sinking. One or more compartments of full shape from the middle body must be included in the fore or aft block to maintain its stability.

5. RESULTS & DISCUSSIONS

The final conditions of blocks after cutting are shown in Figures 8 to 12. Green represents ballast water while red represents water in compartments open to the sea. It is clear that the void is very small, and the effect of damage is neglectable. The statical stability curves are shown in Figures 13 to 17. The curves reflect that each block complies with the stability criteria. Table 2 shows all the results of stability calculations.

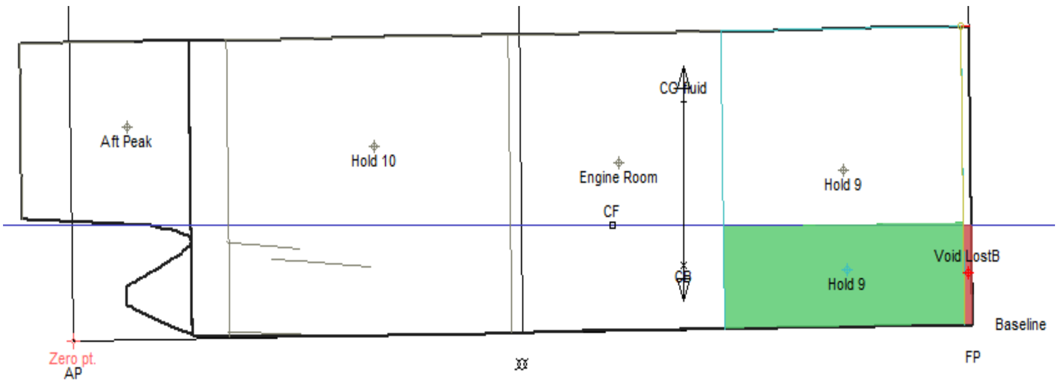

Figure 8: Block One

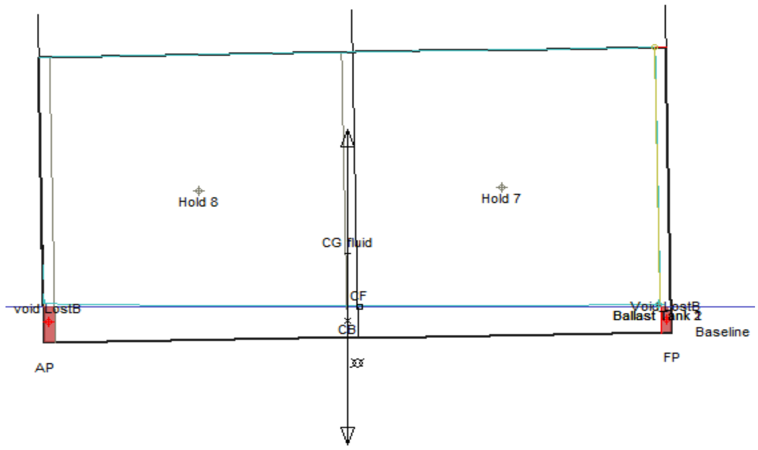

Figure 9: Block Two

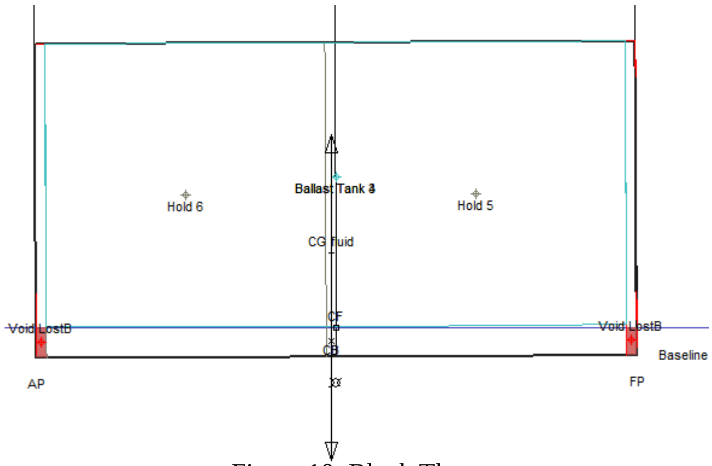

Figure 10: Block Three

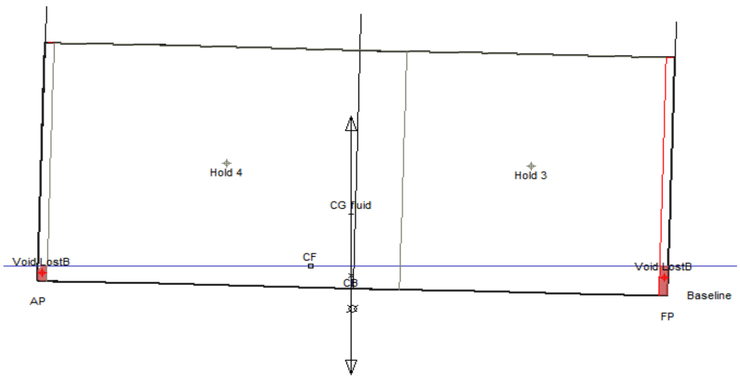

Figure 11: Block Four

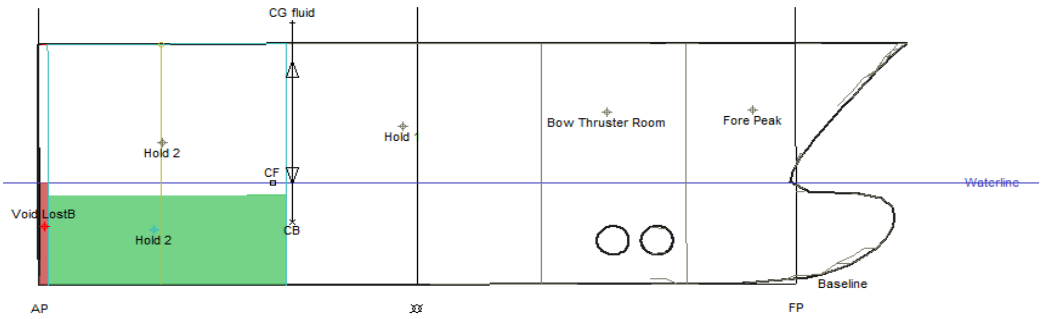

Figure 12: Block Five

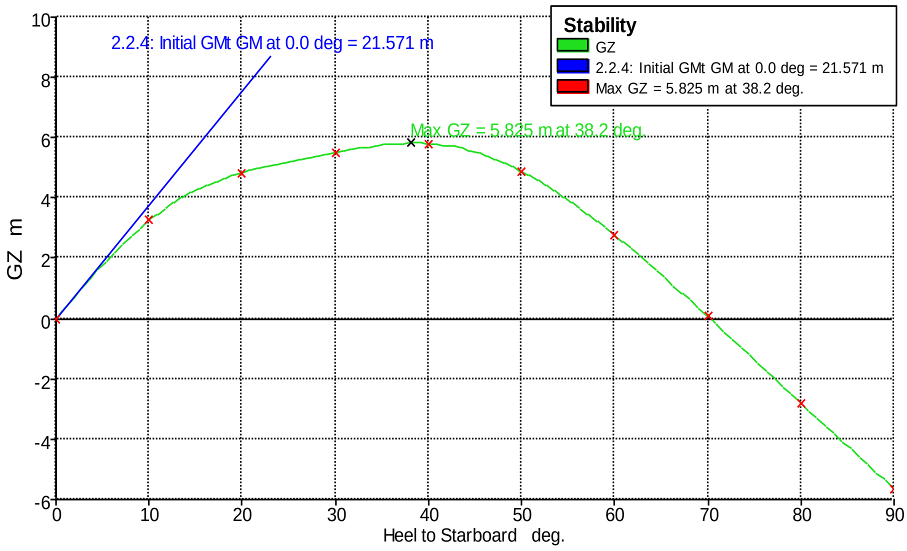

Figure 13: Statical stability curve of block one

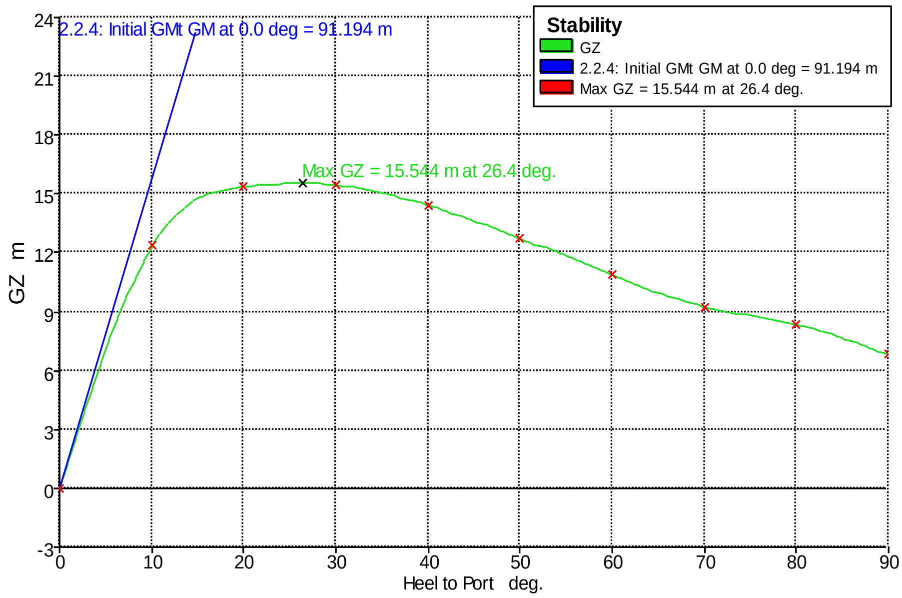

Figure 14: Statical stability curve of block two

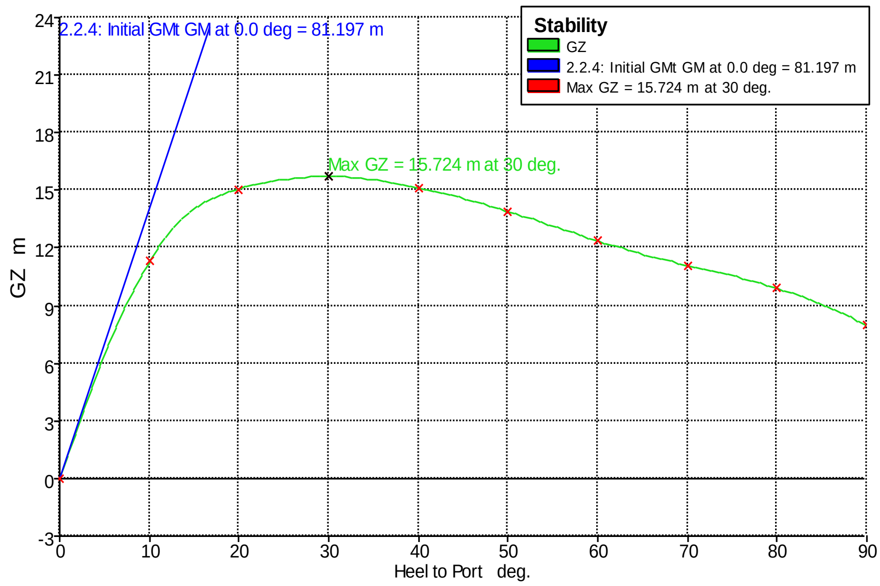

Figure 15: Statical stability curve of block three

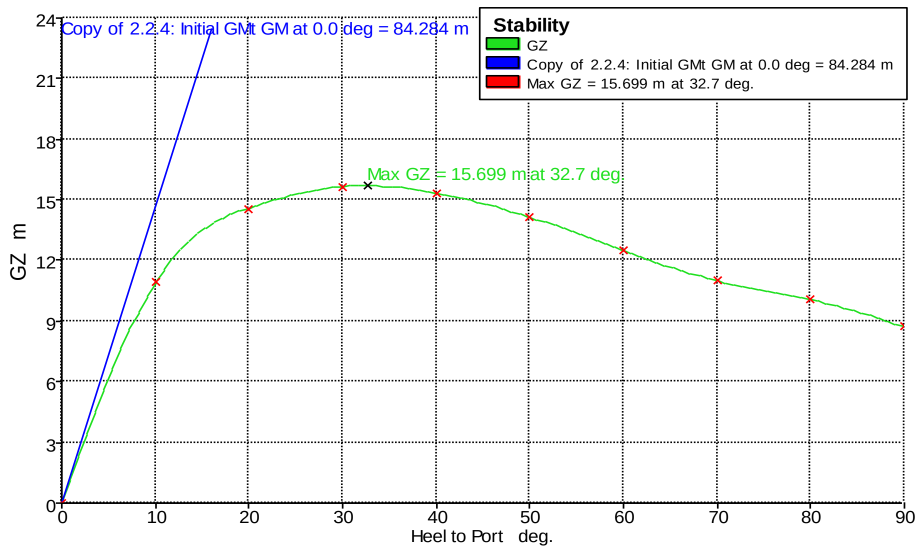

Figure 16: Statical stability curve of block four

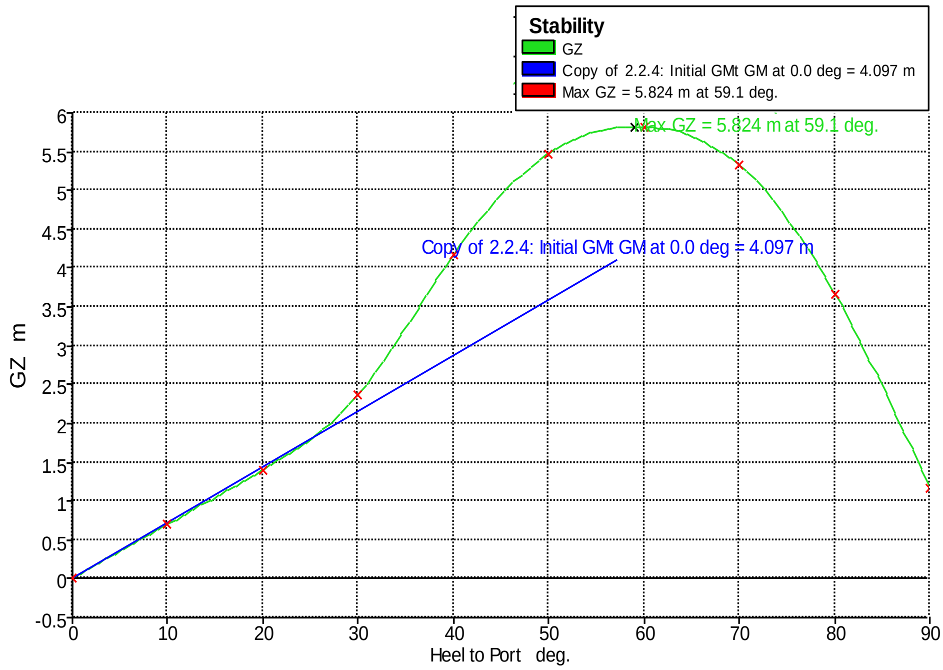

Figure 17: Statical stability curve of block five

As demonstrated by these data, the ship owner and the ship recycling yard can benefit from changes made to the ship's design throughout the design phase. Using a crane, mechanical slipway, synchro-lift, or any other lifting mechanism available in the shipyard, each smaller unit of the vessel could be independently transported to the cutting workshop.

It is possible to recycle the ship using methods that aren't feasible for the entire ship by implementing the suggested strategy. For the conforming ship recycling yard or the shipbuilding yard, the ship scrapping procedure is simplified. Consequently, it is important to take the ship recycling process into account when designing the vessel.

Table 2: Results

Results	Block 1	Block 2	Block 3	Block 4	Block 5
Length m	102.834	58.410	58.401	70.927	85.913
Weight of Block ton	20037	8415.3	7580	11138	9937
Weight of outfitting & machinery	-4356	-285.9	-373.7	-1778.747	-473
Ballast	14922.9	0	0	0	8760.155
Displacement	30603.9	8129.4	7206.3	9359.253	18224.155
LCG from AP of Ship	74.668	137.93	196.61	261.31	325.851
LCG from the aft end	74.668	28.43	28.71	35.01	28.651
LCF from AP of Ship	65.765	138.829	197.04	256.882	323.715
LCF from the aft end	65.765	29.329	29.14	30.582	26.515
Draft at Fore end m	10.135	2.792	2.631	3.863	12.538
Draft at Aft end m	11.835	3.850	2.936	1.906	12.938
Trim (+ve by stern) m	1.699	1.058	0.305	-1.957	0.400
Trim angle (+ve by stern) deg	0.8891	1.0381	0.2996	-1.5811	0.2671
IMO MSC267(85) Ch2 - General Criteria	Pass	Pass	Pass	Pass	Pass

6. CONCLUSIONS

The goal of the design for recycling idea is to minimize environmental damage while maximizing the value of an end-of-life ship. The suggested method is predicated on taking into account the scraping procedure early in the design phase. By using this method, a random recycling procedure at the end of the ship's life is prevented.

Preparing a recycling plan approved by HKC forces a legal obligation on the ship's recycling yard. This plan must consider the current and future technologies under development. This approach offers better handling of mega-ships which are initially difficult to handle by reducing the size of ship units and hence ease further cutting processes of the block into much smaller parts which can handled by smaller facilities.

The case study, which examines one of the biggest ships available, demonstrates that slicing the ship into smaller floating blocks is a more cost-effective option than dismantling the ship in the dock. It entails choosing the ideal locations for the new ship's extra bulkheads early in the design process. Hydrostatic and stability calculations for each block individually must be done to ensure the divided block stays stable and floating. These changes must be included in all structural plans and details to facilitate the green recycling process.

Thus, a shipbuilding yard can also be used as a recycling yard. The scrapped ship will be cut into separate blocks that can be pulled by tugs to the slipway dock via the cradle and then winched to the cutting workshop to finish the cutting process. The slipway dock would remain empty and be available for new construction or docking maintenance.

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