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WARSHIP DAMAGE STABILITY CRITERIA CASE STUDY

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ABSTRACT

All navies struggle to achieve a balance between safety and military capability, ensuring that activities in peace time are undertaken with an acceptable level of risk. Despite the need for intrinsic differences in construction, increasingly, the acceptable level of safety for the navies is becoming equivalent to those of merchant vessels under civil law. Navies are resorting to Classification Societies for assistance in this matter. Rules and regulations of the Classification Societies for ships are set within the framework of international law overseen by International Maritime Organization (IMO), particularly the international convention for the safety of life at sea (SOLAS). These "IMO" agreements are not always appropriate for the majority of warships, so that the military mission demand solutions in the design and operation that are not fully compatible with the philosophy of the conventions "IMO" and prescriptive solutions. Separate rules of the Classification Societies of the conventions "IMO", to apply to ships of war, create a vacuum that can lead to confusion. This confusion can be misinterpreted and as a result there can be a drop in safety standards. Stability in case of collision is a critical theme to maintain buoyancy in ships. These aspects are even more critical given the increasing size of the boats and the growing number of passengers and crews onboard. Both experience and performed studies demonstrate that the most dangerous issue for the ships with closed deck is the impact of an accumulation of water on the deck. The studies have clearly shown that the residual freeboard of the ship and the height of the

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waves in a specific sea area influence in a very relevant manner the amount of water that could be accumulated after a clash. The article concludes by presenting a series of comparisons between the criteria used by both, leading to some interesting conclusions as to the current criteria used by the navy. This can be enormously improved with a few minor changes, to maintain the integrity of its basic approach, and increase the similarities with the criterion of "IMO", such as the calculation of water on deck out in the Stockholm Agreement.

Keywords: Damage stability criteria, Stockholm Agreement, Naval Ship Code.

INTRODUCTION

Admitting that there is no equivalent of the "IMO" for warships, the North Atlantic Treaty Organization (NATO) has established a team of specialists in the Naval Ship Classification Association (NSCA) and a partnership for classification of warships. This has been entrusted with the development of new legislation. This team of specialists has been entrusted with the preparation of the Naval Ship Code (NSC) and benchmark of international standards for ships. This will promote greater transparency and consistency in safety standards for vessels of war. The Code aims to fill the void by providing the framework for the armed security that has achieved acceptable levels of security. To accomplish this, the Code will be the link between "IMO" and Classification Societies. It will promote improvements in vessel design and greater consistency and transparency of safety standards. The United Nations Conference on the Law of the Sea (UNCLO), in article twenty-nine defines a warship as a ship belonging to the armed forces of a State and bearing the external distinguishing marks for the nationality of the vessel, is under the command of an officer duly commissioned by the government whose name appears on the list of appropriate services or the equivalent, and manned by an allocation under the discipline of the navies. The "SOLAS", in its third rule "Chapter I-General Provisions", states that its rules do not apply to warships and ships to transport troops. Warships are exempt from most of the laws of the merchant ships, and as such both international and national levels have directed the

SOURCE: www.nato.int

Figure 1. In front a Dutch frigate followed by the Spanish and German frigates.

Naval Forces ships safety independent of the statutory organizations. There are exceptions to this. The vessels may be classified and certified by Classification Societies or flag authorities and there are some aspects of the statutory legislation that warships have to consider.

These include the navigation of ships through international waters, communications with other ships and increasingly support, environmental protection. Moreover, due to a combination of resources restriction and increasing public pressure, most of the navies are resorting to Classification Societies for support. In this way, for example, approximately ninety percent, by tonnage, the fleet of the British Royal Navy is in hull classified either by Lloyd's Register of Shipping (LLR). At this time almost all new buildings are being conducted under the rules of any of the Classification Societies. Problems will arise if the ships engaged on the Classification Societies compare their management of safety against civilian vessels.

Perhaps, to avoid duplication, gaps and shortcomings in safety, it is important for the navies to work together with the Classification Societies in the development of effective and sustainable arrangements. Thus, development of rules for warships Naval Ships Rules by various Classification Societies is the most important contribution to work in this area. The idea of cooperation to make a "SOLAS" goes back to the nineties. In September 1998, Classification Societies of the Member States of the "NATO" met to establish links with their own "NATO". This meeting established the "NSCA", in May 2002, and the cooperation was defined according to the following terms of reference: promote safety standards at sea, promote measures to protect the marine environment, promote and develop common operating standards, undertake "R&D" to support the above and communicate the views of the partnership agreements and the "NATO". The philosophy of the "SOLAS" is applicable to merchant ships, and is not fully transferable to a warship, for example, radar transponders are quite undesirable for the feature to be a stealth warship and that a lifeboat is orange can hardly be regarded as an improvement in optical characteristics of such a vessel. This list would be too long, and serves to demonstrate that the requirements of civil security should be tailored to the needs of the Navy. A warship has requirements for acoustic signature, electromagnetic signature, signature radar, electronic warfare, antisubmarine warfare and it demonstrates that a ship is not civil.

DAMAGE STABILITY CRITERIA ACCORDING TO DESIGN DATA SHEET

The criteria to evaluate adequate damage stability performance according "DDS 079-1" are based on the "Figure 2". A reduction of the righting arm equal to $(0.05 \cdot \cos\theta)$ is included in the righting arm curve to account for unknown unsymmetrical flooding or transverse shift of loose material. Beam wind heeling arm curve is calculated with the same method as used for intact stability calculations, but considering a beam wind velocity of around *32-33 (knots)* as defined in "DDS 079-1"

(Naval Ship Engineering Centre, 1975). The damage stability is considered satisfactory if the static equilibrium angle of heel "θc", point "C" without wind rolling effects does not exceed *15(°)*. The dynamic stability available to counter the heeling forces imparted to the ship by moderately rough seas in combination with beam winds is a measure of adequacy of the stability after damage. The limit angle "θ_1" of the damage righting arm curve is *45(°)* or the angle at which unrestricted flooding into the ship would occur, whichever is less. The angle "θr" is the expected angle of roll into the wind from the point of intersection of the righting arm and heeling arm curves for the assumed wind and sea state. Subject to later verification by experience and model testing, the value of the rolling angle "θr" to be estimated according to "DDS 079-1".

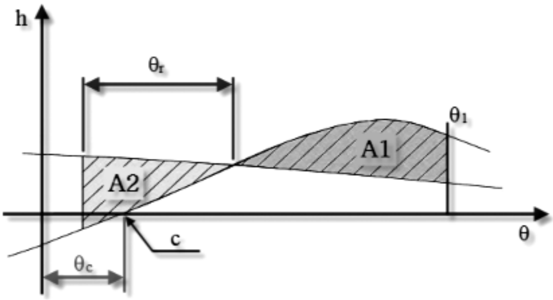

Figure 2. Damage stability criteria.

The criterion is considered fulfilled if the reserve of dynamic stability "A1" is not less than (*1.4·A2*), where "A2" extends "θr" to windward as shown in the "Figure 2". The tendency during recent decades in surface naval ship design was to assess and minimize susceptibility through detailed signature management. Therefore the probability of detection was usually estimated and it was considered as input in simulations scenarios. On the other hand the probability of staying afloat and upright was less frequently taken into account. Most of the simulations assumed a single-hit-kill probability equal to one for small naval ships whereas two hits where considered adequate for the sinking of larger vessels. Thus the defence analysis was actually never treating the vulnerability as a probability. For naval architects it is usually enough to assess the adequacy of its design with respect to vulnerability through the

SOURCE: Surko, S.W. (1994)

Criteria	UK "NES 109"		US Navy "DDS-079"	
Damage length	L_{WL} < 30 m	1-compartment	L_{WL}<100 ft	1-compartment
	30m < L_{WL} < 92m	2 comp of at least 6m	100ft < L_{WL} < 300ft	2 comp of at least 6m
	92 m < L_{WL}	Max {15%L_{WL} or 21 m}	300 ft < L_{WL}	15%L_{WL}
Permeability	Watertight Void	97%	Watertight Void	95%
	Accommodation	95%	Accommodation	95%
	Machinery	85%	Machinery	85% - 95%
	Stores	60%	Stores	60% - 95%
Area "A1"	> 1.4 Area "A2"		> 1.4 Area "A2"	
"GZ" at "C"	60 % of "GZmax"			
Longitudinal "GM"	> 0		—	

Table 1. Current UK & US damage stability criteria for surface warships.

use of damaged stability requirements introduced by the various navies, such as those used by the US Navy and the UK MoD, depicted in "Table 1".

Based on the concept of the damage function used in the theory of defence analysis, the fraction of the target assumed to be damaged within a radius r from the impact point is assumed to follow the well-known log-normal distribution given by the "Equation 1" (Przemieniecki, 1994):

$$d(r) = 1 - \int_0^r \frac{1}{\sqrt{2\cdot\pi}\cdot\beta\cdot r}\cdot\exp\left[-\frac{\ln^2\left(\frac{r}{\alpha}\right)}{2\cdot\beta^2}\right]\cdot dr \qquad (1)$$

Where "R_{SK}" is the sure kill radius which means that [$d(R_{SK}) = 0.98$], "R_{SS}" is the sure save radius which means [$d(R_{SS}) = 0.02$] and "z_{SS}" constant equal to (*1.45222*).

$$\alpha = \sqrt{R_{SS}\cdot R_{SK}} \quad (2) \qquad \text{and} \qquad \beta = \frac{1}{2\sqrt{2}\cdot z_{SS}}\ln\left(\frac{R_{SS}}{R_{SK}}\right) \quad (3)$$

The damage extent ranges of naval ships may result from test analysis, analysis of data from actual engagements, empirical formulas linking the damage range with the type and the weight of the warhead or from the use of damage lengths defined in current deterministic damage stability regulations for naval ships.

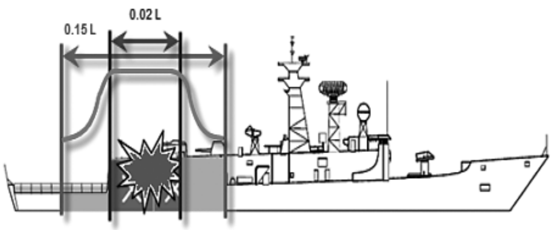

Figure 3. Damage extent on naval ship profile.

In the later case a first approximation of the "R_{SS}" can be taken according to "NES-109" and "DDS-079" and it would be (*0.15·L*), see "Figure 3" (Boulougouris and Papanikolaou, 2004). The "R_{SK}" has been assumed equal to (*0.02·L*).

A more efficient methodology to implement the suggested survivability assessment procedure within a ship design optimization scheme is an approach that considers the probability of survival based on quasi-static survival criteria, like those of the British Royal Navy and the US Navy. They take into account data of real damage incidences of World War II and they have proved to be reliable until today, in so far as they appear satisfactory to not have been changed over a long period of time. The philosophy for transforming these deterministic criteria into a set of rational probabilistic approach criteria will be herein based on an approach similar to the "IMO" Resolution *A.265* for passenger ships. It is well established that in all relevant criteria there is an underlying assumption that the sea conditions at the time of damage are moderate. This constraint could be lifted if there was a requirement for specific survival sea state in case of damage. This would allow the correction of these requirements by consideration of the probability of exceedence of the wave height considered as basis for the current deterministic British Royal Navy and the US Navy criteria.

NEW DAMAGE STABILITY CRITERIA. NAVAL SHIP CODE

The Naval Authority Knowledge Management Office (NAKMO) library is a website, an unclassified version of the Naval Authority System (NAS) library. In addition to navies, Classification Societies through the Naval Ship Classification Association (NSCA) have a standing invitation to attend the meetings of the specialist team as active participants. The specialist team is tasked with the development of a "NSC" that will provide a cost-effective framework for a naval surface ship safety management system based on and benchmarked against "IMO" conventions and resolutions. The Specialist Team has established a Goal Based Approach to the development of the "NSC" and is now developing each chapter in turn. This folder in the "NAS" library contains the latest documents including "NSC" chapters, related guidance and records of meetings. The "NSC" adopts a goal based approach. The basic principle of a goal based approach is that the goals should represent the top tiers of the framework, against which ship is verified both at design and construction stages, and during ship operation. This enables the "NSC" to become prescriptive if appropriate for the subject, or remain at a high level with reference to other standards and their assurance processes. The goal based approach also permits innovation by allowing alternative arrangements to be justified as complying with the higher level requirements.

The increasing width of the triangle as the "NSC" descends through the tiers implies an increasing level of detail. Limit state design methods are good, but in practice can be rather academic and purist; they will not generally be familiar to the shipping industry. The thought processes behind them are transparent and, while ending up at much the same place, do provide a good philosophical framework. The opportunity to know how the variability is in one parameter may affect the resultant demand or capacity. Limit State methodology also provides essentially a two-stage digitization of the analogue concept of graceful degradation. Another way of looking at the approach is to define green, amber and red zones where green equates to safe, amber to take care/start taking remedial action, and red equates to take remedial action immediately. Such information is of great use in providing guidance information to the ship and to inform decision-making in an emergency. The hierarchy of limits states is not well understood in marine circles. There are only two generic limit states: the Serviceability Limit State and the Ultimate Limit State. For each of these two limit states a number of scenarios need to be developed, and these should generally be based on the reaching of a defined structural capacity (e.g. fracture, elastic-

SOURCE: Guide to the Naval Ship Code. Prepared for MCG6 Specialist Team

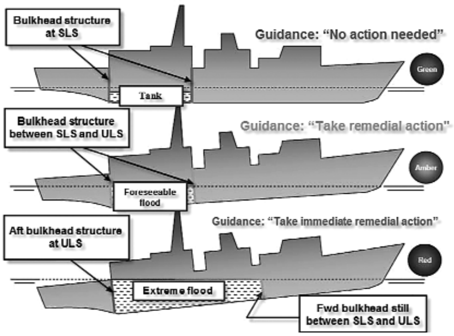

Figure 4. Structural Limit State Zones.

plastic buckling of a hull girder flange in compression when subjected to a characterization of loads and load combinations as a single load, and avoidance of fatigue crack initiation as established from a series of laboratory-scale fatigue specimens, commonly referred to as the Fatigue Limit State etc. Terms like Accident Limit State may be convenient but have no meaning without a precise definition of the limiting criteria, or the demand.

Environment

Foreseeable environmental conditions include extremes of wind, wave height, modal period and temperature. Operating environments refer to the ship specific conditions which limit the operational capability. For example, an aircraft carrier would not be expected to be able to launch aircraft in very high sea states. To assist in defining the foreseeable operating conditions and therefore bounding the risks due to the sea environment for a given ship, the type of service and environment that a ship is expected to endure should be defined in the Concept of Operations Statement.

SOURCE: Extract from DEF (AUST) 5000, Royal Australian Navy. Stability of Surface Ships and Boats, May 2003

Service	Description	Weather & Sea Characteristics	Survival & Rescue Infrastructure
Ocean Unlimited	Fully independent operation at sea, able to hold station in all but extreme conditions, able to resume duties after conditions abate	Severe tropical cyclone or equivalent, extreme winds and extreme seas	Early rescue not likely. Probable extended period in survival mode
Ocean Limited	Independent operation at sea, avoiding centres of tropical disturbance, able to resume duties when conditions abate	Storm force weather or equivalent. Very high winds and very high seas	Early rescue not likely. Probable extended period in survival mode
Offshore	Independent operation within 200 nautical miles or 12 hours at cruising speed (whichever is less) of a safe haven. Return to safe haven if winds likely to exceed Beaufort 8	Gale force weather and very rough seas	Survival in moderate conditions or early location likely and within helicopter range for rescue
Restricted Offshore	Restricted operations within 4 hours travel at cruising speed of a safe haven	Near gale force weather and rough seas	Survival in benign conditions or early rescue
Protected Waters	Operates within specified geographical limits or within 2 hours travel at cruising speed of a safe haven in waters specified as 'partially smooth'	Strong breeze winds and moderate seas	Rescue facilities and/or shoreline nearby

Table 2. Service classifications.

Loss of Watertight or Weathertight Integrity

A damage incident for the purposes of this chapter is defined as a breach of watertight or weathertight integrity. When the watertight or weathertight integrity of a ship is breached by any mechanism the ship is at risk of loss due to flooding. The extent of the breach and the ship's initial loading condition and material state will dictate the likelihood of the ship being lost. Irrespective of whether the damage is caused by an accidental or hostile event all damage can be categorized. The level of safety and performance following damage will depend on the severity of the damage incident. This is illustrated in "Figure 5" showing a green, amber and red condition corresponding to foreseeable, extreme and catastrophic events.

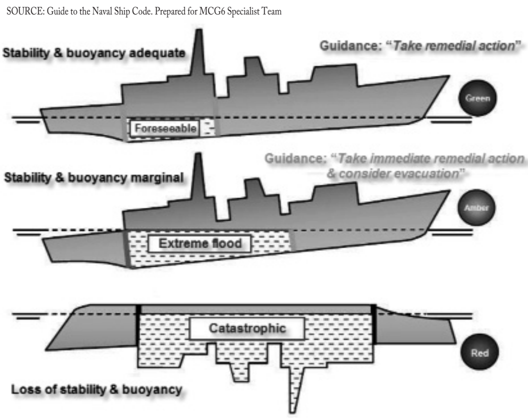

Figure 5. Severity of Damage Event for Stability

A catastrophic event caused by damage that the ship and persons on board would not be expected to survive, will result in rapid loss of the ship. Following an extreme event, resulting from damage more severe than foreseeable but not catastrophic, the ship would be expected to remain afloat in a condition that will allow personnel to evacuate if required. In the event of damage below the extreme level, foreseeable damage, the ship would be expected to survive although the level of real operational capability will depend on a particular navy's concept of operations. "Chapter III" is primarily concerned with foreseeable operating conditions up to extreme damage, with exception of the Regulation *6* preservation of life.

Dynamic Capsize

The loss of dynamic stability will occur due to a lack of righting energy under a variety of conditions, intact or damaged. The capsize mode is often one of four phenomena:

— Dynamic Rolling. Generally occurs in stern quartering seas. This is the generation of large amplitude fluctuations in roll, surge, sway and yaw motions. The roll behaviour is asymmetric in nature and builds with each wave encounter finally resulting in capsize.

— Parametric Excitation. This mode of capsize is as a result of a gradual build up of excessively large rolling. A low cycle resonance can occur when travelling at the wave group speed at approximately the natural roll period and simultaneously at twice the wave encounter period.

— Resonant Excitation. This mode of capsize occurs in beam seas when a ship is excited at or close to its natural roll period.

— Impact Excitation. This mode of capsize occurs when steep or breaking waves impact the ship and cause extreme rolling.

DAMAGE STABILITY CRITERIA ACCORDING TO IMO

Historically, most changes in international regulations for ship design and operation have been introduced as a result of major disasters with a large loss of life. The first notable of such disasters was the sinking of the "HMS Titanic", which led a year later to the first international convention for the safety of life at sea in London. The first damage stability requirements were introduced, however, following the 1948 "SOLAS" convention and the first specific criterion on residual stability standards at the 1960 "SOLAS" convention with the requirement for a minimum residual "GM" *0.05* (*m*). This represented an attempt to introduce a margin to compensate for the upsetting environmental forces. Additionally, in cases where the administration considered the range of stability in the damaged condition to be doubtful, it could request further investigation to their satisfaction.

Although this was a very vague statement, it was the first attempt to legislate on the range of stability in the damaged condition. It is interesting to mention that a new regulation on watertight integrity above the margin line was also introduced reflecting the general desire to do all that was reasonably practical to ensure survival after severe collision damage by taking all necessary measures to limit the entry and spread of water above the bulkhead deck. The first probabilistic damage stability rules for passenger vessels, (Wendel, 1968), were introduced in the late sixties as an alternative to the deterministic requirements of "SOLAS '60". Subsequently and at about the same time as the 1974 "SOLAS" convention was introduced, the "IMO", published Resolution *A.265(VIII).* These regulations used a probabilistic approach to assessing damage location and extent drawing upon statistical data to derive estimates for the likelihood of particular damage cases. The method consists of the calculation of an attained index of subdivision (A), for the ship which must be greater than or equal to a required subdivision index (R), which is a function of ship length, passenger/crew numbers and lifeboat capacity. The equivalent regulations raised new damage stability criteria addressing equilibrium as well as recommending a minimum "GZ" of *0.05* (*m*) to ensure sufficient residual stability during intermediate stages of flooding. The next major step in the development of stability standards came in 1992 with the introduction of "SOLAS" part *B-1*, in "Chapter II-1", containing a probabilistic standard for cargo vessels, using the same principles embodied in the aforementioned regulations. The same principle is also the basis for the current "IMO" regulatory development of harmonization of damage stability provisions in "SOLAS" based on the probabilistic concept of survival. The 1980 UK passenger ship construction regulations introduced requirements on the range of the residual stability curve as well as on the stability of the vessel at intermediate stages of flooding.

The loss of the "Herald of Free Enterprise" in 1987 drew particular attention to roll on-roll off ferries in which the absence of watertight subdivision above the bulkhead deck is a particular feature. The implications of this feature were highlighted by the court of inquiry, which observed that the "SOLAS" conventions and UK passenger ship construction rules had been aimed primarily at conventional passenger ships in which there is normally a degree of subdivision above the bulkhead deck, albeit of unspecified ability to impede the spread of floodwater. In response to this, the UK department of transport issued consultative document number three in 1987, which outlined a level of residual stability that required all existing roll on-roll off ferries to demonstrate compliance with the 1984 passenger ship construction regulations. This standard had previously formed the basis of a submission by the UK and other governments to "IMO", which considered the question of passenger ship stability in some detail. This was the forerunner to "SOLAS '90". Due to its idiosyncrasies, purpose and function, there is not, in the world, naval equivalent to the "IMO" to regulate the minimum standards of construction of warships. This is reflected explicitly in the third rule of "SOLAS", warships and troop carriers are excluded of the compliance of these regulations.

After the disaster of the "MV Estonia", that in September 1994 killed more than eight passengers, eight countries from northern Europe, Denmark, Finland, Germany, Ireland, the Netherlands, Norway, Sweden and the United Kingdom, decided in February 1996, in Stockholm, impose standards stricter than those were adopted a few years earlier by the "SOLAS-90" of "IMO". The basic idea of this initiative was that passenger ships should be designed for road transport so as to withstand the anxiety even when a given quantity of water has reached the car deck. The Stockholm Agreement was established in the context of resolution of the fourteen "SOLAS" of the "IMO" in 1995, and authorized government contractors to enter into such commitments if they believe that the predominant sea conditions and other conditions require specific local stability in a certain sea area. In short, these rules are complementary to the rules "SOLAS-90", with the addition of technical specifications to explicitly take into account the risk of accumulation of water on the car deck. Compliance with these requirements is measured in terms of numerical calculations defined in the treaty or by testing models, according to the model test of the resolution fourteen "SOLAS-95". The introduction of the Stockholm Agreement is closely associated with three unprecedented stops in the history of damage stability/survivability assessment:

— Water on deck was explicitly taken into account for the first time. This is remarkable in view of the knowledge that *85* (*%*) of all deaths with ferry accidents relate to car deck flooding.

— The effect of waves, and this is even more remarkable, was explicitly taken into account also for the first time.
— It paved the way to the introduction of performance-based standards for assessing the damage survivability of ships.

All three steps represent gigantic improvements in the approach to addressing ferry safety but any potential benefits will have to be balanced against any likely costs that might be incurred through the introduction of inappropriate standards.

DEVELOPMENT

Explanation

Nowadays, in both practical navigation and shipyard technical offices, stability tests in load and sea conditions, as in working or faulty conditions, are performed with software packages that starting from the ship design are able to quickly computed the required data. Even, in the comparative studies regarding model behaviour, combined with actual physical models these type of software packages are also needed. Managing, as user, this computerized technique is completely independent of the design. The precision will depend of the accuracy of calculations performed and its numerical-graphical output. This research focuses on evaluating the configuration of warships, with empty deck that could be a frigate, using the working and faulty stability "FORAN" modules, in particular Architecture-Project subsystem property of "SENER Ingeniería y Sistemas". The approach taken to perform the analysis has been the following: In the "FSURF" module, shapes, decks and walls are defined. Then, "VOLUME" module defines ship volumes and computes their volumetric capacity. The "LOAD" volume allows visualization of the detailed requirements generated from the stability requirement chosen, and also enables data entry to compute minimum "GM's". Inside this module, "LOAD", it is possible to check the most common standard stability criteria and a user define criteria obtaining if necessary the limiting "KG" values. The naval architecture calculations that will be with this module use the sections generated in "HYDROS" module. These sections take information about the forms of the ship and the designed decks that give limits to the ship.

This data is initial draft and trim values, and also a description that is used as identified in the minimum "GM's" drawing. In order to calculate the maximum "GM's" that is needed to define the drafts value range between minimum, empty load draft and maximum, scantling draft. It is also required to define the number of increments between minimum and maximum values (Pérez Fernández, 2009). Finally, in addition to the draft range definition, it is needed to define the initial trim. Then the calculation in intact is performed, in order to verify that the ship meets the intact stability requirements, if these requirements would not be met, the final results would be invalid. As a function of the draft and flooding conditions, the faulty stability results are obtained as load conditions are not required to calculate the faulty stability conditions given that stability is a function of bottom what is lost when a ship is flooded. The faulty condition could be caused by flooding through a breach in the side, bottom or a breach on the deck that allows water into the ship hull and provokes the flooding of the ship. When a compartment is flooded, there is a lost of floatability, a change of trim, and changes of transversal metacentric height and longitudinal metacentric height. Therefore, in order to study the stability in faulty conditions a capable software package is needed to perform the calculations. In this research work, "FLOOD" module will perform required calculation.

Application

A flooding condition is made up of initial condition, defined by a load condition, or by the drafts at aft, fore and height of the centre of gravity or by a set of drafts and by a faulty condition characterized by the identifiers of the flooded compartments. Regarding the computation of stability, it could be considered; either free communication amends flooded compartments or held sea water once floatability condition is reached. The calculations could be taken care of by two different methods thrust loss or additional weight. In this paper, the study will make use of the thrust loss. The method of thrust loss establishes that the volume remains constant throughout the different calculations, except when there will be flooded compartments with liquid load, what could happen when the initial situation will be given by a load condition. In this case, the fist step is losing the weights corresponding to the liquid loads. Then, volumes for compartments flooded up to initial floating condition are calculated, with the corresponding modifications for thrust, bottom centre, floating characteristics etc. This new situation will not be an equilibrium one, but it will be necessary to re-estimate the new draft, trim and heel to achieve equilibrium. The first thing to do is the ship selection that will be used for the study. For this selection, different factors, such as type of ship and compartment layout must be taken into consideration. Compartment layout not only consists on having a number of transversal and longitudinal walls separated from each other by optimum distances, but also a number of generic considerations and specific details that demand special attention paying to.

The ship must remain afloat during enough time, the people evacuation must be performed without major shifts in centre of gravity that could impact its viability and the safety equipment (boats and etc) must be available and usable at 100 (%) independently of ship equilibrium condition. These principles drive that the condition to be searched after of the damage will be without heel, i.e. a symmetrical condition. Then, the chosen ship for this analysis is a support ship with the dimensions shown in "Table 3", with one propeller shaft; which has a double bottom with a height upper to a tenth of the beam (*B/10*), where "B" is beam to the scantling draft. To find these dimensions, a database with other ships of similar characteristics has been used. While there are not requirements regarding the longitudinal walls, these should be placed one fifth of the beam (*B/5*) respecting to the shell, because this is the distance of the transversal penetration of the flood that the rules considers. As it was mentioned in the above paragraphs, as results of the "Parsiphae" accident, in this support ship, lateral tanks have been chosen. These tanks quickly connect with each other through tunnels placed on the superior side of the double bottom and are impregnable to water in case of any breach.

Length at waterline	125 (m)
Design beam	12 (m)
Design draft	6 (m)
Design height	10 (m)

Table 3. Main dimensions of the "NVSH" project.

The "LOAD" volume allows visualization of the detailed requirements generated from the stability requirement chosen, and also enables data entry to compute minimum "GM's". This data is the initial draft and trim values, and also a description that is used as identified in the minimum GM's drawing. The ship that we have selected, that we have called "NVSH", has a minimum draft *3.650* (*m*) and a maximum draft *6.210 (m*). We need to define the increments between both of the drafts. In this case, the number of the increments will be two. We have defined trim equal to zero. Both, ship and configuration have been evaluated with high degree of detail in order to achieve equivalent comparisons. The fact of placing a longitudinal bulkhead below the deck number three has not been random. By designing the compartment layout in this way, a bigger number of faulty conditions and higher number of possible combinations are achieved. In the module called "VOLUME", we have defined the next compartments:

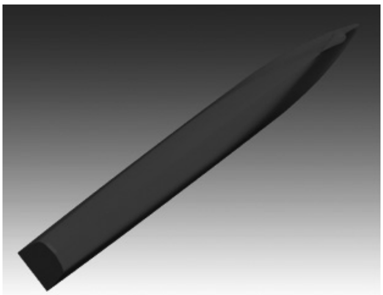

Figure 6. Visualization of "NVSH" project with the "FORAN System" design module.

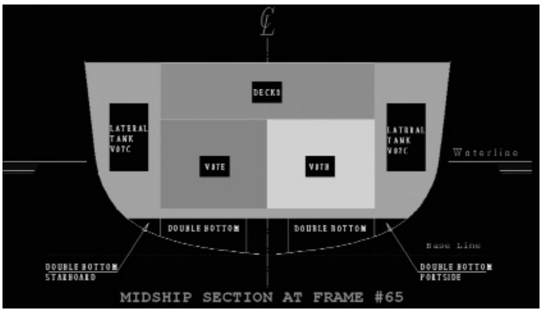

Figure 7. Midship section of the "NVSH" project.

RESULTS

Safety at sea has improved considerably in recent decades thanks to the incorporation of new technologies to the ships and the legislative effort made by the "IMO", without forgetting the work of ship inspections and Classification Societies ensuring that vessels are constructed and operated according to existing regulations. The major maritime disasters have traditionally been coupled with the pressure of public opinion, alarmed at the loss of life at sea. It has prompted the governments of the major maritime nations in a legislative effort to improve the safety of ships. This is the first case of "SOLAS", held in London in 1914, two years after the sinking of the "RMS Titanic", though it was not actually due to the outbreak of the World War I. It is not necessary to go back to early last century to find new examples, the collapse and subsequent overturning of the "MV Estonia" in 1994, in waters of the Baltic Sea, was the driver, as discussed in chapter two of this article of the Stockholm Agreement and a series of resolutions "IMO" related to the stability of such vessels. The "IMO", as a UN agency, was founded in Geneva in 1948, but did not start its activity until 1952, to develop and maintain the regulatory framework for governing the shipping, including aspects such as security or pollution, taking into account the international conventions as "SOLAS", "MARPOL" or International convention on standards of training, among others. It is organized into specialized committees and subcommittees, consisting of experts from member countries to study various aspects of maritime safety and the updating of legislation regulating. This is the case of the "MSC", which means all aspects that directly affect the sea, such as construction and equipment or the training of crews.

The establishment of an international maritime law, especially regarding safety, is a long process that is not without difficulties, it requires a lengthy period of research and analysis, consensus and ratification by a sufficient number of countries. Its implementation is not always possible in older ships. The first result is that ships can coexist for years, with two standards widely depending on their seniority or banner, as happens with the well-known case of oil tankers without dou-

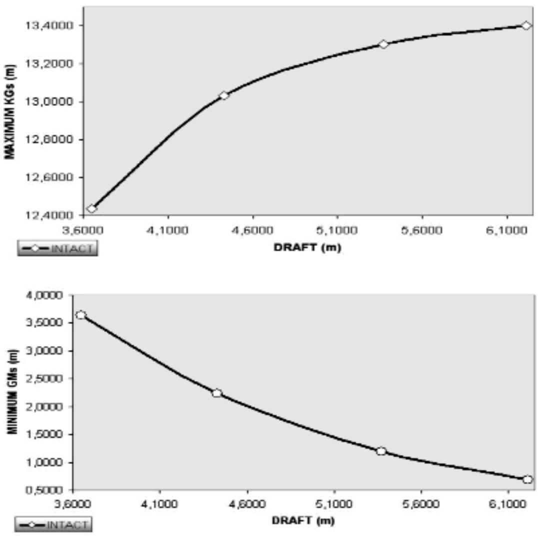

Figure 8. Intact stability criteria curves for "NVSH" project according to "IMO".

ble hull as the “Prestige”. However, despite the remarkable technical and legislative effort that are carried out by “IMO” or the major advances in the safety convention “SOLAS”. Warships are exempt from these rules and do not exist. In the naval field, there are not organization equivalent to “IMO” to understand the international level about the safety of such vessels. Traditionally, the warships are taking the rules of “IMO” exists that do not interfere with naval objectives and adapting them to the extent as far as possible. Then the calculations are made on intact to see if the warship, “NVSH”, complies with the stability intact, and that if not fulfilled, the values were obtained at the end of the study would be worthless.

The angle of progressive flooding is greater than forty degrees. Depending on the drafts and the flood conditions will get stability in damage, and to remember that for stability in damage, it is not necessary to know the load conditions, since it depends on the stability of the hull forms, it is this that is lost when a ship is flooded. The flood damage can be considered by an opening in the side, at the bottom or the failure of the deck to allow the entry of water and lead to flooding of the ship. In this paper, the fault occurs on one side, bottom up. For this paper, the ship has been damaged, compartment by compartment. When one compartment is flooded, there is a loss of buoyancy, a change of trim, a variation of a transverse metacentric height and longitudinal metacentric height variation. Now intends to study the “GM´s” minimum, or “KG´s” maximum for the three criteria that we want to compare. To explore the stability problems, it needs the help of software to carry out the calculations. In the case of this research to study the “SOLAS”, the U.S. Navy and the British Royal Navy criteria, the calculations were made using the module “FLOOD”, choosing a damage condition and a load condition of the vessel intact, and are getting results that are developed below. The worst damage is whose “KG´s” maximum is the minimum among all possible failures, or put another way, which has the stronger “GM´s” minimum for each draft.

CRITERIA NUMBER	DESCRIPTION
1	“GZ” of 0.2 (m) between 30° and 90°
2	“DN” of 55.0 (mm.rd) between 0° and 30°
3	“DN” of 90.0 (mm.rd) between 0° and 40°
4	“DN” of 30.0 (mm.rd) between 30° and 40°
5	“GM” > 0.150 (m)
6	Angle for which a maximum “GZ” is obtained > 25°
7	“IMO” weather criterion

Table 4. “NVSH” project criteria.

Draft (m)	DP (T)	Criteria	GZ (m)	GM (m)
3.65	4069.5	7	12.43	3.64
4.43	4801.9	7	13.03	2.23
5.37	6364.5	7	13.30	1.19
6.21	7488.1	7	13.40	0.68

Table 5. Limit values for the "NVSH" project.

Where "DP" is displacement in tons, "GM" is minimum permissible metacentric height in meters and "KG" is permissible height of the centre of gravity in meters.

SOLAS. Stockholm Agreement

"SOLAS" implies safety, but by no means applicable to all types of vessel, mainly because many of those rules are unworkable or unrealistic for warships. For example, the orange colour of the lifeboats. Shipyards are based primarily on the experience, or benefiting from the lower standards in other countries, the consequences of ignorance and dependency involved. Due to the need to unify criteria for the countries of the "NATO" and the spirit of the lack of a security policy that ensures compliance minimal, formed a group of specialists with the task of developing the "NSC", a naval military code based on national standards, international standards such as High Speed Craft, high-speed vessels, and primarily, the applicable rules of the "SOLAS", to promote improvements in the design construction and in specific areas such as navigation in international waters, communications or environmental protection. The criterion "SOLAS" begins by defining the extent of damage to consider. These dimensions, based on statistics of failure, are defined as a fault length equal to 3 (%) of the length plus three meters, a penetration of damage equal to (*B/5*) and a height of damage that goes from bottom to top without limit (Riola, Perez Fernandez, 2009). The worst damage in "SOLAS", considering water on deck, is composed of two compartments, from the frame # 138 to frame # 162. The following is the "Table 6" with the data obtained with the "FLOOD" and its corresponding graph, "Figure 9".

MAXIMUM KG AND MINIMUM GM CALCULATION				
Trim (m)	Draft (m)	Displacement (T)	$KG_{MÁX}$ (m)	GM_{MIN} (m)
0	3.65	4069.5	14.761	1.301
0	4.43	4801.9	13.959	1.048
0	5.37	6364.5	13.335	0.889
0	6.21	7488.1	12.996	0.791

Table 6. Worst damage according to "IMO" criteria for the "NVSH" project.

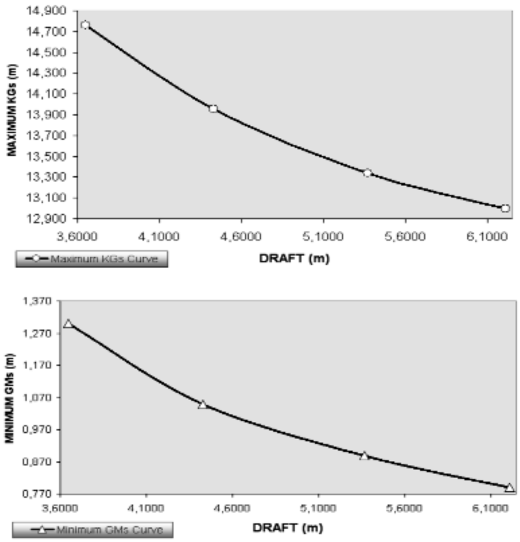

Figure 9. Damage stability criteria curves for "NVSH" project according to "IMO".

There are certainly some obvious weaknesses in the requirements of the Agreement and this must be borne in mind when assessing roll on-roll off safety. The Stockholm Agreement was created on the presumption that a vessel designed, or modified, to "SOLAS '90" standards ensures survival at sea states with Hs of only *1.5* (*m*). This was suggested in the face of uncertainty and lack of understanding of the phenomena involved. The evidence amassed so far and presented in the following suggests that this was a considerable underestimate. The maximum penalty of *0.5* (*m*) height of water on deck is ill based. It is to be noted that the forty-nine tests used to measure water accumulation on the car deck comprised only four open-decked ships, the others having car decks with: three transverse bulkheads, five central casing, nineteen central casing with transverse bulkheads, eight side casings and ten side casings with transverse bulkheads. It is straightforward to prove that the height of water accumulated on a subdivided deck is considerably larger than the height of water accumulated on open decks. More importantly, requirements based on subdivided decks are likely to promote designs with similar arrangements, which is contrary to the roll on-roll off concept itself. Finally, the effect of water on deck is taken into account by a calculation method that does not preserve the physics of the problem, and being based on static and deterministic approaches, it tends to negate the potential for adopting rational approaches to safety through the introduction of operational sea states and performance-based standards.

U.S. Navy

The US stability criteria are documented in the Design Data Sheet (DDS 079-1) printed in 1975, which is divided into criteria for damage stability for both sideprotected and non-protected vessels. The non-protected criteria relate to the 270 (*ft*) cutter that is the class used in this investigation. The "DDS 079-1" states that an angle of less than fifthteen degrees is required after damage for operational requirements. There is no mention of cross-flood systems except for in the side-protected vessels, which states that the maximum list shall not exceed twenty degrees and that

MAXIMUM KG AND MINIMUM GM CALCULATION				
Trim (m)	Draft (m)	Displacement (T)	$KG_{MÁX}$ (m)	GM_{MIN} (m)
0	3.65	4069.5	15.147	0.919
0	4.43	4801.9	14.232	0.787
0	5.37	6364.5	13.641	0.673
0	6.21	7488.1	13.412	0.620

Table 7. Worst damage according to US Navy criteria for the "NVSH" project.

arrangements exist for rapidly reducing the list to less than five degrees. The current stability criteria used by the US Navy were developed during and shortly after World War II (Sarchin, Goldberg, 1962). These criteria are based on static righting arm curve, are largely empirical, and do not explicitly consider many variables which can have a major impact on dynamic intact stability. However, they are well-accepted by the naval architecture community, and within the bounds of conventional hull forms, have proven to be a reliable, generally conservative, ordinal measure of intact stability. Current international efforts for improving naval ships stability criteria are focused on time domain analysis including the capability to model a steered ship.

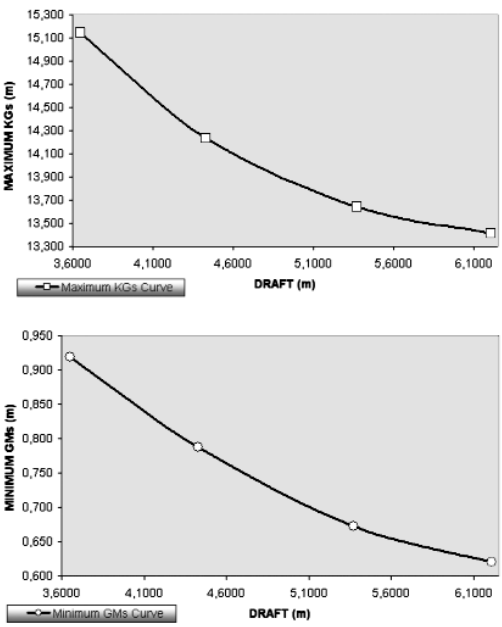

Figure 10. Damage stability criteria curves for "NVSH" project according to US Navy.

Commercial ship intact stability is addressed in a number of "IMO" regulations. The following is the "Table 7" and its corresponding graph, "Figure 10".

The "IMO" weather criteria considers wind with gusts and a roll-back angle which is dependent on the ship's static righting arm and other ship roll characteristics (IMO 1994). The US Navy and other navies have not kept pace with "IMO" developments. They continue to rely on the empirical World War II criteria until the more sophisticated methods are developed and validated. Current naval ship can be greatly improved with a few small changes which maintain the integrity of their basic approach, and increase their commonality with the "IMO" criteria. These changes are worth making now, to support the design of new ships until more sophisticated methods are in place. The worst damage is that which includes three compartments, ranging from frame #138 to frame #174.

British Royal Navy

The damage categories, in the "NSC", are based on defined shapes:

— Sphere. To be used for explosions. For explosions detonating against the outside of the hull, half the sphere to be used.

— Cube. To be used to define the volume directly affected by fire and which may change in shape to fit the compartment.

— Raking/grounding. To be used in the appropriate horizontal orientation to describe the extent of raking or grounding damage, the apex representing the maximum penetration.

— Collision. To be used in the correct vertical orientation to describe the extent of collision damage from the bow of another ship, the apex representing the maximum penetration.

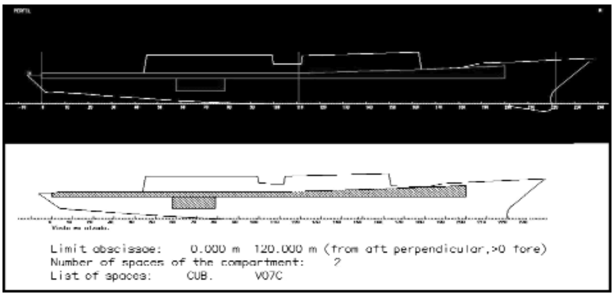

Figure 11. Longitudinal section in the "NVSH" project for the first flood.

The extent of the worst damage category is defined as damage category C, significant: sphere with *10 (m)* of radius, cube with *20 (m)* of sides, raking/grounding with *40 (m)* of length and *5 (m)* of equal sides and collision damage with *40 (m)* of height and *5 (m)* of equal sides. The temperature is heat caused by initiating event assuming no other combustion. Time to rise to peak of *20 (min)*, peak temperature *400° (C)*, duration of peak temperature *400 (min)* and time for temperature to revert to normal *200 (min)*.

Raking/grounding is the worst of all, proof that our ship, "NVSH" meets all known criteria, will not tolerate a failure of forty meters in length in the double bottom. Therefore, for comparison between the criteria, we will not use the failure of raking/grounding which was defined in the "NSC". Of the other three types of damage, and if comparable with the "SOLAS", the worst of all is the one defined by a cube of twenty meters on the side, which affects the compartments that are defined between frames # 138 and # 162. Such as the title of the work submitted for this article it is important to note that a detailed study of the navies criteria to use for the calculations, made by the CAD/CAE "FORAN", the criterion of the British Royal Navy "NES-109". It is necessary in this case study the damage defined as the "NSC" with a cube. The following is the "Table 8" with the data obtained with the "FLOOD" and its corresponding "Figure 12".

MAXIMUM KG AND MINIMUM GM CALCULATION				
Trim (m)	Draft (m)	Displacement (T)	$KG_{MÁX}$ (m)	GM_{MIN} (m)
0	3.65	4069.5	15.034	1.045
0	4.43	4801.9	14.089	0.902
0	5.37	6364.5	13.501	0.771
0	6.21	7488.1	13.248	0.663

Table 8. Worst damage according to British Navy criteria for the "NVSH" project.

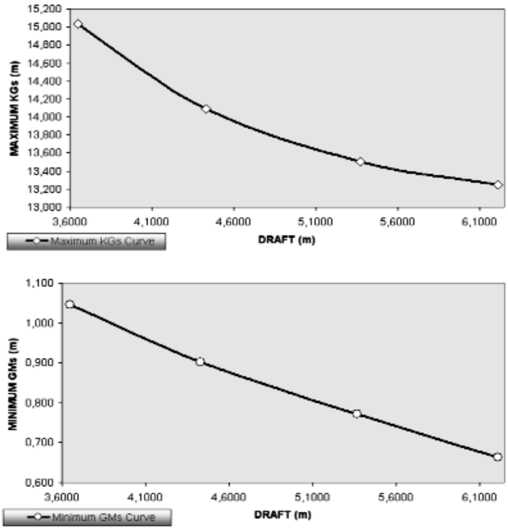

Figure 12. Damage stability criteria curves for "NVSH" project according British Navy.

CONCLUSIONS

In this paper, we have proposed a comparative analysis of the different criteria of stability after damage. In fact, very interesting results have been obtained. The theoretical calculations are made taking into account the affect of the damage in the ship's side. It dispenses, in the calculation the effect of the superstructure that surrounds the garage of the main deck and the only thrust the boat is which gives the volume of vessel that lies beneath this deck. The concept by which it calculates the effect of the superstructure is due to the damage that always occurs, equalizing the water levels outside and inside. It should be borne in mind that it does not correlate with the theoretical model test results. In the tests, once the water is on the deck the boat is heeling to one side of the equilibrium due to the balance of the ship. The flood occurs on one side and, therefore, when trim to the side is not damaged a clear thrust of the intact side, which in turn is causing right.

When the heel toward the damaged side exterior water levels are never the same so there may be a push, when the level inside is greater than the outside inside. These effects of thrust, related with the balance of the ship, are ignored in the calculations and whether any effect they have on the test. The solution could be adopted to give the true value of a superstructure permeability to allow for this right effect, if only for the calculation of water on deck, this value could be inferred from the trials to date and of tests to be conducted in the near future. Curiously this consideration of buoyancy, as a concept of open superstructure, was considered in the Rules of Freeboard in 1930, but was subsequently deleted in the Load Line Rules of 1966. Also in the summary of trials survival ferries, made by the United Kingdom as a result of the sinking of the "MS Herald of Free Enterprise" is induced to think of the obvious effect of the superstructure of the garage as a right arm, although affirms the difficulty of their assessment. It should be stressed that while the "SOLAS" floods one compartment in merchant ships such as tankers, ro-pax and roll on-roll off two; warships governed by the US Navy "DDS" three. For this research the various studies and calculations have been carried out on purpose designed test vessel. We have created a vessel to comply with different conditions, like having an empty deck, without pillars, one propeller shaft and whose forms are the same as far as possible to a warship, in fact, to a frigate. Having created a ship, which by its nature would be a warship, she might consider that the criteria are compared in this article, on the same ship. "Figure 13" presents a chart that summarizes the behaviour of each criterion.

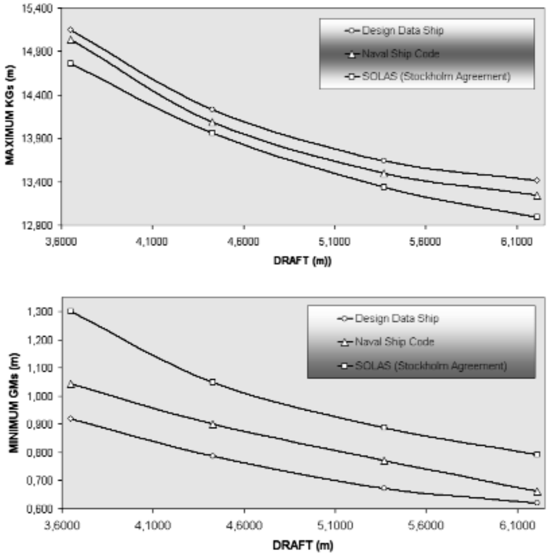

Figure 13. Comparative between criteria.

A most important conclusion to emphasize, that while the approach of the British Royal Navy is more restrictive than the US Navy, if we are considering the Stockholm Agreement to "SOLAS", is that this convention is the most restrictive of all. If water is seen on deck, no military approach is more restrictive than the "IMO". Depending of these damages, we expose a comparison between the "NSC" damages in the warship studied, see "Figure 14".

There are many areas where military vessels could improve safety standards, although not necessarily to be regarded as less secure than the civil vessels. It is the opinion of every government and authority for the establishment of naval security level to offer their equipment and how it is achieved. For example, the "MoD" requires that the security level of the allocations of their vessels at least, whenever possible, similar to the crews of merchant ships. The Classification Societies arose in the early nineteenth century to assess the capacity of a vessel to transport cargo. By the simple process of open and inspect all spaces and compartments of a vessel or measure the wear of the bearing, the inspectors of the Classification Societies were able to estimate the condition of the vessel to which assigned a certain level of class . The owner could, through the favourable report of the inspectors, win the confidence of the owner of the cargo for carriage and to secure favourable conditions. This inspection system has evolved towards preventative maintenance, which the manufacturer of the equipment recommended to replace a number of parts and components over time and reached a number of hours of advanced features, and then towards the maintenance or predictive maintenance based on condition, in which actions depend on the maintenance of certain parameters, such as the vibration level. Since the mid-seventies, the main Classification Societies employ maintenance plans together with the registration books to determine what equipment should be examined, thus avoiding unnecessary inspections that may even damage the proper functioning of a team. At the end of the Cold War, the main armed world have been forced to undertake a transformation of their fleets by varying the way they are constructed, operated and maintained its naval units in order to reduce costs. In this context the contribution of the Classification Societies, has been essential for the incorporation of standard commercial shipbuilding in the area, enabling better resource management or operation more efficiently.

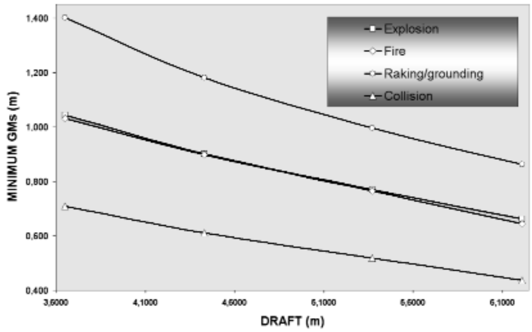

Figure 14. Comparative between "NSC" damage category C (DCC) significant.

The reality is that today, in some countries, warships frontline are built in accordance with rules of the Classification Societies, private agencies for their requirements ensuring compliance with building regulations stricter than the requirements of "SOLAS". An example of this is that ninety percent of the British fleet is classified, in part or in whole, under "LLR" or "DNV" (Ingram, 2007). However, there are major difficulties in implementing all the rules of the Classification Societies at the naval field (Boral, Gurley Tar Becker and Humphrey, 2005); especially to establish a priority mission and capacity combat against security. It is important to distinguish the importance of the new rules "NSC". As we have tried to reflect throughout the paper, the "NSC" has become the criterion of stability in damage than more is acclimating to the standards of the navies in the *XXI* century. For each type of vessel could be a priority for study in terms of damages of the "NSC". For a better under-

Kind of damage	"NSC" damages	Ship affected	Damage level
1	Raking/grounding	Frigate	Dangerous
2	Fire	Aircraft Carrier	Important
3	Explosion	Merchant ship	Important
4	Collision	Roll on-roll off	Severe

Table 9. Explanation about "NSC" by kind of ship.

standing of the damages of the "NSC" and how they affect different types of ships, will be presented in the "Table 9" the most revealing.

As the "NSC" is to provide a level of safety appropriate to the role of the ship and benchmarked against statute while taking into account naval operations, it is necessary to define the degree of survivability in a form that can be taken into account in the development and application of all "NSC" chapters. As an example, the main difference between the approach to fire safety for naval and civilian shipping is that "SOLAS" considers the risk of fire based on the function of each compartment whereas for naval ships, hostile acts may result in fire anywhere on the ship, both externally and internally. The consequence is that the solutions that are adopted for accidents may differ from those that are required to prevent and counteract hostile damage events. Thus, for the effective application of the "NSC", it is necessary to clearly define the extent of damage that reflects both accidental damage and potential damage caused by hostile acts, the damage location, the degree of vulnerability (protection, redundancy of systems, materials used), the required post-damage ship capability and the philosophy for recovery from the damaged state. Each navy will have its own unique approach to this issue, and it is not possible to be prescriptive in the "NSC". However, it is possible to provide a basic framework that can then be adapted by each Naval Administration. It is then essential that the owner and naval administration agree the required level of survivability in these terms for each class of ship.

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CASO DE ESTUDIO DE LOS CRITERIOS DE ESTABILIDAD PARA BUQUES DE GUERRA SINIESTRADOS

Resumen

En la actualidad todas las armadas se esfuerzan por lograr un equilibrio entre seguridad y capacidad militar, asegurándose que las actividades en tiempo de paz sean realizadas con un nivel aceptable de riesgo. Pese a la necesidad intrínseca de diferencias de construcción, el nivel aceptable de seguridad para las armadas está equiparándose a los buques bajo legislación civil. Por ello, las armadas han recurrido a las Sociedades de Clasificación, cuyos reglamentos para buques mercantes están sujetos a la legislación internacional controlada por "OMI", particularmente el Convenio "SOLAS". Estos convenios "OMI" no son siempre adecuados para la mayor parte de los buques de guerra, de modo que el objetivo militar requiere alternativas de diseño y operación, no enteramente compatibles con la filosofía de los acuerdos "OMI" y sus soluciones.

Separar las reglas de las Sociedades de Clasificación de los convenios "OMI" para aplicación a los buques de guerra puede traducirse en malas interpretaciones y un descenso en los criterios de seguridad, por ello las armadas continúan confiando en los criterios empíricos en vigor desde la II Guerra Mundial, hasta que se validen otros métodos mejores. El artículo presenta una serie de comparaciones, entre los criterios navales más utilizados, dando lugar a conclusiones muy interesantes, como que los actuales criterios de estabilidad pueden ser enormemente implementados con unos pocos cambios que incrementen puntos en común con criterios "OMI", como por ejemplo, el cálculo de agua en cubierta desarrollado en el Acuerdo de Estocolmo.

METODOLOGÍA

En este artículo se realiza un estudio sobre la configuración de un buque de guerra, que podría ser un buque anfibio o una fragata; con los módulos de estabilidad en estado intacto y averías del Sistema "FORAN", subsistema de Arquitectura-Proyecto, propiedad de SENER, Ingeniería y Sistemas. El proceso seguido para realizar el análisis ha sido el siguiente; en el módulo "FSURF" se crean las formas, cubiertas y mamparos, posteriormente con el módulo "VOLUME", se definen los espacios del buque y el cálculo de sus capacidades. El módulo "LOAD" permite visualizar los subcriterios generados a partir del criterio de estabilidad seleccionado, así como posibilita introducir los datos necesarios para el posterior cálculo de "GM´s" mínimos.

El buque escogido para hacer el estudio se llamó "NVSH", proyectado con un calado mínimo de *3.65 (m)* y máximo de *6.21 (m)*. Se definieron dos incrementos entre dichos calados con trimado nulo y se realizaron los cálculos en estabilidad intacta para comprobar que el buque "NVSH" cumple con los criterios mínimos. El diseño del buque se ha realizado con una alternativa de compartimentado, a *(B/5)*. Se calcularon los "GM´s" mínimos o "KG´s" máximos, para los tres criterios que se quieren comparar en estabilidad en averías y para ello se necesitó de un software específico. Para el criterio del "SOLAS", de la armada americana y de la británica, los cálculos se hicieron con el módulo "FLOOD". Se consideró la peor avería la que necesitase mayores "GM´s" mínimos para cada calado.

CONCLUSIONES

La normativa mititar para los cálculos de estabilidad es inicialmente más estricta ya que mientras el "SOLAS" obliga a realizar los cálculos inundando sólo un compartimento en los buques mercantes, tales como lo petroleros, y en los buques roll on-roll off de pasaje dos; las "DDS" americanas exigen un mínimo de tres.

De todas las averías estudiadas, el encallamiento o desgarro del fondo, es la peor posible, tanto que el buque prueba, "NVSH", que cumple todos los criterios conocidos, no aguantaría una abertura de cuarenta metros en eslora en el doble fondo. El criterio de la armada británica "NES-109", es el más riguroso, seguido del criterio de las "DDS" norteamericanas y por ultimo del criterio de las marinas civiles sin considerar agua en cubierta, el "SOLAS" sin Acuerdo de Estocolmo. Si se considera agua en cubierta el anexo del "SOLAS" relativo al Acuerdo de Estocolmo es lo suficientemente riguroso que pasa a considerarse el criterio más rígido de los conocidos hasta el momento, sin contar con el "NSC". La adopción del "NSC" mejorará el modo y la eficacia con que se gestiona la seguridad a lo largo del ciclo de vida del buque.

Una de las razones principales de ser del "NSC" es la de poder aplicar, debidamente adaptadas, normas civiles a buques de guerra, en especial las resoluciones "OMI". Las armadas tienen ahora un criterio de estabilidad después de averías, el "NSC", que se adecua a cada tipo de avería, basándose en las condiciones del diseño de las futuras operaciones del buque y sus posibles daños.

El "NSC" constituye un importante paso en la homogeneización de criterios de seguridad en los buques de guerra, lo que sin duda facilitará en el futuro los proyectos conjuntos internacionales para la construcción de nuevas unidades navales. Es importante destacar la importancia del nuevo código "NSC", que se ha convertido en el criterio de estabilidad después de averías que más se aclimata a las necesidades de las armadas del siglo *XXI*.