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Researches and Preparation Status on IMO Second-generation Stability Criteria

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***Abstract*—Even though the ship was designed and constructed by applying the current IMO (International Maritime Organization, here in after "IMO") stability standard "IS CODE 2008", it has been found that the ship can be capsized due to the waves even in the static condition due to frequent accidents in the ocean. Therefore, a new IMO second generation stability criteria was proposed based on the results of the researchers of advanced technology related fields such as Germany and Japan. The other many country and Korea, which has a large shipbuilding capacity, lacks proactive measures such as failure to present amendments to the proposals proposed by advanced technology holders. In this paper, it introduces the proposed new stability criteria currently being discussed in IMO, and progress of the proposed research, which is studied by the advanced technology holders, to lay the foundation for other country researchers to participate in research and development more quickly and easily. And to propose amendment proposals.**

Keywords—IMO Second-Generation Stability criteria; pure loss of stability; parametric roll; surf-riding; broaching to; dead ship; excessive accelerations

I. INTRODUCTION

Established in 1959, the International Maritime Organization (IMO), one of the specialized agencies under the United Nations, promotes intergovernmental cooperation on all technical and administrative issues affecting shipping and shipbuilding and promotes maritime safety, it is an international organization that revises and enforces international standards for the prevention of marine pollution.

IMO discusses the main points of the problems that arise during the operation of the ship, and conducts various meetings each year with delegates from each member country to prevent marine accidents, which could result in loss of life and enormous environmental and property damage. It revises and oversees all international standards on maritime safety and shipbuilding facilities and its implementation.

So far, the ship has been constructed on the basis of the stability standard of the existing ship. However, a new standard for stability of the ship, which is the most important factor about the safety of the ship overturning, occurs frequently due to the loss of stability, Second Generation Stability [W. Peters, 2011]. As a result of analyzing the cause of the problem of the existing stability criterion, the fact that the existing stability criterion does not reflect the situation in which the stability of the ship in the blue is remarkably lost because the stability is calculated based on the hydrostatics in the pure state respectively. Based on these facts, the necessity of establishing a new stability standard of the ship has been raised, and by intensive investigation of experts, it is proceeding to add a stability standard against the fluid dynamic phenomenon of about 5 waves. However, we are discussing the application of step-by-step standards, as existing ship owners are worried about shipbuilding price hikes and cargo load reductions.

In order to remain in the shipbuilding industry, strategies to respond promptly and effectively to the entry into force of the new regulations are needed. Second-generation stability regulations by IMO have a major impact on the design of ships to be constructed in the future, it is necessary to actively participate and closely respond to the enactment. Germany, the European countries, Japan and the United States, are actively proposing IMO 's second - generation resilience regulations, but the other country such as Korea has much less response. At the recent IMO SDC-5 meeting held in Korea in February 2018, many country has been unable to actively respond to proposals of amendments to the proposals of the member countries. Even so, it is imperative that Level-3 standards are settled at the IMO meeting to be held in February 2019.

In light of these circumstances, the present authors first analyze the problems of the current IMO stability regulations and introduce the status and standard of research on the second generation resilience newly proposed by the advanced technology nations, so that researchers can more easily and quickly develop related research and development. And to make it possible to participate more actively in dealing with IMO second generation restoration regulations and Korea's amendment proposals.

II. PROBLEMS OF CURRENT IMO STABILITY CRITERIA

The current IMO stability criterion, which began around 1900, is the concept of resilience in the water (without waves). This criterion is based on the empirical equation of Rahola et al. And various semi-empirical equations. The problem is that buoyancy changes in the longitudinal direction of the hull by the waves, waterline changes, hull motion, acceleration, and dynamic load are not considered.

The following is a list of the main relevant items classified under the "IS Code 2008" in the IMO Regulations.

- General Stability Criteria (SOLAS-A.749 Criteria)
  - Minimum metacentric height:

$$GM \geq 0.15[\mathrm{m}] \quad (1)$$

- Minimum lever arm at 30 degrees heel:

$$h(\phi = 30°) \geq 0.20[\mathrm{m}] \quad (2)$$

- Maximum of lever arm curve beyond 25 degrees heel:

$$dh/d\phi(\phi = 25°) \geq 0.0 \quad (3)$$

- Integrated area below the lever arm curve has to reach the following minimum values:

$$-\int_{0}^{30} h(\phi)\, d\phi \geq 0.055[\mathrm{mRad}]$$

$$-\int_{0}^{40} h(\phi)\, d\phi \geq 0.090[\mathrm{mRad}] \quad (4)$$

$$-\int_{30}^{40} h(\phi)\, d\phi \geq 0.030[\mathrm{mRad}]$$

III. CURRENT RSEARCH AND DISCUSSION

A. *Discussion on International Maritime Organization*

Recently, as the size of the ship has increased, the length of the hull has been increased to 400[m]. Therefore, Fig. As shown in Fig. 1, the range of the GM value changes considerably with the change of the hull length and the incident wave wavelength, the decrease of the resonance frequency with the increase of the hull weight and the increase of the height of the container line. The results of this study are as follows.

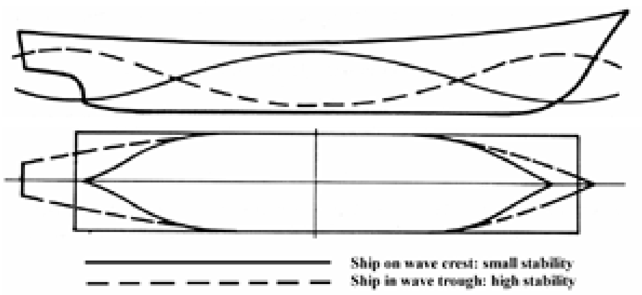

FIGURE I. SHIP STABILITY ON WAVE CREST AND IN WAVE THROUGH.
(Source: HeVert Scheekluth, 1988, Friedrich Mewis et al., 2003)

TABLE I. STABILLITY FAILURE MODES IN WAVE

Cause of stability loss	Description	Remark
Pure loss of stability	When the ship hits the wave crest, the hydrostatic restraint is reduced. High speed line static loss of stability	Realistic needs
Parametric roll resonance	When the frequency of the shore is twice the transverse frequency of the hull, the change of the restoring force with time acts like an external force. Container line	Container ship
Surf-riding (broaching to)	When unstable equilibrium is achieved when the hull is at the same velocity as the line and the hull is "caught" in the wave. Small ship / fishing boat	Small vessel
Dead ship condition	A large roll occurs when the ship comes to the side due to engine failure. The existing regulations are judged by the restoring force curve, but in the next generation restoration.	Mechanical defect
Excessive accelerations	Excessive GM to accelerate the resilience of the cargo, such as falling out of the board	Container ship, Cruise ship

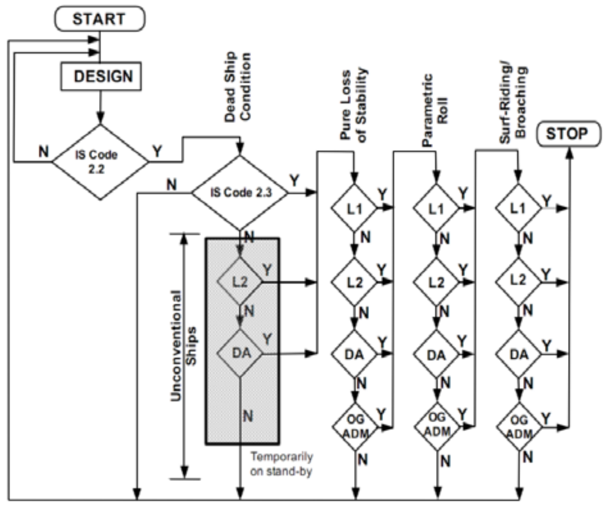

FIGURE II. MULTI-TIERED APPOACH FOR THE SECOND GENERATION INTACT STABILITY CRITERIA.
(Source: SLF53/WP.4 Annex 3)

In terms of applying the new second-generation stability standard of IMO, the conflicting interest of each stakeholder, shipowner, shipowner, shipbuilder's government and other related organizations, and the consistency and setting problems of new standards are exposed, I'm having a hard time.

For this reason, the second-generation stability criterion is shown in Fig. 2, it has been proposed to apply the method to the step-by-step application. Particularly, it is being studied in practice to divide the application into one level (Level-1) r and two-level (Level-2). The first step is based on a simple calculation based on a standard hydroistaic table. If the method does not satisfy the criteria, a more precise method of judging the second step is discussed.

The two-step criterion involves many calculations in a way that takes into account the calculation of hydrostatics in waves. If the stability criterion cannot be satisfied even in the second step, a method of judging by the transverse motion calculation using the direct simulation method ("DAS") is proposed (SDC 4). The specific criteria for each of the first and second phases, especially the status of the waves to which they are applied, are still being discussed, and the content has been closely researched through discussions to date. Table 2 summarizes the step-by-step decisions and features currently under discussion. The physical causes / characteristics of each of the five vulnerable modes are as follows.

B. Five Failure Modes

- Failure mode (1): "*Pure Loss of Stability*"

  When the ship navigates in the direction of a wave or a puddle, the partial bubble of the hull which is flooded by the wave shape changes relatively large in comparison with the distribution in the still water, which involves a change in the restoring force moment. In particular, the wave length is similar to the length of the hull, and the wave steepness increases further. If the GZ curve is weak for a long period of time, it can cause a large lateral tilt or rollover. It is known that the stability is relatively weak when the ship is operating at high speed during the following wave, and relatively safe because the duration of the weak stability is short.

- Failure mode (2): "*Parametric Roll*"

  Parametric roll phenomenon is a weak mode that is caused by a phenomenon that the restoration force changes (increases) repeatedly with time in waves (especially transverse waves), and when the frequency of the incident waves is twice the hull natural frequency. & Lt; / RTI & gt. This phenomenon occurs mainly in large container ships, because large container ships have smaller restoration moments than conventional ones, and the transverse frequency is small. A way to eliminate this risk by dampening the roll by the bilge keel is now known as the most realistic countermeasure.

- Failure mode (3): "*Surf-riding/Broaching to*"

In case the ship is navigating during the shakes, if the hull is located at a specific point of the wave and the stability of the hull is in a weak state (the ship is traveling on the waves). It is a phenomenon that the stability of ship is remarkably reduced. If the ship hits the downslope of the wave, the direction stability of the hull is lost and the stability is lost in the unmanageable state. Surf riding occurs when the length of the hull is smaller than the length of the wave and when the direction and speed of the ship and the wave are the same or similar. When the length of the hull is long, the phase of the wave is restored in the hull length. The effect is canceled, and the velocity at which the waves pass is too high in the wave guide, so that the weak mode is not generated because the unstable state disappears for a moment. It is a general situation that fishing boats whose length is shorter than the wavelength are vulnerable in the mode.

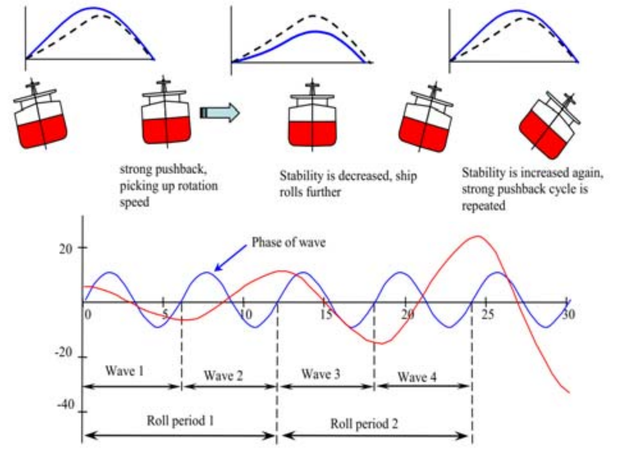

FIGURE III. MECHANISM OF OCCURRENCE OF PARAMETRIC ROLL. (Source: W. Peters. et al., 2011)

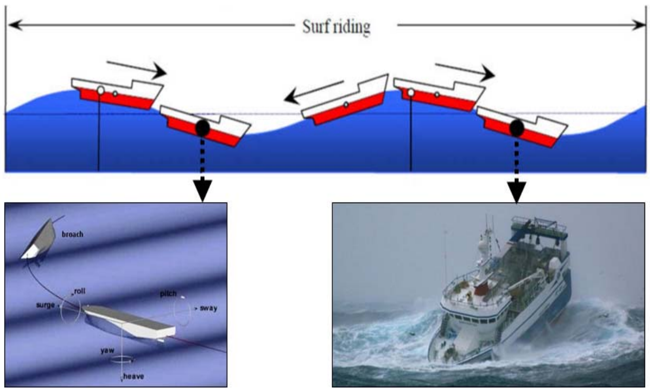

FIGURE IV. SURF-RIDING PHENOMENA. (Source: K.J. Spyrou, 2011, Vadim Belenky et al., 2011)

- Failure mode (4): "*Dead Ship*"

  A ship is in a state of inability to steer because of mechanical failure, or when it has decided to suspend engine power in order to avoid other dangerous phenomena, in which case the vessel is in an unmanageable condition, Because there is no way to avoid it, you are exposed to very dangerous situations in terms of resilience. The risk assessment in the dead ship condition is determined by weather conditions, but the need for new regulations has arisen due to the fact that current dangerous weather conditions are over-proposing the freedom of modern ship design such as large cruise ships.

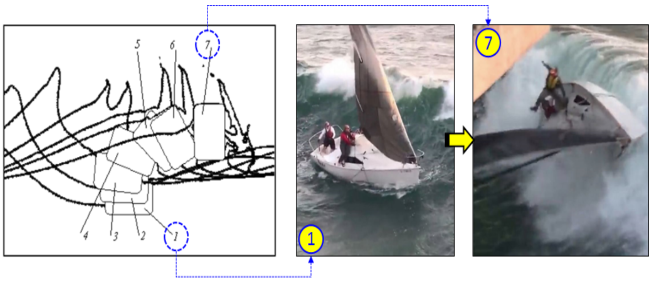

FIGURE V. DEAD SHIP PHENOMENA AT BEAM SEA.
(Source: Vadim Belenky et al., 2011)

TABLE II. FIVE PHYSCAL PHENOMENA DEPENDING ON THE CAUSE OF STABILITY LOSS.

Mode	Level-1	Level-2
Complicity	simple	complication
Cost	not high	swell
Design margin	very high	low
Pure loss of stability	$Fn \geq 0.24$ $GM_{min} > R_{PL1}$ $R_{PL1} = 0.05\,[m]$	$\max(CR_1, CR_2) < 0.06$ $CR1 = \sum_{i=1}^{N} W_i C1_i \,,\; C1 = \begin{cases} 1\ (\phi_v > 30\,[^\circ]) \\ 0\ (\phi_v < 30\,[^\circ]) \end{cases}$ $CR2 = \sum_{i=1}^{N} W_i C2_i \,,\; C2 = \begin{cases} 0\ (\phi_s > 25\,[^\circ]) \\ 1\ (\phi_s < 25\,[^\circ]) \end{cases}$
Parametric roll (Broaching to)	$\frac{\Delta GM_1}{GM_C} > R_{PR}$ $R_{PR} = 1.87$	$\max(CR_1, CR_2) < 0.06$ $CR1 = \sum_{i=1}^{N} W_i C1_i$ $C1_i = \begin{cases} 1 \left(GM(H_i, \lambda_i) > 0,\ \frac{\Delta GM(H_i, \lambda_i)}{GM(H_i, \lambda_i)} < R_{PR},\ V_{PR} > V_s \right) \\ 0 \end{cases}$ $CR2 = \sum_{i=1}^{N} W_i C2_i$ $C2_i = \left[\sum_{i=1}^{3} C2_h(Fn_i) + C2_h(0) + \sum_{i=1}^{3} C2_r(Fn_i) \right] / 7$
surf-riding	$L > 200m$ $Fn \leq 0.3$	$C < 0.005$ $C = \sum_{HS} \sum_{TZ} \left(W2(H_S, T_Z) \frac{\sum_{i=1}^{N} \sum_{j=1}^{N} W_{ij} C2_{ij}}{\sum_{i=1}^{N} \sum_{j=1}^{N} W_{ij}} \right)$ $C2_{ij} = \begin{cases} 1\ (Fn > Fn_{cr}(\lambda_i, a_j)) \\ 0\ (Fn \leq Fn_{cr}(\lambda_i, a_j)) \end{cases}$
Summary	The first stage decision formula is a very simple formula Deterministic judgment method	Although the formula for the 2-step decision equation is different depending on the weak mode. The second stage judgment formula calculates the probable risk by several wave components.

- Failure mode (5): "Excessive accelerations"

  When the GM of the ship is large, the transverse period of the ship becomes extremely short. Such excessive acceleration occurring during the voyage is a dangerous factor to the safety of the crew and the safety of the cargo. In recent years, serious accidents have occurred frequently in ballast condition, and it has been treated as an important stability related factor. In particular, it is known that the greater the distance from the center of gravity acting on ship, the higher deckhouse of large container ships.

These items currently under discussion are about the above five modes, but the most physically difficult to determine are the items (1) to (3) that are summarized above. The current progress has been prepared by the structure of the discrimination formula as shown in Table 2. However, the differences between the two countries were not adjusted in the last IMO meeting, so it is expected to be adjusted the detailed in February 2019.

IV. Conclusion

The IMO is discussing the status of the second-generation stability standard, and the need for detailed inspection in terms of preparing a meeting for Level-3 standard consultation, one of the important agenda items of the meeting scheduled for February 2019.

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