Guidelines for Hull Condition Assessment Applicable to Single Skin Bulk Carriers on International Trade

Javier Bru Roncallo

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Supervisor: Dr. Zbigniew Sekulski, West Pomeranian University of Technology, Szczecin

Internship Tutor: Eng. Juan Jose Moron, OMCS CLASS, Panama

Reviewer: Prof. Robert Bonsart, Rostock University

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ABSTRACT

The poor safety record and innumerable accidents recorded on board of bulk carriers coupled with the type of cargoes and hardship that bulk carriers endure during its operational life; have triggered the maritime community to pay special attention to the design, construction and overall the scope and quality of the inspection of the bulk carriers in service.

As it is widely known, due to several reasons, during the ship's life of a bulk carrier, the vessel is affected by structural defects leading to deterioration of its condition. These structural defects may take the form of material wastage (corrosion), fractures or deformations, origin of which may be traced during the building stage to poor structural details, deficient materials, misalignment, welding defects and in-service stage to heavy cargos, environment, heavy weather, material wastage, collision, poor maintenance, improper loading/unloading operations, among others.

In general, ship hull structure assessment is a process to determine the reliability of the existing structure in terms of carrying current and future loads and to fulfil its task for a given period. In this process, if paramount to be always clear of the assessments objectives and acceptance criteria. In the shipping world, there are two main objectives to conduct the hull assessment of existing ship hull structures, the assurance of structural safety and serviceability and the minimisation of costs and repair time.

Due to the great dimensions of the vessels nowadays, the dangers and difficulties to access the different ship structure of a bulk carrier make the classification and statutory inspections on board bulk carriers very challenging. Especially, when one takes into account the commercial pressure inherited in the maritime operations and that these inspections will last maximum one or two days and while the vessel is performing cargo operations. Being the only exemption when the inspection is carried out in conjunction with a dry-dock.

The main objective of this thesis is to develop a documentation aide in the form of clear procedures and guidelines for hull condition assessment of single skin bulk carriers to be used by Overseas Marine Certification Services (OMCS CLASS) attending surveyors during their inspections. Overseas Marine Certification Services (OMCS CLASS) is a recognized organization, recognized security organization and classification society acting on behalf several flag states in order to survey, certify and classify vessels registered on those flags. These guidelines should assist the attending surveyors in conducting their inspections as informed as

possible and making sensible decisions by focusing on structural areas that are most prone to failure or degradation.

It includes a review of the survey history of ten (10) single skin bulk carriers classified by OMCS CLASS; which were randomly selected from a list of sixty (60) vessels provided by the company. The review consisted on verifying the class survey statements, transfer of class information, list of deficiencies or conditions of class related to the hull raised during that period, thickness measurement reports and finding, enhanced survey program survey reports and port state control detention records. As well, a review of the safety aspects related to the performance of the survey, the necessary access facilities, the preparation necessary before the surveys can be carried out and expose the different main hull structural areas where damages have been recorded, focusing on the main features of the structural items of each area.

Due that the information gathered during the internship was deemed to be confidential by the company and that the propose guidelines is to be of exclusive use of OMCS CLASS, the thesis is divided in two parts; a first part is made public and comprise of five sections on which a brief description of the propose guidelines is included and an appendix no. 1 on which the complete propose guidelines is included on OMCS CLASS letter head ready for their review and hopefully future exclusive use. On the appendix no. 2 of this thesis, the different existing forms of OMCS CLASS for the survey program questionnaire, program and the reporting format that were reviewed and updated are included.

These guidelines encompass and summarize the different requirements, recommendations and guidelines found on IMO Resolution A.798 (19), A.866(20), A.1049(27), A.1104(29), and IACS Unified Requirements Z7, Z10.5, Z11, and IACS Recommendations 46, 47 and 87, IACS Harmonized Common Structural Rules for Bulk Carriers, and IMO MSC.1/Circ.1502 among others.

1 INTRODUCTION

Throughout their existence bulk carriers have been a heated topic which has continuously evolved in regards to their safety and structural requirements; mainly due to their safety records throughout the years while these vessels were evolving on their size due to economies of scale. A basic example; it is just the difficulty that the industry, the International Marine Organization (IMO) and the International Association of Classification Societies (IACS), has faced in agreeing for a definition of a bulk carrier. The International Convention for the Safety of Life at Seas (SOLAS) gives a rather broad definition of bulk carrier, whereas on the other hand, IACS's Common Structural Rules (CSR) presents a narrower definition.

The SOLAS 1974 Convention definition can be found in Chapter XII, Regulation 1 of the 2016 consolidated edition, which states a bulk carrier is a ship which is intended primarily to carry dry cargo in bulk, including such types as ore carriers and combination carriers ((IMO), International Convention of Safety of Life at Sea, 1974, 2016 Consolidated Edition). IACS's 2006 Common Structural Rules defines them as seagoing self-propelled ships which are generally constructed with a single deck, double bottom, hopper side tanks and topside tanks and with single or double side skin construction in the cargo length area, and intended primarily to carry dry cargoes in bulk ((IACS), Common Structural Rules or Bulk carriers, 2006).

For the purpose of this thesis, single side skin bulk carrier refers to a single deck vessel with a double bottom, hopper tank, topside tank, cargo hold area with single side skin and deck hatches and which is intended primarily to carry dry cargo in bulk. On the figure no. 1, one can observe the general layout of the single skin bulk carrier construction provided by the IMO. ((IMO), Bulk Carier Safety, 2013).

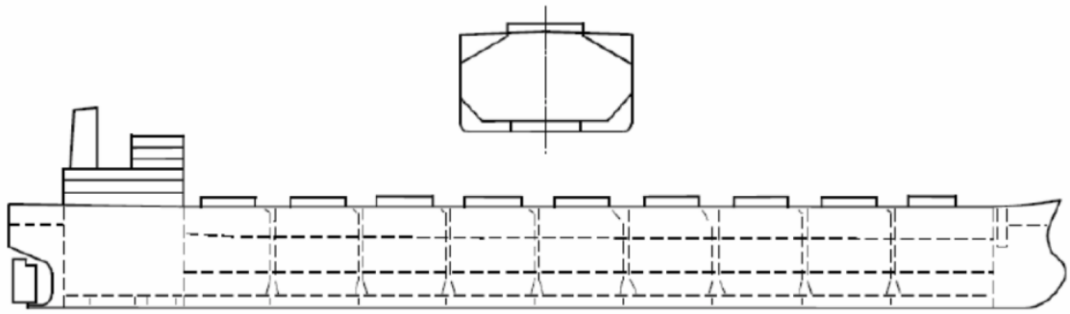


Figure 1 - Typical Configuration of Single Side Skin Bulk Carrier

Bulk carriers were initially designed and developed in the 1950s for the main purpose of carrying large quantities of bulk commodities such as grains, coal, and iron ore in the Great Lakes of Canada and the United States. On the bulk carrier world, single side skin with double bottom arrangement using mild steel is the most common structural layout, although, double side skin designs and high strength steel are becoming popular nowadays. The first bulk carrier designed with hopper tanks and top wing tanks was the MV Cassiopeia built in 1954. Nowadays, per the latest statistics provided by Clarksons Research in 2016, there are approximately more than 10,000 bulk carriers of different sizes in service trading around the world, providing the crucial service of trasporting the world raw commodities necessary to fuel global economy. Bulk carriers are categorised according to its navigation route and deadweight such as Handy Size, Handymax, Panamax, Neo Panamax, Cape Size and Great Lakes bulk carrier. On the table no. 1, the current fleet of bulk carriers in service and on order can be seen segregated by their deadweight as per Clarksons Research 2016 figures.

Table 1 - World Bulk Carrier Fleet (Clarksons Research, 2016)

WORLD BULK CARRIER FLEET[1] PROFILE AS OF JANUARY 1st, 2016										
SIZE GROUP BY DWT	**AVERAGE DIMENSIONS, SPEED**				**IN SERVICE**			**ON ORDER**		
	Length (Meter)	**Beam (Meter)**	**Draft (Meter)**	**Speed (Knots)**	**SHIPS**	**DWT (000s)**	**Average DWT**	**SHIPS**	**DWT (000s)**	**Average DWT**
Handy Size (10,000-29,000 dwt)										
10,000-19,000	138.7	21.4	8.2	13.1	614	9,031	14,708	17	214	12,588
20,000-24,999	158.2	24.7	9.5	13.6	348	7,954	22,855	8	177	22,075
25,000-29,000	170.9	26.3	9.8	13.9	745	20,834	27,965	13	361	27,776
Handymax (35,000-59,999 DWT)										
30,000-39,999	181.2	28.6	10.3	14.2	1.551	54,049	34,848	359	13,348	37,179
40,000-49,999	190.6	31.2	11.4	14.2	838	38,388	45,809	39	1,773	45,465
50,000-59,999	193.1	32.3	12.6	14.3	2,482	141,021	56,818	562	34,820	61,957
Panamax (60,000-79,999 DWT)										
60,000-79,999	225.2	32.4	13.9	14.2	1,329	99,195	74,639	25	1,906	76,245
Cape Size (80,000 DWT and over)										
80,000-99,999	239.1	34.5	14.4	14.3	1,124	96,222	85,607	308	25,483	82,735
100,000-119,000	252.3	43.0	14.3	14.6	125	14,079	112,635	5	551	110,136
120,000-159,999	270.9	43.5	17.0	14.0	69	10,193	147,720	9	1,322	146,888
160,000 & over	298.5	47.7	18.4	14.8	1,437	285,094	198,395	226	46,652	206,425
Total	**208.6**	**32.9**	**12.8**	**14.2**	**10,662**	**776,060**	**72,787**	**1,571**	**126,606**	**80,590**
(1) Excludes vessels confined to the Great Lakes						Source: Bulk Carrier Register 2016, pp 13,17-18				

IACS's 2006 common structural rules recognises three (3) categories of bulk carriers ((IACS), Common Structural Rules or Bulk carriers, 2006):

- BC-A: bulk carriers designed to carry dry bulk cargoes with a density < 1.0 tonne/m^3,
- BC-IB: BC-A, plus carriage of cargoes with density ≥ 1.0 tonne/m^3 (with all cargo holds loaded),
- BC-C: BC-B, plus carriage of cargoes with density ≥ 1.0 tonne/m^3 (with specified holds empty at full draught).

The accident database from International Association of Dry Cargo Ship Owners (INTERCARGO) and International Association of Classification Societies (IACS) showed that from 1983 until June 1997 inclusive, 73 bulk carriers were lost due to known or probable structural failure and at least more than 40 ships suffered severe damages. Further investigation carried out by IACS shows that 70% of the total losses had three common factors ((IACS), Formal Safety Assessment of Bulk Carrier Fore-end Watertight Integrity, 2001):

- ship with age > 18 years,
- carrying heavy ore cargoes,
- suffered water flooding of the cargo holds during bad weather conditions.

Following a spate of losses of bulk carriers in the early 1990s, the world maritime community got together to address the different safety issues pertaining to the standards of design, construction and in-service inspection on these vessels. Due to this, classification societies were heavily questioned on their role in safeguarding the safety of life at sea and the protection of the marine environment and the quality/reliability of the inspections performed on board Bulk Carriers. An example of these accidents is seen on the MV Boca Grande which had her side shell fractured that led to the vessel sinking in shallow waters off the coast of Venezuela as it can be seen on the below figure no. 2.

Figure 2 – Side shell fractured and ruptured of MV Boca Grande grounded off the coast of Venezuela

Unfortunately, throughout history, the shipping industry has been a rather reactive industry which most of the new safety regulations are triggered by maritime accidents. In the bulk carrier world, the MV Derbyshire, which in 1980 sank off the coast of Japan with a death toll of forty-four (44) persons, stands as one of those that assisted partly trigger new regulations, since it was widely investigated. The IMO, as the international body in charge of standardising the international safety regulations, adopted several new regulations in the International Convention of Safety of Life at Sea (SOLAS) and several Maritime Safety Committee (MSC) resolutions and circulars were developed. Among the most important regulations adopted which will be the base of this study will be the IMO International Code on the Enhanced Program of Inspections during Surveys of Bulk Carriers and Oil Tankers (2011 ESP Code), the IACS Unified Requirements and Common Structural Rules (CSR). The ESP Code includes more extensive surveys of all bulk carriers regardless of size and date of construction. The new rules required a specific survey program to be worked out by the owner in co-operation with the classification society, in advance of the renewal survey of the hull, in order to establish an agreement for providing safe and sufficient means of access and cleanliness to allow a close-up inspection.

Detailed inspections and maintenance programs are vital to maintain the hull watertight integrity and hatch covers weathertightness since, as the ship structures age, the like hood of the hull structure suffering from a wide range of damages such as corrosion wall thinning, pitting and multiple fatigue cracks increases significantly. These inspections are performed by various entities such as surveyors of classification societies, by ship's crew or owner's superintendents, by vetting inspectors and by thickness measurement companies. Hull inspections typically cover the state of coating, the assessment of possible structural defects and, most prominently, the remaining thickness of plates and profiles. (Chritian Cabos, 2008)

The objective of the present thesis is to develop documentation in the form of guidelines for hull condition assessment for single skin bulk carriers that will be used internally and exclusively by OMCS CLASS, the company on which my three months and half internship took place as a partial requirement of my master degree in naval architecture. Overseas Marine Certification Services (OMCS CLASS) is a recognized organization, recognized security organization and classification society which started operations on 2004. Presently, OMCS CLASS is authorized to act on behalf eleven (11) maritime administrations among them Panama, Belize, Vanuatu, Barbados, Palau, Sierra Leone, Moldova and others in order to survey, certify and classify vessels registered on their flags. Per statistics provided by OMCS CLASS, the company currently classifies more than 500 vessels worldwide; of which its bulk carrier fleet represents approximately 12% of the total number of vessels.
The methodology requested by the OMCS CLASS to be used for the development of these propose guidelines was to perform a thourough bibliographic review of the different literature

material related to single skin bulk carrier available at the IMO, IACS, INTERCARGO, Marine Circulars at the different Flag Administrations, Port State Control Regimes circulars and different documentation within OMCS CLASS. In addition, a review of the survey history of ten (10) selected single skin bulk carriers currently classified by OMCS CLASS was performed where the class survey statements, transfer of class information, hull related deficiencies and/or conditions of class, PSC detention records, thickness measurement reports and finding, and ESP survey reports were reviewed. This documentary review was then to be supplemented by on the field inspections that were carried out along with OMCS CLASS Surveyors.

These proposed guidelines were to include safety aspects related to the performance of the survey, the necessary access facilities, the preparation necessary before the surveys can be carried out and expose the different main hull structural regions where damages have been recorded on OMCS CLASS single skin bulk carriers, focusing on the main features of the structural items of each region.

As it is known, hull inspections are a time-consuming endeavour of which with the commercial pressure currently on a crunching shipping market, ship owners try to reduce the time that their vessels are off hire to their minimum. A cruel mix of commercial, time and safety oriented pressures fall on the shoulder of the classification surveyor, since the ship owner is the one paying the fees to the classification society and the international safety standards must be maintained to avoid fatal accidents. With the development of these propose guidelines, OMCS CLASS surveyors might be able to conduct their inspections effectively and efficiently by being as informed as possible and by focusing during the inspections on structural areas that are most prone to failure or degradation with clearly defined acceptance criteria's. Hopefully, they might also assist ship owners of vessels classified by OMCS CLASS to properly maintain their assets, cargo owners to protect their shipment and lastly might give the men and women that work and operate these vessels a safe and secure environment to work on and a fair chance of survival in case an accident happens.

Figure no. 3, from IACS's 2006 Common Rules depicts one of the main aim of the classification rules which is the relation of between the structural requirements and the satisfactory durability of the ship, where the ship structure should have sufficient durability in terms of corrosion margin and fatigue endurance for carrying the intended cargo throughout the intended service period.

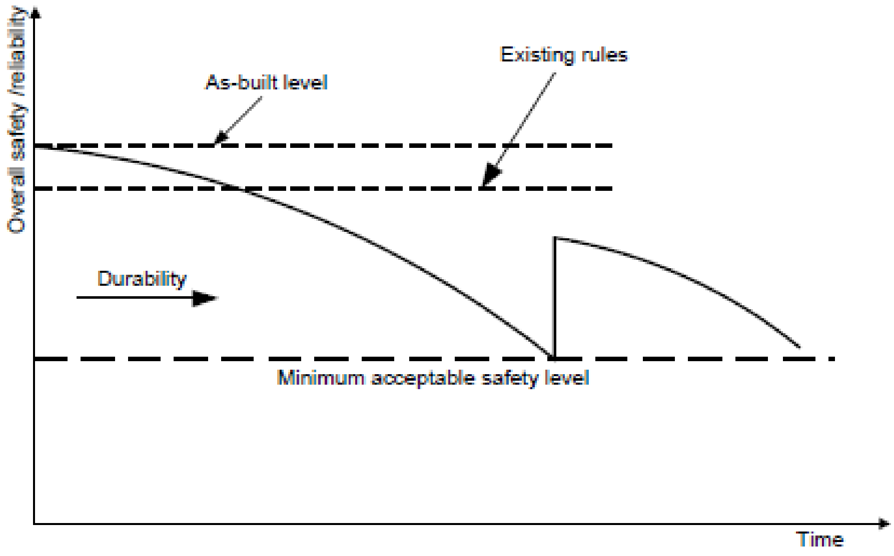


Figure 3 - Structural Safety and Durability ((IACS), Common Structural Rules or Bulk carriers, 2006)

One of the final objectives of developing these propose guidelines and procedures is to have a balance in the relation between performance and durability on which the inspections will attest that the structural requirements and conditions related to the remaining service life of the vessel is satisfactorily. Meaning that the vessel is capable of carrying the intended cargo with the required flexibility in operation to fulfil its design role and that the structure has sufficient durability in terms of corrosion margin and fatigue endurance.

Due that the information gathered during the internship was deemed to be confidential by the company and that the propose guidelines is to be of exclusive use of OMCS CLASS, the thesis is divided in two parts; a first part is made public and comprise of five sections on which a brief description of the propose guidelines is included and two appendixes on which the complete propose guidelines is included on OMCS CLASS letter head ready for their review and hopefully future exclusive use as the appendix no. 1 and the different existing forms of OMCS CLASS for the survey program questionnaire, program and the reporting format that were reviewed and updated are included as the appendix no. 2.

2 BACKGROUND INFORMATION

2.1 Factors on Influencing the Condition of Ship Hull

2.1.1 Introduction

There are several factors influencing the condition of the ship hulls among them are the ship age that leads to structural deterioration due to coating damage, corrosion, cracking and deformations (dents) and mechanical damages due to wear and tear. Single skin bulk carrier has some unique characteristics that influence and affect the condition of the hull such as large net load on double bottom, high shear stresses on the shell sides, sensitive to leakage and prone to total structural loss, high loading rate, transverse strength, green seas among others.

Even though, the total number of vessels total losses due to hull damages have decreased throughout the years; nevertheless, they still represent one of the five (5) most important causes of ships total loss for vessels greater than 500 Gross Tonnage. This can be evidenced on the recent statistics of the International Union of Marine Insurance (IUMI) on total vessel losses during 2001-2015 on the figure no. 4.

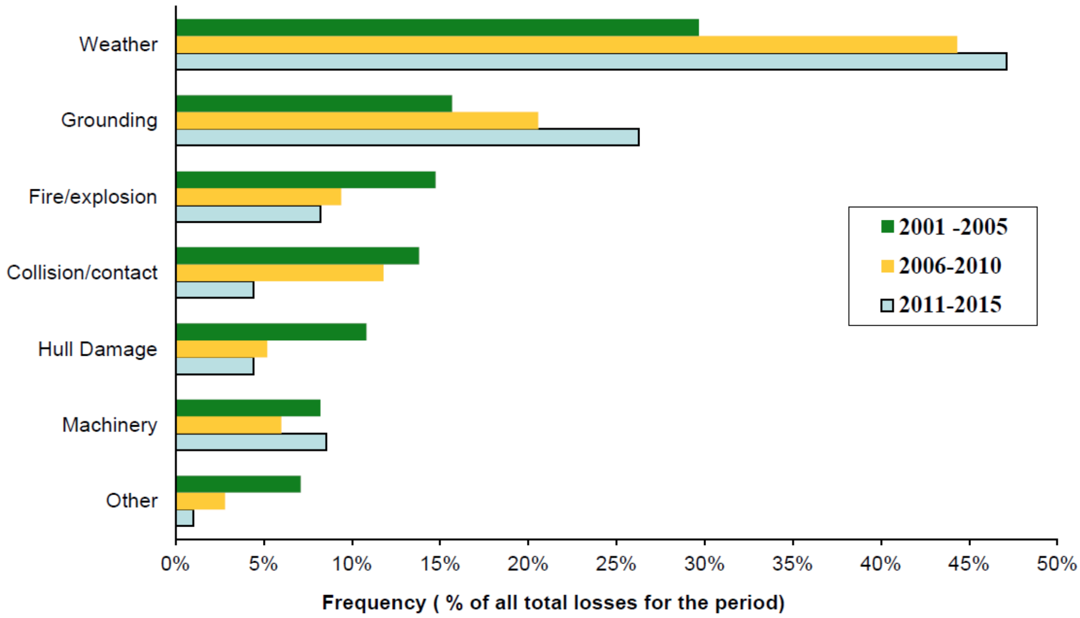


Figure 4 - Total losses by causes for all vessel types greater than 500 GT ((IUMI), 2016)

This decrease can be attributed to many factors, however, according to my opinion that one the main reasons is the better understading on the loads that acts on the hull structure and the new requirements of performing numerical analysis on the hull structure.

2.1.2 *Ship Ageing*

Ageing of ship structures may be defined as the progressive deterioration of structures as a result of normal operational use and environmental influences. The effects of ship ageing and the effects of corrosion on structural damages go hand to hand. With the execption of the bulk carrier fleet the average age of the major vessel classes has increased despite the increase in global tonnage capacity, this is depicted on the figure no. 5 from IUMI. According to my opinion, this increase in age for most of vessel classes is due to the reduction in a number of new deliveries and in the amount of tonnage being scrapped. For the specific case of bulk carrier, the great number were ordered during the economic boom of 2006 and 2007 and delivered shortly after and older tonnage was then force to go to scrap. One can correlate that the decrease of total loss due to hull damages on the years 2011 to 2015 is directly related to the drastic decrease in ship age on the bulk carrier fleet. It is expected that in the coming years we will have delivered approximately 1,500 bulk carriers with an aggregate capacity to the market of approximately 125 million deadweight, with the handymax bulk carriers leading the booking orders.

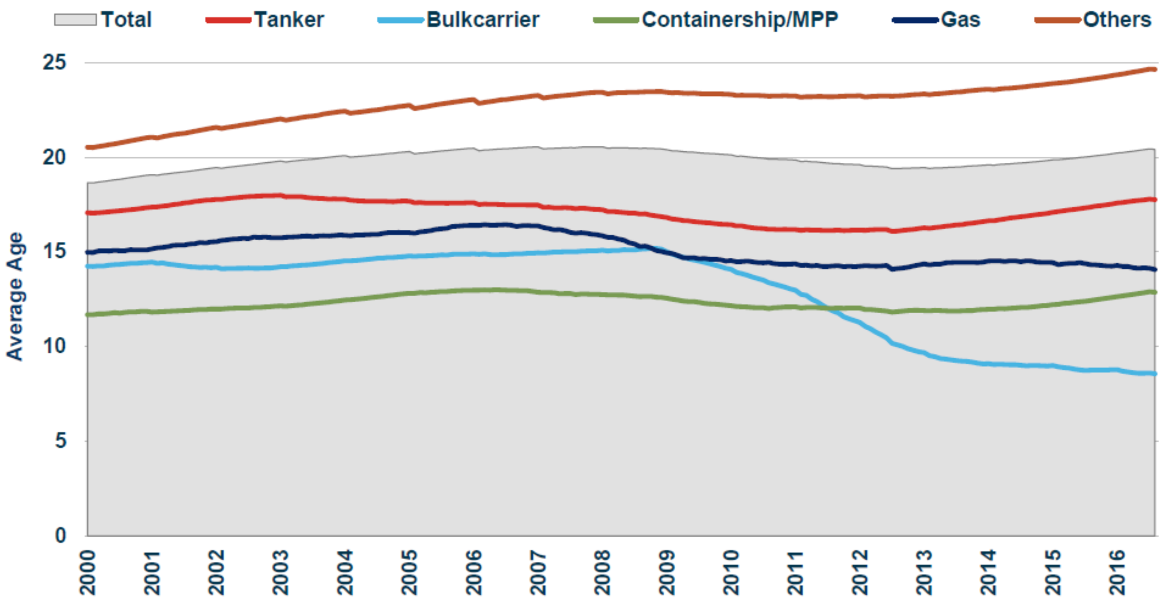


Figure 5- Average age of the World Fleet for all vessel types greater than 100 GT ((IUMI), 2016)

Even though that the total losses due to hull damages on the period of the years 2011 to 2015 has been reduced from the last figures from the period of 2006 to 2010 as shown on figure no. 6, the ones that occur show a direct link to the ship ageing as per IUMI statistical analyses. In addition to the reasons stated before, this reduction can also be attributed to the new safety regulations specifically for bulk carriers that have been enacted throughout the last decade, the ongoing enhance survey program for bulk carriers and the experience gain throughout the last years of the most commons defects on their hull structure.

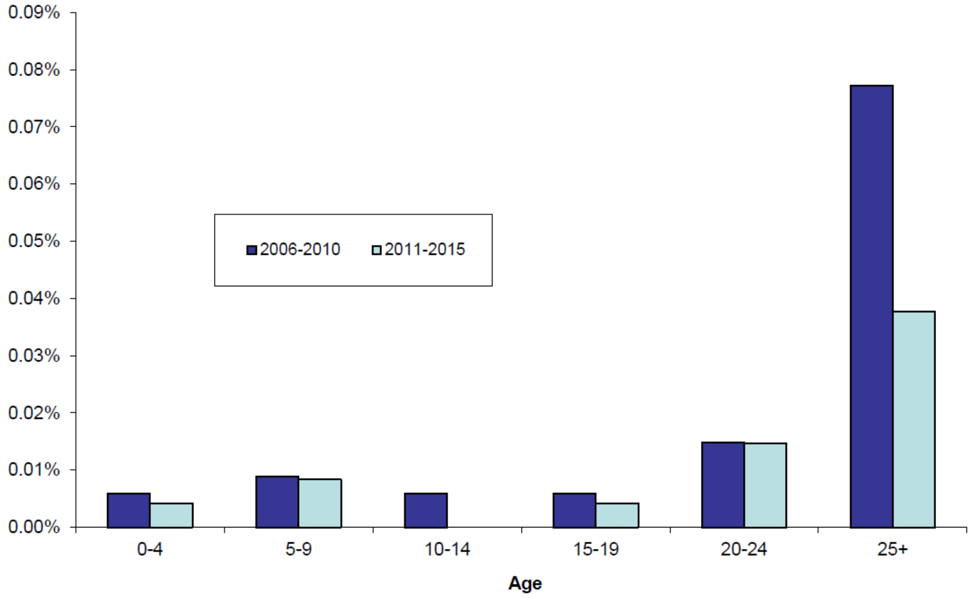


Figure 6 - Total losses of bulk carriers greater than 500 GT ((IUMI), 2016)

Another visible way to internationally monitor the condition of the vessels is through the different port state control inspections and/or detentions. With their statistical information, one can observe on the relation between ageing and vessel detention which would indicate vessels that due to the hull conditions or others do not comply fully with the standards. This relation can be easily observed on Class NK 2015 annual port state control report (Class NK, 2015), on which on figure no. 7 shows that even though the detention rate on older tonnage is slowly decreasing, over 20% of the detentions that took place on 2014 were on vessels of 20 years old and above.

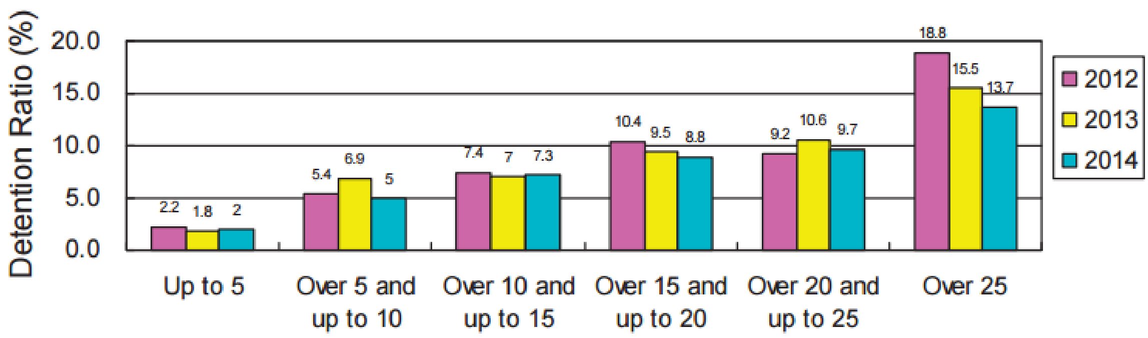


Figure 7 - Class NK PSC Detention Statistics by Age

For OMCS CLASS technical personnel and field surveyors point of view, it is worthwhile to mention that the ageing of the ship is an important factor when establishing the cause of damage and repairs proposals to be carried out. The surveyor should take into consideration the ship age and an estimation of how much longer a ship is expected to stay in service. For example, in the case of defects due to fatigue then the age of the ship gives an indication of the actual levels of stress, since damages occurring on a young ship may indicate that there is a poor design feature or a structural fault and damages occurring on an older ship, the damage is more likely to be age-related.

2.1.3 Protective Coating

The requirement of having the ballast tanks of vessels properly coated to prevent corrosion is an early one. Before this, sacrificial anodes were used to achieve this; however, it is widely recognized that anodes alone cannot protect a tank. The current accepted method of good corrosion protection is a hard coating of good quality and a backup system of sacrificial anodes of sufficient size and number. Such a system can last for many years provided it is properly maintained.

Protective coating it is usually fitted during the ship's construction inside the vessel ballast tanks and cargo holds. If the coating is not properly maintained, it will be damaged in a couple of years and will lead to increase rates of corrosion. Lack of maintenance is usually the reason why many good systems do not last the predicted period. The ship owner should realize that steel renewal at a later stage is more costly than the maintenance of the protective coating inside the tanks.

A protective coating system will normally require being a hard coating; however, other types of paint coating or corrosion prevention system, with the exception of soft or semi-hard coating, may be considered as an alternative to the hard coating. Proper preparation of the surfaces is paramount for the successful application and proper adherence of the protective coating. This surface preparation is done by degreasing, removal of mill scale by weathering, mechanical cleaning, blast cleaning, fame cleaning, pickling among others. A significant contributing factor to coating degradation is loss of coating flexibility over time, causing cracking and debonding in the following areas:

1) structural hot spots,
2) structures with large deflections,
3) areas in the way of indents (contact damages),
4) structures prone to vibrations,
5) exposed areas in tanks frequently used for ballasting.

The evaluation of the coating condition in ballast tanks is critical, as the commercial consequences for a ship could be serious in the cases where the rating is changed from GOOD to FAIR or FAIR to POOR, since this could affect the ship in the frequency of inspections and the ability to get good charters. Thus, the surveyor should strive to get a correct rating. If only the outer coating layer is damaged, so that no steel is yet exposed, the coating may be given a rating of GOOD, no matter how big area is affected.

2.1.4 Brief Description of Corrosion Wastage

The term corrosion is chemical progress used to denote the physical and chemical changes to bodies that result from interaction with the environment. To the naval architect, corrosion is regarded as process of thickness diminution of the different structural members of the hull that inevitably comes with the aging of the vessel and result to a loss of engineering designed function. These changes, which may occur rapidly or slowly, sometimes with catastrophic consequences. On this thesis, we will not give an in-depth discussion with regards to corrosion since the literature on this subject is quite extensive the subject of corrosion has been widely researched and discussed.

Corrosion is one of the most important causes of structural damages and wears of a ship structure causing the reduction in thickness of the ship steel which varies considerably from ship to ship, but for uniform corrosion of unprotected ballast tanks, one may expect an annual reduction rate of 0.2 - 0.4 mm per year (Caridis, 2001). In the worst cases, the rate can get up to 0.5 mm per year. It not only affects the vessel from the point of view of strength loss but also is a highly influential factor in the increase of local stresses, the appearance of cracks, dents, buckling's and vessels total loss due to the loss of watertight integrity.

Even though, corrosion arises in all environments, even without the direct contact of metals and alloys with oxygen or moisture; nevertheless, there are quantitative differences in the rates of corrosion. The most intense corrosive environment is seawater because it contains salts that increase its electrical conductivity. The presence of micro-organisms and bacterias in the seawater which causes inhomogeneity of the material surfaces is another cause that increase the propensity to corrosion. In summary, the main factors influencing the progress of corrosion of mild steel in seawater are; salinity, pH, water temperature, dissolved oxygen content, water velocity, sulphide pollution and bio-fouling.

Corrosion takes the form of general corrosion, pitting corrosion, stress corrosion cracking, corrosion fatigue, microbiological corrosion, galvanic corrosion, erosion corrosion, etc. (Boon, 1997). The corrosion rate will increase with temperature, and may even double per 10°C temperature increase. Thus, unprotected surfaces in ballast tanks close to heated cargo tanks or bunker tanks, or underneath deck exposed to sunlight, may be the areas the most prone to uniform corrosion attacks. The corrosion rate will also increase locally where only parts of the coating have broken down, with the protected steel acting as a cathode and the unprotected steel as the anode. (Guttormsen, 2000)

The areas exposed to solar heat, upper deck level / upper part of ship sides and areas adjacent to heated fuel oil tanks are areas that surveyors should inspect with due caution. As well, it is important to stress that corrosion at the point of stress is greater than in other areas of a ship.

On an empirical study on an approach to the corrosion analysis of bulk carrier hull structured performed by Mr. Piro Ivosevic for the Scientific Journal of Polish Naval Academy on 2015; where the cumulative amounts of steel replaced on twelve (12) bulk carriers of almost 25 years of ageing and their different areas during the whole life cycle were analysed showed that intense corrosion process and reducing the thickness of the bulk carrier's hull structural areas led to an enormously large amount of steel replacement carried out mainly in the cargo holds of aging bulk carriers; specifically in areas of the inner bottom and hopper plating, the internal structure in top side tanks and the cargo hold transverse bulkheads. (Ivosevic, 2015)

Excessive loss of material due to corrosion may lead to fracture, buckling and/or yield failure. It causes loss of cross-sectional area and reduces local and global strength due to the deterioration of ship structures. On ballast tanks, the corrosive action of seawater on various marine steels increases with increases in temperature, speed of water flow, oxygen content, content of corrosive elements and conductivity.

2.2 Factors that influence corrosion on bulk carriers

The rate of corrosion, the breakdown of protective paint coatings and the corrosion of structural members of the different sections of a bulk carrier is influenced by many factors, among the key factors we have fatigue, corrosion, stress, heat, and humidity. Corrosion being one of the most important ones.

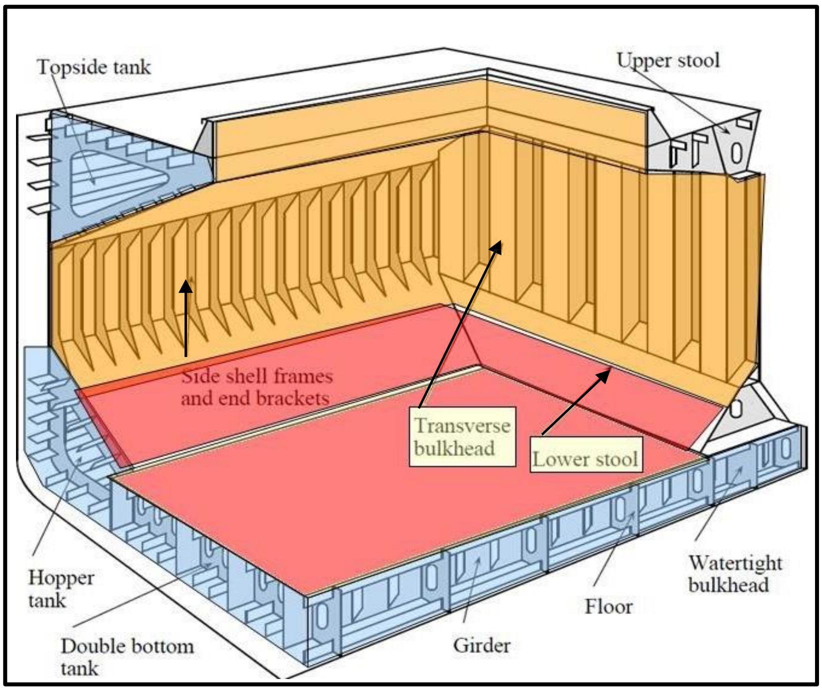
Poor geometrical details is often one of the commonest causes of corrosion, especially in static structures such as double bottoms that results in the entrapment of corrosive environment. Construction details should be such that moisture and dirt are not trapped, involving the use of adequate drainage holes if necessary.

Through the recent years that have been several proposals of models to approach the issue of the estimation of the corrosion rate on ships structures such as the ones proposed by N. Yanamoto et al (Yanamoto N, 1996). These models range from simple empirical and probabilistic models to more complex non-linear models all of them based on an understanding of the corrosion process occurring within each environment, and the consideration of bulk carrier operation (C.P. Gardiner, 2003).

Analysing the different parameters that will come into play for determining the corrosion rate on bulk carriers, initially one can state that there are three main types of corrosive environments, namely, immersion in seawater, exposure to an enclosed atmosphere (ballast tanks), and exposure to porous media (inside cargo holds). The main factors to take into consideration that contribute to deterioration at various locations on a bulk carrier would be type of cargoes (acidity of the cargo), frequency of ballasting, sludge/scale accumulation, frequency and method of tank cleaning, trade route, structural flexibility, corrosion protection effectiveness, marine fouling, corrosion films, speed of flow, an enclosed atmospheric environment, without discarding the effect of abrasion from cargo handling equipment (C.P. Gardiner, 2003). Since these factors vary greatly from vessel to vessel and they can act individually or in combination, and their influences are difficult to quantify, and the corrosion wastage of structural members is highly dependent on the location of the member (Ohyagi, 1987).
It is known that stress concentrations on a structure will accelerate the rate of corrosion; even within the same space, corrosion rates at locations of stress concentration will be greater than in those locations where stresses are lower and it is a self repeating cycle, since wastage corrosion diminish the thicknes of the structure which in turns leads to higher stresses at that specific location.

The most common locations on board vessels where accelerated corrosion is likely to occur is generally the areas where the coating is inadequate, defective, or poorly maintained. Other areas prone to accelerated corrosion are the corners and dead ends where water is accumulated and not draining such as the bottom connection at aft bulkheads, elbows where the scuppers are led into the shell, at bulwark and coamings stays in way of deck connection, and along deck connections with coamings of hatches.

In the specific case of a bulk carrier apart from the ballast tanks, holds can be divided in two parts, a lower part which is usually in contact with cargo and the equipment use for loading/unloading (tank top, sloping plat of hopper tank and lower part of vertical frames) and a middle and upper part which the condensation and high temperatures due to solar heating. This is depicted in the figure no. 8.



<u>Ballast Tanks</u>:
- ✓ All: Immersion in seawater, high humidity and enclosed atmospheres
- ✓ Topside: High Temperature

<u>Hold</u>: (middle and top) - COATED
- ✓ Condensation on side shell plate
- ✓ Acidity due to cargo
- ✓ Temperature

<u>Hold:</u> (bottom) – NO COATED
- ✓ Abrasion due to cargo
- ✓ Condensation on side shell plate
- ✓ Acidity due to cargo
- ✓ Temperature

Figure 8 - Bulk Carrier Cargo Hold Environment. Drawing from ((CCRS), 2011)

For topside tanks, solar heating in one side of the ship due to the navigational route can lead to increase corrosion rates. Topside, hopper and double bottom tanks have a high humidity while empty and susceptible to atmospheric corrosion. It is important to mention that a protective coating in good condition is the first line of defence against corrosion, since the sacrificial anodes only work when submerged in water. In the below images on figure no. 9, sacrificial anodes inside ballast tanks can be observed.

Figure 9 - Sacrificial Anodes inside Ballast Tanks

Lastly, it is worth to mention that the proper records of original structural scantlings, measured thickness measurements, repair history, voyage history, minimum allowable thickness and condition of the coating are of paramount importance for identifying the trends in corrosion.

3 SINGLE SKIN BULK CARRIER HULL STRUCTURES

3.1 General

The principal global loads that induce stress on the hull structure are waves, which provide varying degrees of buoyancy along the hull, and the loading of the ship. The response of the ship depends very much on the ship type, its construction arrangements. Since bulk carriers are ships designed to carry a wide range of heavy solid bulk cargoes such as iron ore in alternate holds that are loaded directly into the cargo space without any intermediate form of containment thus resulting in a weight distribution that varies enormously at each transverse bulkhead, leading to very large shear forces. The hydrostatic and hydrodynamic pressures and the pressure from the weight of cargo flow from the plate through the longitudinal stiffeners into the web frames, girders and bulkheads. In general, bulk carriers are subject to great structural stresses during their lifecycle from the nature of their purpose and versatility on the different types of cargo which increase with ageing of the ship.

A bulk carrier must maintain its structural integrity and water tight envelope when exposed to the different internal and external static and dynamic loads. Longitudinally framing system is most typical structure layout of a bulk carrier which consists of stiffened plates and transverse web frames. In the structural arrangement of bulk carriers, high stresses tend to occur at some parts of the cargo areas, such as deck corner, connection between hopper tank folded corner and floor, connection between longitudinal girder and transverse bulkhead, connection between lower shelf plate and corrugated bulkhead, shedder plate of corrugated bulkhead, areas around floor lightening holes or manholes.

The vessel hull can be divided into different hull structural elements, and each element has its own function in the total hull integrity. To assess the structure of a single skin bulk carrier, one needs to understand the function and importance of each structural element locally and how it contributes to the global vessel strength.

We have divided the bulk carrier structure into seven (7) main structural regions:

1) Side
2) Bottom
3) Deck
4) Corrugated Transverse Bulkhead
5) Topside Tank
6) Hopper Tank
7) Hatch Coaming and Cover

Figure no 10 depicts the different seven (7) main structural regions:

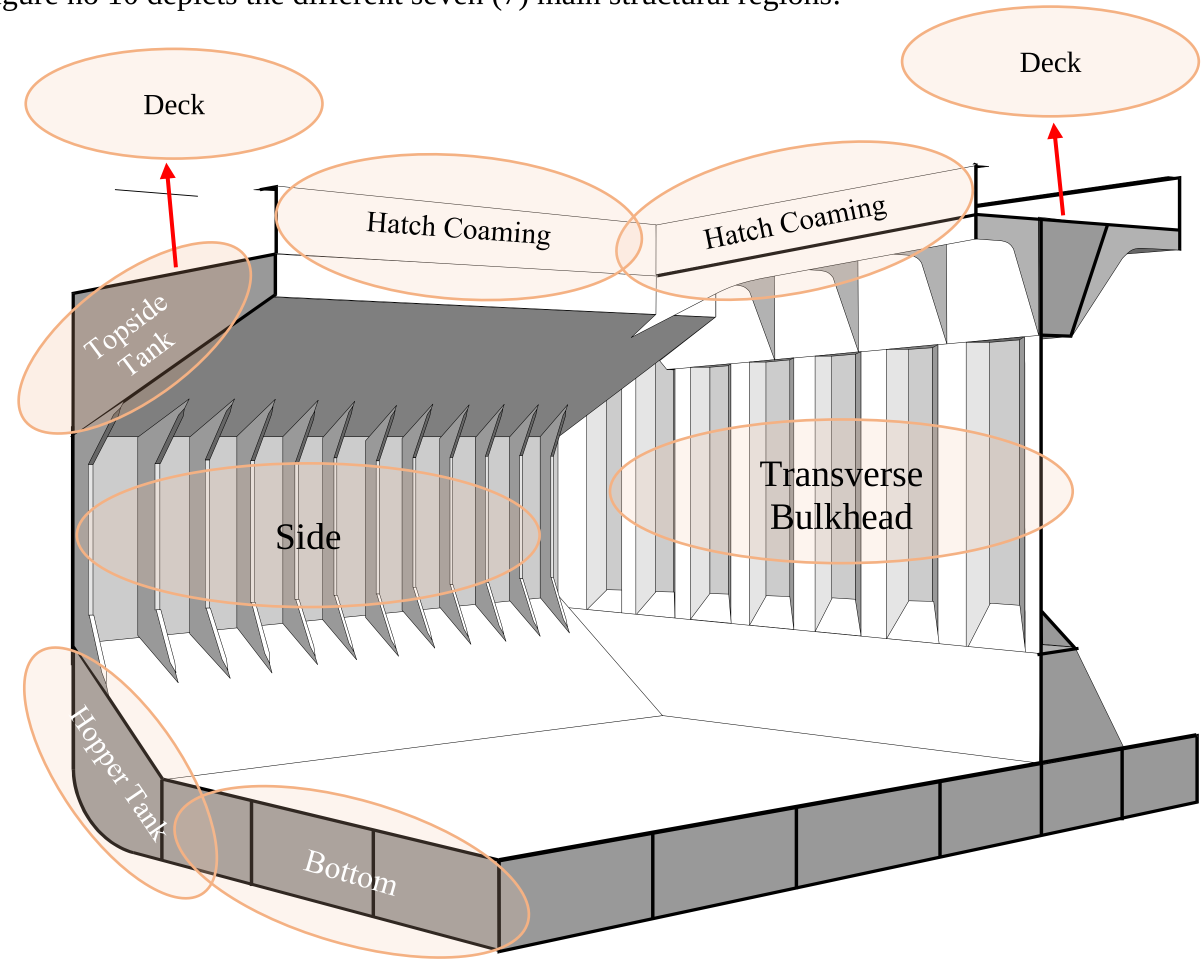


Figure 10 - Single Skin Bulk Carrier Main Hull Structural Regions

The typical structural damages and deterioration in the context of these guidelines are damages caused by excessive corrosion, overloading due to navigation in extreme weather conditions, unsafe loading and unloading operations of cargo or water ballast exchange. As well as, due to design faults, material defects or bad workmanship, normal wear and tear, contact damages with the exeption of damages or defects cause by accidents such as collisions, groundings and fire/explosions. These defects are normally recognized as material wastage, weld defects, fractures, and deformations.

In order to provide the attending surveyor with a better understanding of the different important roles of each structural element with regards to the distribution of stress locally and globally on the hull girder and the different specific elements that encompass these seven (7) main structural regions, the following summary is provided:

3.1.1 Side

The side shell provides the watertight integrity and takes up external sea loads and transfer these loads into the hull girder; it resists internal pressure from cargo and ballast and act as the web in the hull girder beam.

Loads are taken by the side shell hull plating, stresses are transferred into the vertical side frames and further into the upper and lower brackets and from there into the top wing tank and hopper tank structure. Lateral loads induce shear forces and bending moments in the vertical side frames which are considered as a single beam supported at hopper / top wing tank brackets.

When the vessel is loaded, the net load down generated by the weight of the cargo causes rotation of hopper tank structure and additional moments in the mid-field and upper end. When the vessel is on ballast (holds empty) the net load up generated by the hydrostatic forces causes rotation of hopper tank structure and additional moment in the mid-field and lower end.

These dynamic and static loads that are transferred to vertical side frames and subsequently to the upper and lower brackets, gives a bending moment and shear peak in way of lower bracket connection. The sniped termination of the bracket flange creates a local stress concentration, which may develop cracks from the toe of the bracket. In this point a high bending stress in flange and a stress concentration due to weld (overlap) increase the risk for fatigue cracks. Cracks in vertical side frame may increase moment in field and loads on adjacent frames which may cause water ingress leakage and in worst cases may cause the collapse of the side shell panel. General corrosion of side frames reduces the shear area and section modulus causing an increase in bending moment stress levels and side frames may collapse in buckling.

The ship side structure is prone to damage caused by contact with the pier during berthing operations and to damages cause by cargo handling equipment during loading and discharging operations and impact by the cargo itself during loading operations. As well, some bulk carrier's cargoes may contain sulphur impurities that when in contact with humidity produce sulfuric acid which cause severe corrosion to the structure. Side vertical frames and brackets are then prone to both general corrosion as well as grooving corrosion

The structural build-up of the side structural region consists of:

1) Upper Bracket of Side Frames
2) Side Shell Plating
3) Side Vertical Frames
4) Lower bracket of Side Frames

Figure no. 11 depicts the different structural elements that comprised the side region:

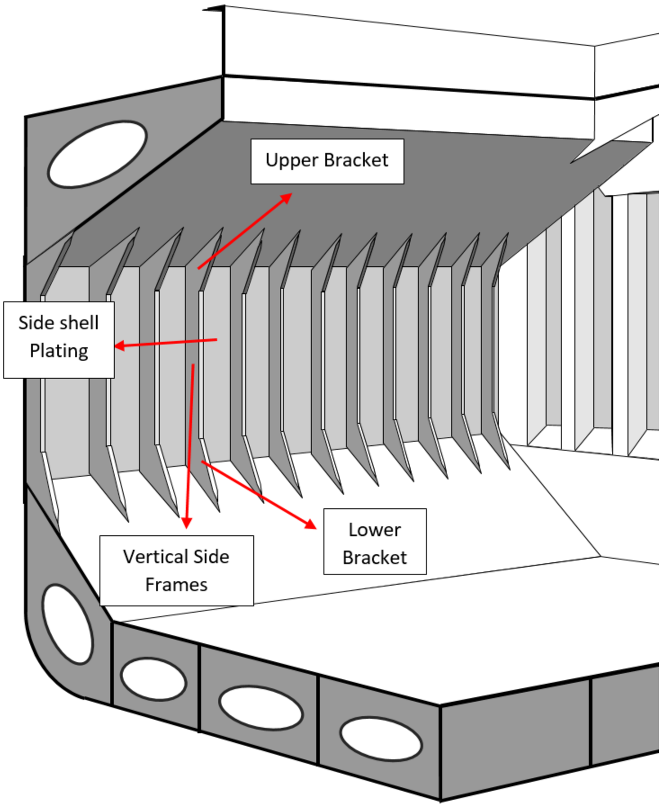


Figure 11 - Structural Build Up of the Side Region

3.1.2 Bottom & Inner Bottom (Tank Top)

The bottom plating provides watertight integrity and takes up external loads exerted by the hydrostatic pressure as well as the internal pressure from the ballast. The inner bottom must withstand the static and dynamic load from the cargo hold as well as the static and dynamic pressure from the ballast. Both act as the bottom flange in the hull girder. The bottom and inner bottom longitudinal stiffeners and longitudinal girders are carrying the vertical bending moments from still water and wave induced bending moments along the vessel length.

The stress distribution on a double bottom structure is such that the forces are taken up by the stiffest structure and flows the shortest way to the supports. External loads induce shear forces and bending moments in the bottom longitudinal stiffeners, acting as single beams (between each web frame) In the inner bottom longitudinal stiffeners acts between floors. The girders & floors carry the net load to hopper tank and transverse bulkhead, floors carry most of the loads in middle of hold, longitudinal girders carry most of the load towards transverse bulkhead.

When the vessel is on ballast (holds empty) the bottom plating and longitudinal stiffeners would be in compression an in tension when in loaded condition. Inner bottom plate in the middle of a loaded hold will be in compression.

Inner bottom plating (tank top) is prone to indentations and buckling between the longitudinal stiffeners due to the impact of the cargo during loading, overloading of the cargo and the use of mechanical unloading equipment. The welds in way of the connections of the inner bottom and hopper sloping plate and inner bottom and bulkhead stool suffer damages due to the mechanical equipment used for unloading the cargo. The bilge wells of cargo holds are prone to pitting corrosion and wastage due to the accumulated water/corrosive solution in the wells.
Fractures may occur in way of the welded or knuckle between the inner bottom and hopper sloping plating; especially, if the longitudinal side girder in the double bottom is misaligned.
Inside double bottom tanks, the corrosion rate and extent depends on the condition of the protective coating and the sacrificial anodes. The bottom plating below bell mouth suction head is prone to pitting/erosion corrosion. Fractures in way of the bilge keel endings is also a common defect to be found.

The structural build-up of the bottom region consists of:

1) Bottom & Inner Bottom Plating
2) Longitudinal Girders
3) Longitudinal Stiffeners Floor
4) Floors

Figure no. 12 depicts the different structural elements that comprised bottom region:

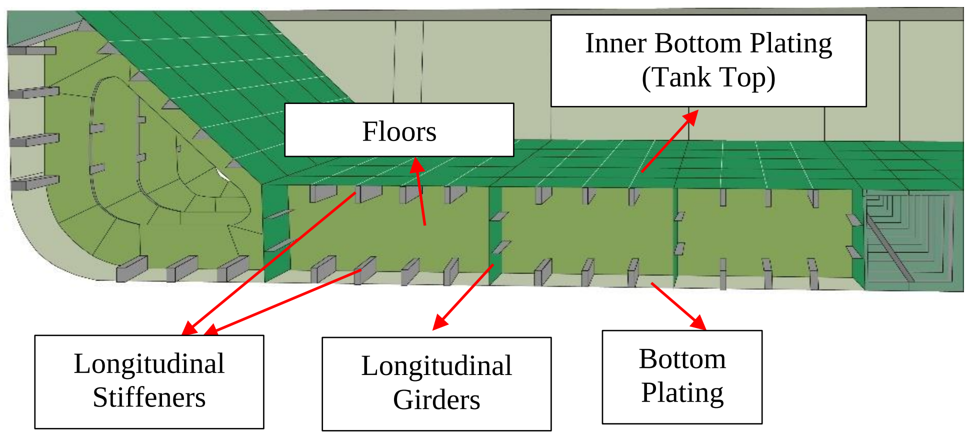


Figure 12 - Structural Build Up of the Bottom Region

3.1.3 Deck

The deck plating provides watertight integrity and it must resist the external sea pressure. It provides transverse strength of the hull girder and acts as the upper flange in the global hull girder. Deck plate must withstand static and dynamic loads from green sea pressure as well as internal pressure from ballast tanks. The deck plating and longs outside line of hatches are carrying the vertical bending moments from still water and wave induced bending moments along the vessel length. The deck elements contributing to transverse strength are the deck plate and transverse stiffener between hatches, the hatch end girder and the upper stool tank.

Deformation on deck such as buckling could be caused by excessive sea water pressure in heavy weather, excessive deck cargo, sea water on deck in heavy weather and/or a combination of these factors. As well, deformation on deck could be a result of over pressure of the top side tanks. Buckling on the cross deck structure (between cargo holds) may be caused due to loss in strength due to wastage, transverse compression of deck due to sea load, and transverse compression of deck due to excessive loading in two adjacent holds.

Fractures on deck may occur in way of its connection with hatch coamings at hatches corners due to stress concentration. As well, attention should be place on locations on deck where there is a transition between two plates of thickness differences above three (3) mm.

Figure no. 13 depicts the deck area and the cross deck structure:

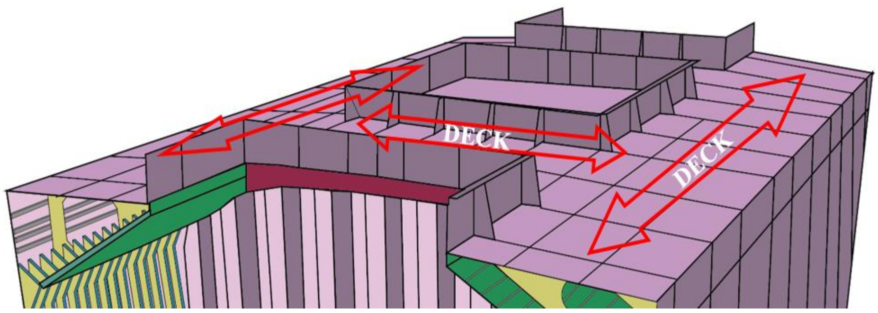


Figure 13 - Deck and Cross Deck Regions

3.1.4 Transverse Bulkhead

The transverse bulkhead plays a very important role on local and global strength requirements of a bulk carrier and it is usually a corrugated bulkhead. It provides transverse strength of the hull girder. Its plating must withstand static and dynamic loads from bulk cargo and withstand the water pressure from flooding of cargo hold without collapsing. The transverse bulkheads at the ends of a combined ballast/ cargo hold in addition must withstand the water pressure from a hold fully filled with water ballast. Transverse bulkhead supports the double bottom longitudinal girders and carries global shear from double bottom to the ships side.

Often, bulk carriers are loaded in alternate holds; when one sided of the bulkhead is loaded, it introduces a moment in lower stool and the size of moment increases depending on how narrow is the lower stool. High shear stresses are usually observed at the intersection of the lower stool diaphragm and longitudinal girders.

Due to the corrosive nature of some of the cargoes transported by bulk carriers, excessive corrosion may be found at the mid-height and at the bottom of the transverse bulkheads plating and their weld connections. Excessive corrosion may also be found on diaphragms in way of their upper and lower weld connections.

In the event of shear buckling or deformation on the transverse bulkhead indicated by the peeling of paint or rust, the attending surveyor must evaluate if this is a result of excessive uniform corrosion and the ineffectiveness of the bulkhead to carry its designed load or instead was due t to poor design or overloading since based on this will decide the repair proposals.

The use of mechanical unloading equipment often cause damages and deformation to the structure of the transverse bulkhead.

Fractures are frequently encounter in way of the boundaries of corrugations and bulkhead stools.

The structural build-up of the transverse bulkhead elements consists of:

1) Corrugated bulkhead
2) Lower stool
3) Upper stool

Figure no. 14 depicts the different transverse bulkhead structural elements:

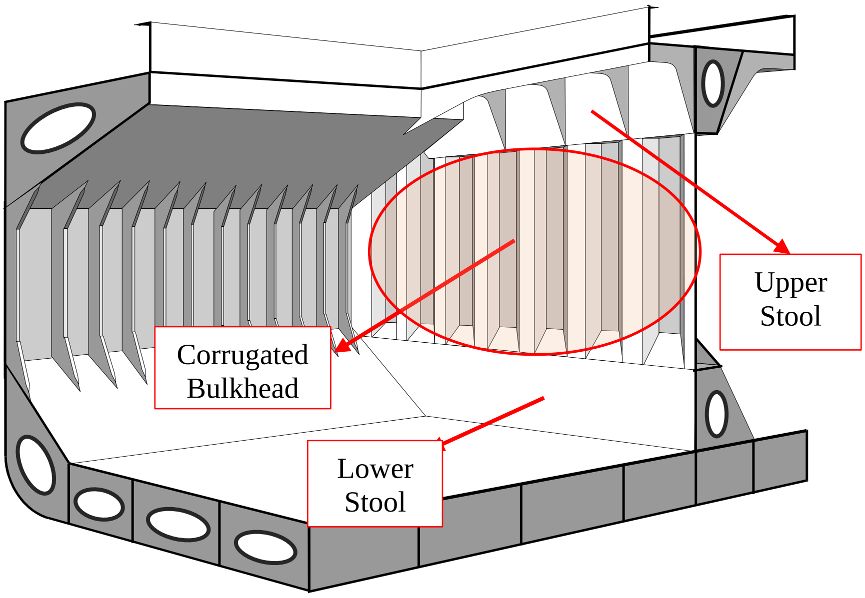


Figure 14 - Structural Build Up of the Transverse Bulkhead Elements

3.1.5 Topside Tank

The topside tanks deck and side plates must withstand static and dynamic loads from external sea pressure and from internal ballast. It gives support for side structure and hatch coaming. The upper part of the ship side and sloping plates are important contributors to the top flange in the hull girder beam. Ship side, hopper tank and top-wing tanks are taking up global shear forces from wave induced loads and weight/buoyancy distribution along the vessel length. The shear force is distributed between hopper tank sloping plate and ship side.

Due to the expose location to sunlight, topside tanks are prone to corrosion and wastage of the internal structure supporting structure, especially if the protective coating is in poor condition. Deformations are also a common damage, most of them are caused by contact damages with the pier while the vessel is berthing/unberthing and over pressurization of the tanks while ballasting and sloshing when the tanks are partially filled. Knuckle joints in the fore and aft regions of the vessel may suffer from fractures, especially in way of the connections with the engine room bulkhead and the collision bulkhead.

The structural build-up of the topside tank elements consists of:

1) Deck plating & longitudinal stiffeners
2) Vertical strake
3) Sloping plate & longitudinal stiffeners
4) Side plate & longitudinal stiffeners
5) Transverse web frame
6) Vertical side frames upper supporting brackets

Figure no. 15 depicts the different topside tank structural elements:

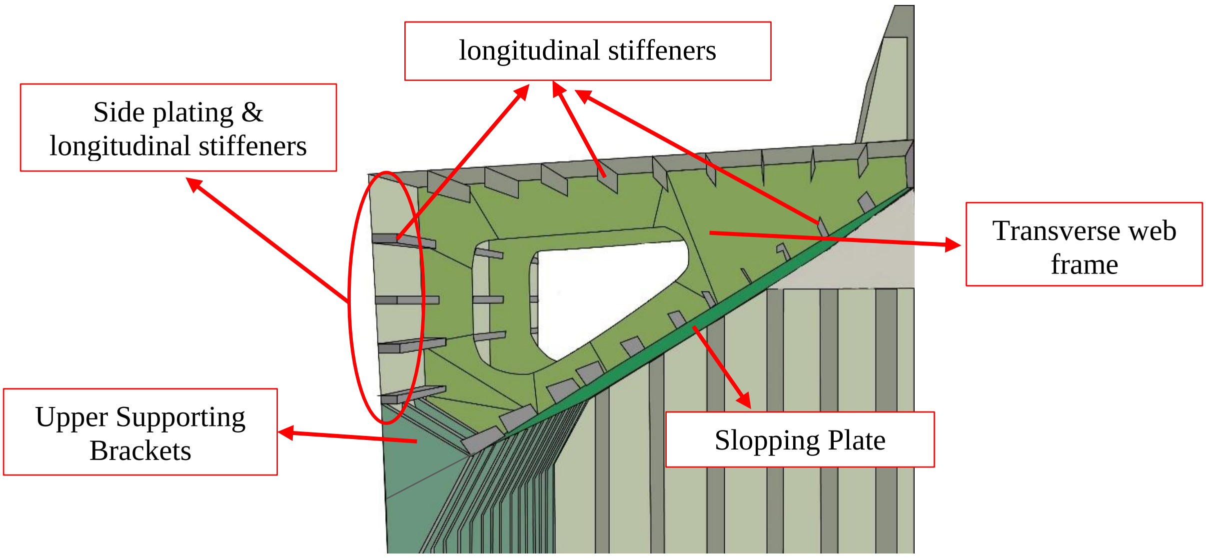


Figure 15 - Structural Build Up of the Topside Tank Elements

3.1.6 *Hopper Tank*

The stresses on the hopper tank structure are various. The hopper tank sloping plate must withstand static and dynamic loads from bulk cargo and ballast and the bottom and side plate must withstand static and dynamic loads from external sea pressure and from internal ballast.

The side plating / hopper tank sloping plate are part of the web in the hull girder beam and the hopper tank bottom plate and lower part of side plate are part of the bottom flange.

The combined effect of pressure on ship side and on double bottom produces compression stresses in the hopper plate. The shear force is distributed between hopper tank sloping plate and ship side. When the vessel is loaded, the effect of side pressure and net load on double bottom from the cargo gives torsion of hopper tank. Transverse webs in the hopper tanks are subject to high shearing stresses at their corners and prone to excessive corrosion.

The hopper sloping plate and its weld at the connections in way of the inner bottom are prone to damages due to the use of mechanical unloading equipment. Fractures may occur in way of the welded knuckle between the inner bottom, hopper sloping plate and the side longitudinal girder in the double bottom. As well as on longitudinal stiffeners in way of its web frame connection.

The structural build-up of the hopper tank elements consists of:

1) Bottom plating & longitudinal stiffeners
2) Sloping plate & longitudinal stiffeners
3) Side & Bilge plating & longitudinal stiffeners
4) Transverse web frame
5) Vertical side frames lower supporting brackets

Figure no. 16 depicts the different hopper tank structural elements:

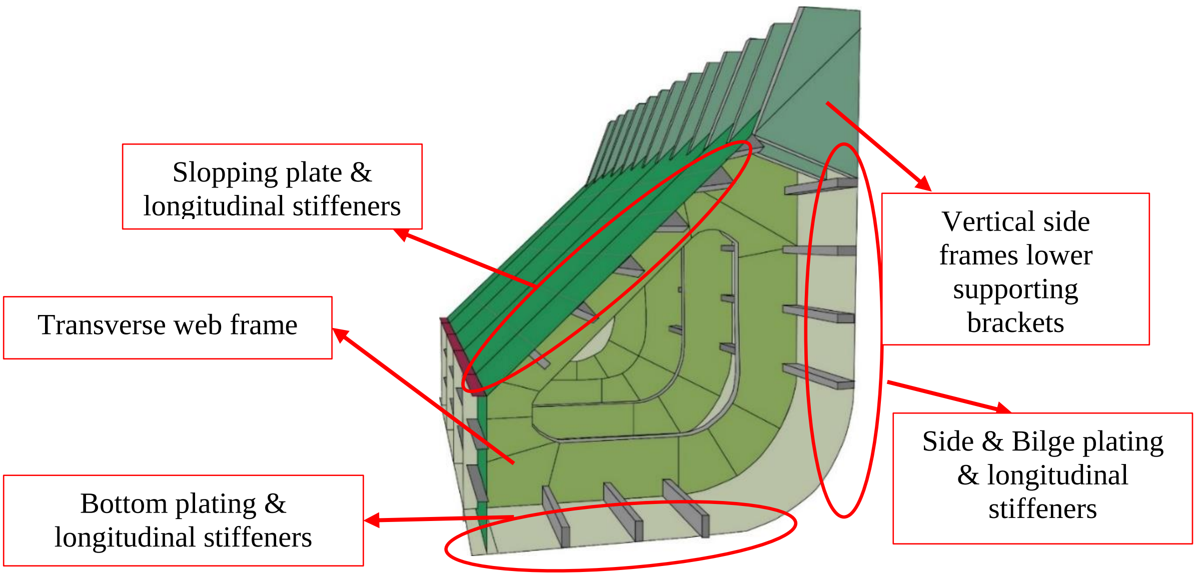


Figure 16 - Structural Build Up of the Hopper Tank Elements

3.1.7 Hatch Coaming

The weathertight integrity of cargo holds and hatch covers is particularly important. Hatch cover & coaming plate must withstand dynamic loads from green sea pressure as well internal pressure from ballast in combined cargo / ballast hold. As well, they must withstand static and dynamic loads from deck cargo if this is allowed (containers, timber, etc.) the hatch end coaming contributes to transverse strength. The longitudinal stresses in deck due to cargo distribution and wave loads will flow into the longitudinal hatch coamings. The midship section of the hatches are subject to great longitudinal and transverse stresses and any discontinuity introduce a stress concentrations point that can result on a crack. Deformation of side-coaming brackets may result from impact of the cargo handling equipment or by green water on deck due to heavy seas.

Due to water vapours and humidity and the difficult access for the maintenance to the hatch end corner brackets, the hatch coaming plating inside cargo hold and the topside tank plating vertical strake this area is prone to excessive corrosion which may lead to fractures.

The structural build-up of the hatch coaming elements consists of:

1) Hatch end coaming, web & flange
2) Hatch end corner bracket
3) Longitudinal hatch coaming, web & flange
4) Hatch side bracket

Figure no. 17 depicts the different hatch coaming structural elements:

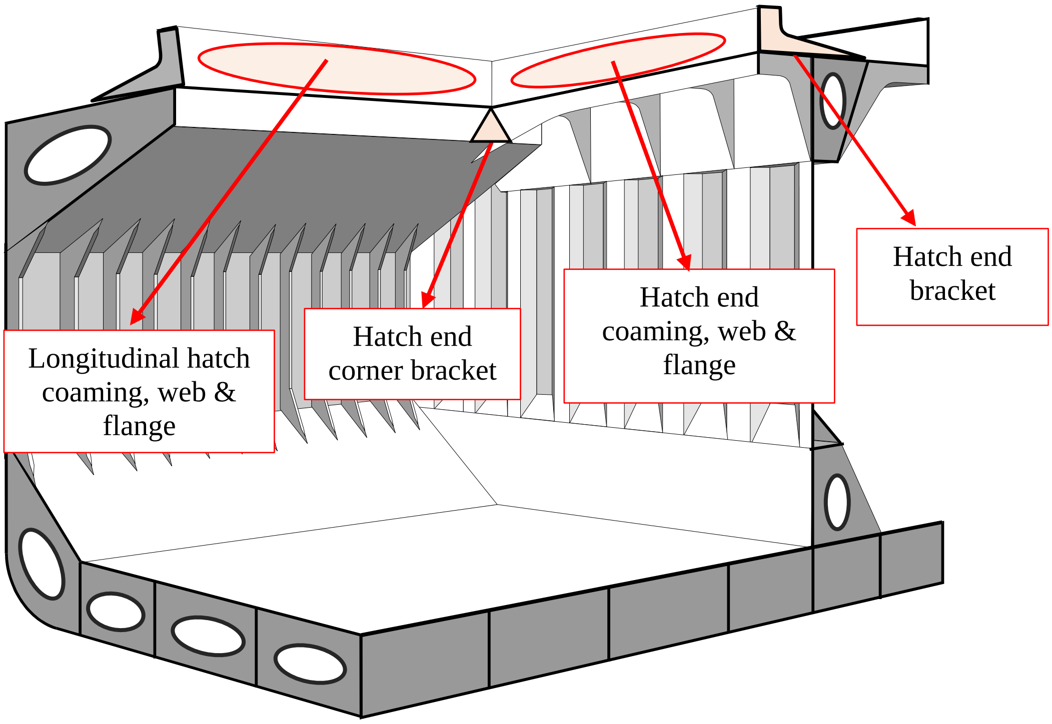


Figure 17 - Structural Build Up of the Hatch Coaming Elements

4 ANALYSIS OF OMCS CLASS BULK CARRIER FLEET

During the period of internship at OMCS CLASS, which lasted for three months and a half, the main task was to develop a set of propose guidelines for hull condition assessment of single skin bulk carriers in international trade. These propose guidelines were developed with the objective of providing a tool to the field surveyors to optimize their inspections and to provide a better understanding during the assessment of the condition of the hulls for their single skin bulk carrier fleet. In order to achieve the planned objective, several key steps were performed, such as a review of the survey history of selected single skin bulk carriers, a bibliographic review of the different literature material related to single skin bulk carrier available at the International Maritime Organization (IMO), International Association of Classification Societies (IACS), International Association of Dry Cargo Ship owners (INTERCARGO), Marine Circulars at the different Flag Administrations, Port State Control Regimes circulars and different documentation within Overseas Marine Certification Services (OMCS CLASS) and in addition, we attended along with OMCS CLASS field surveyors to perform inspections various types of inspections on board vessels. Finally, the experience and knowledge gathered was summarize on the developed propose guidelines comprising topics such as surveyor basic requirements from essential virtues to personal safety, hull survey requirements, planning, preparation and execution of surveys and lastly providing a summary of the most common defects found on board OMCS CLASS single skin bulk carriers with photographs depicting some the defects encountered during the vessels surveyed as part of the internship. These propose hull condition assessment guidelines are included on the appendix no. 1 of this thesis.

Overseas Marine Certification Services (OMCS CLASS) currently classifies more than 500 vessels worldwide; of which its bulk carrier fleet represents approximately 12% of the total number of vessels as depicted in figure no. 18.

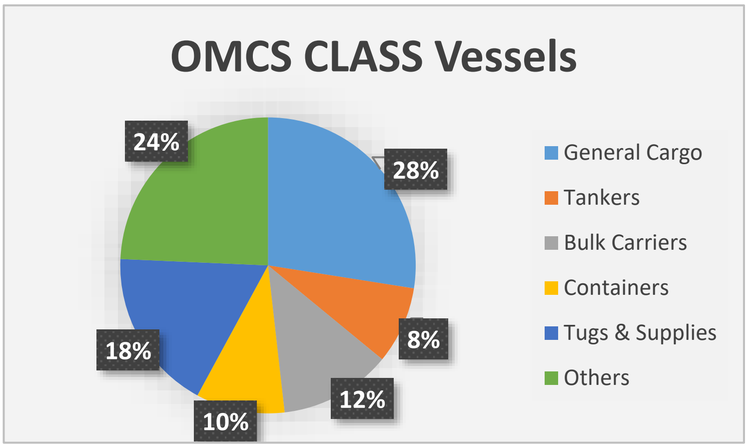


Figure 18 – Distribution of OMCS CLASS Vessels per type

The review of the survey history was performed on ten (10) single skin bulk carriers classified by OMCS CLASS; which were randomly selected from a list of sixty (60) vessels provided by the company. As per the company these sixty vessels (60) vessels were believed to be representatives of the average fleet of OMCS CLASS. The review consisted on verifying the following surveying history information up to the last two special surveys for these ten (10) vessels:

1) Class survey statements,
2) Transfer of class information,
3) Hull related deficiencies and/or conditions of class,
4) PSC detention records,
5) Thickness measurement reports and finding,
6) ESP survey reports.

The ten (10) vessels selected were the most representative vessels of the bulk carrier fleet of OMCS CLASS. The general characteristics of the vessels reviewed are stated on table no. 2.

Table 2 - OMCS CLASS Vessels Selected for Historic Survey Review

OMCS CLASS VESSELS							
Vessel Sample	**Gross Tonnage (Tons)**	**Deadweight (Tons)**	**Length (m)**	**Breadth (m)**	**Depth (m)**	**Year of Built**	**Ageing**
S1	36,698	69,221	225.00	32.20	18.30	1997	19
S2	22,385	37,636	187.00	29.00	16.00	1983	33
S3	16,405	26,045	172.00	25.00	14.50	1998	18
S4	16,344	28,358	180.00	23.00	14.81	1986	30
S5	15,888	24,111	160.40	25.79	13.70	1997	19
S6	15,867	26,369	167.00	26.02	13.30	1991	25
S7	15,850	26,320	160.00	25.40	14.20	1984	32
S8	15,737	24,318	158.80	26.00	13.50	1995	21
S9	14,922	25,486	159.76	25.23	14	1984	32
S10	14,095	21,902	160.91	22.38	13	2007	9
	Average Grt	**Average DWT**	**Average Length**				**Average Ageing**
Averages	**18,419 tons**	**24,054 tons**	**173 m**				**23.8 years**

As it can be seen from the table above, OMCS CLASS has mainly handy size bulk carriers on their fleet with an average age of 23.8 years and deadweight of 24,054 Tons. All the above vessels trade internationally in the far east and middle east region; since it was not possible for the undersigned to physically inspect none of them. The average ageing of the vessels of almost twenty-four (24) years, clearly present a challenge to the organization, since many defects are expected to be encountered specially knowing that the design life of most of these vessels was for twenty (20) to twenty-five (25) years of service. However, depending on the level of preventive and corrective maintenance given to these vessels by previous owners, it could be possible to prolong the vessel life spam. The vessels are relatively small in size with an average length of 173 meters which will give a slight relief on the longitudinal stresses and bending moments. Nevertheless, the effect of corrosion on the hull structure is a main factor on these vessels specially on those that the protective coating on their tanks is in poor condition.

The review of the survey history and the existing literature was the most time-consuming and challenging part mainly due to the vast amount of literature available on bulk carrier safety. In the recent past years, bulk carriers hull structure, the different loads and their interactions were greatly researched and several safety assessments were carried out by the IMO, IACS, INTERCARGO among others, due to the poor safety records of bulk carriers. IACS developed guidelines for surveys and assessment of bulk carriers and IMO enacted several new regulations in order to enhance the safety of this type of vessels.

Most of the vessels classified by OMCS CLASS were existing vessels, which means that none of the vessels reviewed were constructed under the supervision of OMCS CLASS; they were constructed under the rules and supervision of a classification society member of IACS and later transferred to OMCS CLASS. For most cases, vessels entered OMCS CLASS during their third or fourth classification cycle. This presented a challenge during our review of the survey history of the vessels, since not all plans, drawings, class status, repair history and other related documentation were readily available nor digitalized since newbuilding thus a big part of the repair history of the vessels was missing. For the collection of the information, it was necessary to the search of physical files (paper files) on the company deposit and as an average for most vessels at least information on the last two bottom surveys (Renewal and Intermediate Surveys). The information transfer better known as TOCA (transfer of class agreement) that must have taken place among classification societies form the loosing society to the gaining society was mostly lacking on all cases. There were several communications found from OMCS CLASS directed to the loosing society requesting information on the condition of the vessels; however, very few information was eventually provided or on the other side responses stating that since OMCS CLASS was not an IACS member, the loosing society was not willing to release any information. Most of the survey history review was then carried out on the available information since the vessels entered OMCS CLASS register book. After reviewing the different information at hand, we can summarize on table no. 3 the most common defects found during hull inspections on board these vessels were corrosion and cracks and as expected, for the most part at areas of stress concentration.

Table 3 - Most Common Defects found on OMCS CLASS Bulk Carriers

Most Common Defects found on OMCS CLASS Bulk Carriers
1. Generalized and localized corrosion of cargo hold side shell frames and brackets.
2. Cracking at cargo hold side shell frame bracket toes.
3. Excessive corrosion on hatch covers
4. Operational damages (grab & bulldozer) to the side shell frames lower brackets, inner bottom plating, hopper and lower stool plating. (Deformations (buckling and indentations)
5. Cracking at intersection of the inner bottom plating and the hopper plating.
6. Cracking at fore and aft extremities of topside tank structures.
7. Excessive corrosion within topside tanks (Frames, longitudinal stiffeners and brackets).
8. Excessive corrosion within Hopper and Double Bottom tanks (Frames, longitudinal stiffeners and brackets).
9. General corrosion and cracking of transverse bulkheads.
10. Cracking of hatch coamings & hatch corners.

On figure no. 19 shows the percentage distribution of the total number of defects found on OMCS CLASS vessels segregated by hull structure and as it can be seen, defects on cargo holds structure, excessive corrosion on hatch covers and topside tanks structure were the most common and defects on hopper & double bottom tanks and transverse bulkheads transverse bulkheads were the least.

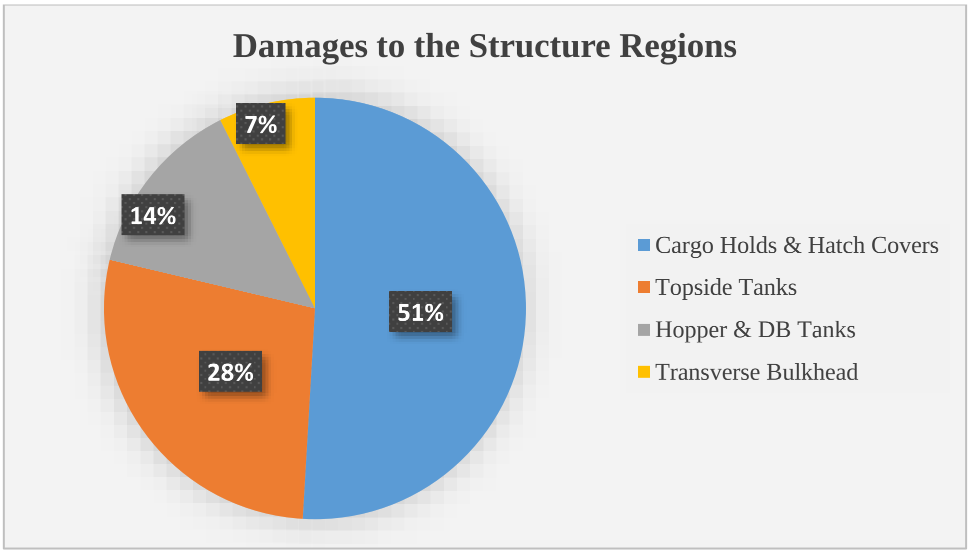


Figure 19 - Defects to the Structure of OMCS CLASS Vessels

With regards to the protective coating inside ballast and fresh water tanks, table no. 4 depicts the condition of the coating per tank with regards to the ten (10) vessels reviewed as per their last survey status.

Table 4 - Condition of Protective Coating on OMCS CLASS Vessels Reviewed

Tanks	Sacrificial Anodes Installed (Y/N)	Condition of Coating	No. of Vessels
Topside	YES	GOOD	1
		FAIR	1
		POOR	8
Hopper	YES	GOOD	2
		FAIR	2
		POOR	6
Double Bottom	YES	GOOD	1
		FAIR	3
		POOR	6
Fresh Water	NO	GOOD	6
		FAIR	3
		POOR	2

Figure no. 20 shows the condition of the protective coating on the different tanks of OMCS CLASS Vessels.

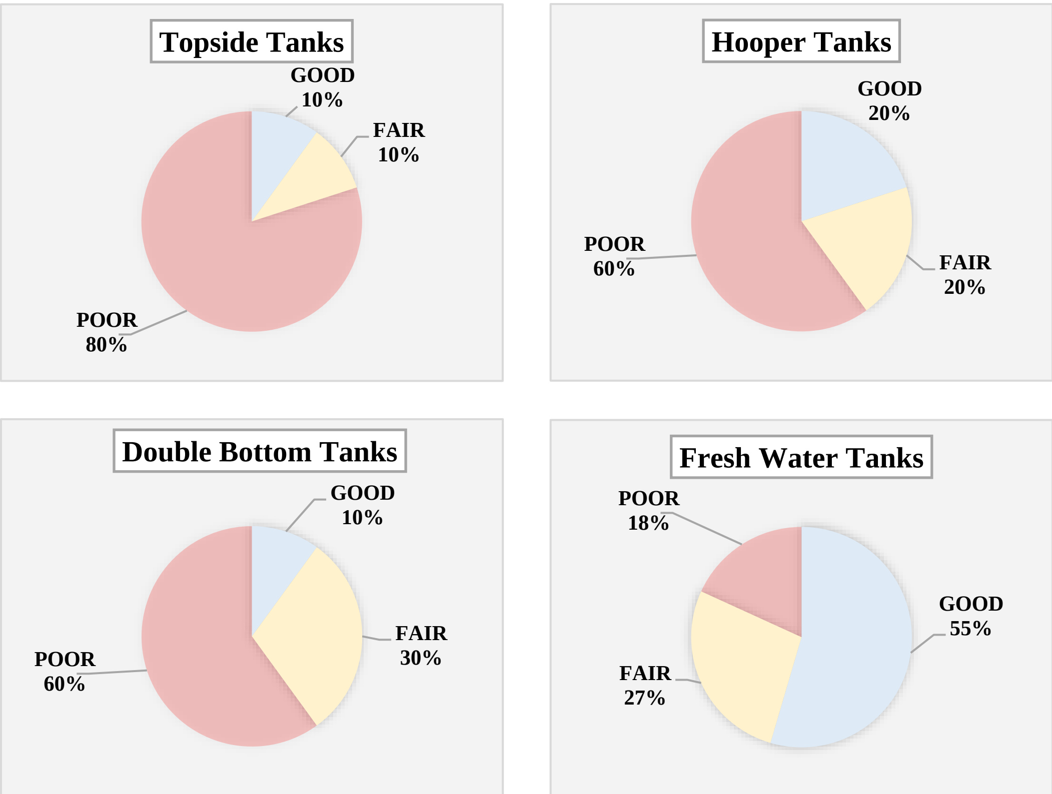


Figure 20 - Condition of Coating on OMCS CLASS Vessels

For ballast tanks, the corrosive protection system for the most part consist only of the presence of sacrificial anodes since the condition of the protective coating is rated in poor condition for most them. In particular, topside tanks were the ones worst rated.

To properly perform its delegated duties, OMCS CLASS technical personnel and field surveyors must be fully conversant and up to date with the different requirements of the IMO with regards to the maritime conventions such as SOLAS, MARPOL, Load Line and others, IMO different resolutions and Circulars, the International Labour Organization (ILO) Conventions, different flag administrations circulars and OMCS CLASS Rules and Regulations. This is a duty that has proven to be of immense undertaking for the organization and the development of guidelines that should assist to standardize the basic knowledge of the attending surveyors and the inspection procedures was foreseen to be of great assistance.

The on the field part of the internship where the theoretical part matched the real world was the most rewarding one. Several surveys were attended along with field surveyors which gave us a on the ground perspective of the different hull defects found on board vessels and the issues faced by the surveyors which ranged from safety aspects to commercial pressure. These inspections were very diverse in nature and not only hull related inspections were carried out but also IMO statutory inspections, ISM/ISPS/MLC audits, damage investigation, flag annual safety inspections and closing of conditions of class; thus, adding positively and immensely on the internship experience.

5 SUMMARY OF OMCS CLASS GUIDELINES

5.1 Introduction

The propose single skin bulk carrier hull condition assessment guidelines were developed exclusively for OMCS CLASS using the company letter head and are included as an appendix of this thesis. These guidelines draw on the experience obtained during a three and half month internship at OMCS CLASS, on the field survey experience gathered during the internship and previously and review of information available from IMO, IACS and other maritime organizations. These guidelines are only intended to provide a general knowledge and guidance to OMCS CLASS surveyors to make sound technical decisions when determining and assessing the actual technical condition of hull and cargo related spaces of single skin bulk carriers at a given point of time by surveys. In no respect these propose guidelines are binding, the professional experience coupled with common sense of the attending surveyor shall always prevail. The guidelines were divided in several sections which covered topics from OMCS CLASS surveyor virtues, duties and responsibilities, hull survey requirements, hull survey planning and preparation, hull survey execution and examination, and areas of concern for cracks and corrosion.

5.2 OMCS CLASS Surveyor

As per OMCS CLASS policies, the surveyor should have basic essential virtues that can be summarized in sound judgement, knowledge, courtesy, honesty and impartiality. The surveyor is expected to have a sound technical knowledge gained from experience, training and qualification so that he is able to perform his duties in a competent and trustworthy manner. For this he should familiarize himself with the latest rules, regulations, conventions and codes applicable and it is recommended that he should subscribe to various periodicals. Surveyor should have high analytical skills and clear thinking ability. He should evaluate all the aspects of the problem, such as the effect on safety of property & life, practicability of his recommendations, owner's commitments, the type of the service the ship is intended for etc. before making any decision.

Communication skills and the proper use of the English language are of paramount importance. Surveyors should be firm in their decisions; however, this should be relay to the owner or manager in a polite manner. Since these decisions have great implications on the commercialization of the vessel and the life of the crew that operate them; they should be impartial in nature and based on the actual condition sighted on board the vessel. Conflicts of interest should be avoided at all times and the code of conduct of OMCS CLASS must be followed.

The work of a hull surveyor is dangerous in nature, the work the environment presents many life-threatening risks from dangers at the working site, entry into enclosed spaces with possible lack of oxygen, working at heights and with toxic cargos. It is the hull surveyor responsibility and duty to make use of the personal protective equipment deemed necessary for the safe performance of his job. The personal protective equipment that the surveyor should use is to be comprised at least of protective clothing, appropriate protection for the eye, head, hand, foot and respiratory protection.

5.3 Hull Survey Requirements

The classification cycle covers a period of five years. During that time, several different types of survey (annuals, intermediates and renewals surveys) are to be carried out at regular intervals. These surveys must take place at the specified intervals in order to keep a ship in class. The extent and scope of the surveys that are carried out on a ship vary according to the type of ship and its age. As a general guidance, the type of hull surveys, their time intervals and scope are specified in the table no. 5:

Table 5 – Classification Survey Type and Intervals

Type of survey	Survey interval	Scope of survey
Initial Survey	Inspection to be held before a ship is put into service	To verify that the vessel has been constructed as per the previously approved plans and that all the relevant requirements are complied with.
Annual Survey	Annual to be held within three months before and after each anniversary date completion. commissioning or special survey.	Hull, machinery and equipment as per annual survey checklist.
Intermediate Survey	Held instead of the second ot third annual survey. Can be commenced on second and progressed with completion at third annual survey May coincide with a docking survey or the in–water survey.	All aspects of the ship.
Special/Renewal Survey	Every 5 years. Must coincide with the annual survey and a docking survey	All aspects of the ship.
Docking Survey	Twice a 5-year period. with no more than 36 months between surveys. A docking survey needs to coincide with the special survey when it falls due or held within fifteen months prior to the due dates of special survey.	Items as per docking survey check list.

In-Water Survey	Held to replace intermediate docking surveys. Can coincide with the intermediate special survey or one of the annual surveys. Not permitted on bulk carrier older than 10 years and other ESP ships older than 15 years.	Underwater structure of the vessel (Bilge keels, rudder, propellers, bow thruster, etc.)

Bulk carriers are subject to the specific survey requirements of the Enhanced Survey Program (ESP) Code of 2011. The ESP Code is based on three principal criteria: overall/close-up examinations of the structure of cargo holds and ballast tanks, thickness measurements and the condition of the protective coating/extent of structural corrosion. It applies to all self-propelled bulk carriers of 500 gross tonnage and above for the surveys of hull structure and piping systems in way of cargo holds, cofferdams, pipe tunnels, void spaces, fuel oil tanks, within the cargo length area and all ballast tanks. This code contains the minimum extent of examination, thickness measurements, and tank testing for bulk carriers and oil tankers.

Specifically, the ESP Code has requirements for number of surveyors, the corrosion prevention system on the different spaces, extent of inspection on hatch covers and coamings, extent of inspections of ballast tanks and fuel oil tanks, tank pressure testing, extent of cargo holds inspections, close-up examinations on specified areas and the extent of thickness measurements on the structure and suspect areas.

5.4 Hull Survey Planning and Preparation

Planning is of great importance regardless of the industry and task to be performed. There is a popular saying that says that "when one fail to plan, one plan to fail." Marine surveying business is not exempted from it. As a matter of fact, its importance in shipping is paramount since shipping is a business that always runs against the clock and when you consider the commercial pressure inherited in the maritime operations, if the surveys are not properly planned; the final objective of assessing that the hull structure is fit for purpose will not be satisfactorily achieved.

The ESP Code 2011 specifically requires the development of a survey planning questionnaire and a survey program (planning document) in advance of every Special/Renewal/Intermediate survey on ships over 10 years of age. On vessels, less than 10 years of age, the survey program is not required to be approved in advance of intermediate survey. The survey should not commence until a survey program has been agreed. The program is to judge the level of danger based on the acknowledged principles and practical operations and to include proposals for the special/intermediate Survey, including the means of providing access for close-up survey, thickness measurements and tank testing among others. It is the attending surveyor responsibility and duty to make sure his personal life is not put in danger; likewise, it is the owner and/or drydock obligation to provide a safe working environment. Proper precautions must be taken and safety guidelines must be followed at all times when entering into confined spaces, inspecting ballast and fuel tanks, working aloft with the use of ladders, cherry pickers and staging's.

Figures no. 21 shows the typical slippery mud that the surveyors encounter during their ballast tanks inspections.

Figure 21 - Typical slippery mud inside ballast tanks

It is of great importance that the attending surveyor does the proper planning before the survey commence, has open and clear communication channels. A kick-off survey planning meeting with the owner's representatives and thickness measuring company on board prior to and subsequent follow up meetings during the survey as an essential part of the safe and efficient way of conducting the survey for the purpose to ascertain that all the different necessary arrangements stated in the survey program are in place. These meetings are of great importance because it establishes the proper lines of communication, the necessary tasks, preparation and close cooperation required among the different personnel involve.

For the attending surveyor, the above information is of immense importance since it will allow him to be acquainted with the job at hand and be able to prepare himself accordingly since often surveys are carried out on a limited time frame. The attending surveyor should get acquainted with the structural layout, and assess the ship's operation and maintenance record. The attending OMCS CLASS surveyor should specifically follow the procedures stated TD-SP-ESP

(Enhanced Survey Program Procedures) and PM-TD25 (Guidelines to Ship owners and Surveyors during ESP Surveys for Bulk Carriers). The ship owners should use form PM-TD26 for the elaboration of the Survey Planning Questionnaire for Bulk Carriers and form PM-TD27 for the Survey Program for Bulk Carriers. These documents can be found on the appendix no. 2 of this thesis.

Thickness measurements of hull structural elements are an integral part of the Enhance survey program basic requirements, and their results constitute one of the most important criteria for the assessment of hull girder strength by the classification societies. The attending surveyor should make sure that before the thickness measurement company commences their job, that the thickness measurement equipment (UTM Equipment) to be used is duly calibrated according to recognized national / international standards and properly labelled, he must witness that the calibration presented is approved for size and type of material, and be satisfied with operator's skills and competence.

Even though the calibration certificate of the ultrasonic measuring equipment is presented, it is always advisable that the surveyor verify its calibration on situ prior to commence the ship measurements. For this, a calibration block is provided and measurements of thickness of known structures can be performed, as depicted on figures no. 22.

Figure 22 - Calibration block and ultrasonic thickness equipment

5.5 Hull Survey Execution and Examinations

5.5.1 Bulk Carrier Hull Structural Elements

In general, the main objective for a ship's hull structure assessment is to effectively determine if the hull structure of a vessel is able to withstand the loads for which it was initially designed for during the extent of time that the classification cycle last that is for five (5) years. In the shipping world, there are two main objectives to conduct the hull assessment of existing ship hull structures, the assurance of structural safety and serviceability and the minimisation of costs and repair time.

Before commencing its inspection, the attending surveyor must have an idea of the expected types of defects and their likely locations, and be aware of those items which are structurally significant such as all external boundary plating, primary and secondary strength members. The single skin bulk carriers hull can be divided into different hull structural elements, and each element has its own function in the total hull integrity. In determining the likelihood and type of defects to be found, the attending surveyor needs to understand the function and importance of each structural element locally and how it contributes to the global vessel strength.

5.5.2 Hull Survey Methods

The hull survey methods are the systematic procedures and means utilized to detect the different deficiencies and damages such as material wastage, fractures, and deformations at an early stage as possible to carry out the necessary repairs and guarantee that the vessel is fit for purpose. Hull survey methods should be regarded as an integral approach and encompass comprehensive means of detecting deficiencies, monitoring structural condition and schemes for inspections which are compromised within the ESP Code.
Means of detection of defects and condition monitoring are inter alia:

- ✓ Visual inspections (Overall & Close-up Inspections)
- ✓ Pressure and Tightness Tests
- ✓ Steel Thickness Measurements
- ✓ Non-destructive testing (NDT)

On figure no. 23, it can be observed non-destructive testing being performed on a side shell welding; specifically, dye penetrant and ultrasonic to determine surface and root defects on the welding seam.

Figure 23 - Welding on the side shell checked with dye penetrant and ultrasonic equipment to detect flaws

5.5.3 Hull Structural Defects

Hull defects mainly take the form of corrosion wastage, deformations, fractures/cracks and normal operational damages (wear & tear). In many cases, these hull defects are preventable with adequate inspections, timely maintenance and an understanding of their causes. Particular attention should be given to areas prone to fractures/cracks, distortion or excessive wastage can occur. This defects are usually a result of overload of the structure, design flaws, poor workmanship, vibrations and normal wear & tear due to ageing. Understanding the causes of the different types of defects is great importance at the time of taking a decision of how to repair the defect since depending on the situation a simple crop and renew will not take the problem away. In many instances the defect will resurface at a quicker rate than the initial found defect. Depending of the severity of the structural defect observed, it is the treatment given to it. Thus, the attending surveyor can raise a memorandum to owners, a condition of class or recommend the suspension or withdrawal of the class certificate.

5.5.3.1 Types of Corrosion

Corrosion is one of the most common causes of material wastage on vessels and it can be categorized on different types depending if it is generalized or localized.

Uniform or General corrosion, which is the most common form of corrosion, it is easily identifiable and least harmful. It spreads evenly over the surface of the metal and forming a uniform layer of constant thickness; however, on the total cost attributed to corrosion repairs, it is the one that adds up to the highest proportion. Figure no. 24 provide a schematic view of how general corrosion looks and affects a steel plate.

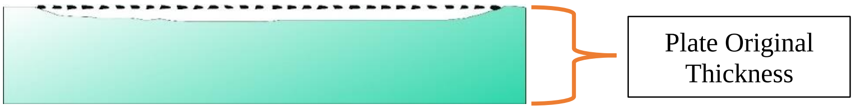


Figure 24 - General Corrosion Schematic View

Pitting corrosion, is a localized form of attack usually resulting in an appreciable formation of a cavity or pit of the material. It can also result on the complete perforation of the metal to the surface opposite to that upon which the pit initiates. The figure no. 25 gives a schematic view of how pitting corrosion looks on plate.

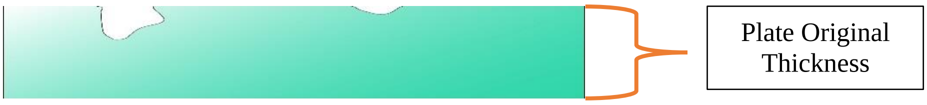


Figure 25 -Pitting Schematic View

Other types of corrosion also described on the guidelines are groove corrosion, edge corrosion, erosion corrosion, bacterial corrosion and stress corrosion.

5.5.3.2 Deformations

Deformation are usually reported as buckling and bending of the hull structure. The hull structure can suffer of structural overloads where the stresses placed on the structure were greater than the allowable designed stresses and it can be the result of heavy weather, improper loading sequences and accidents such as groundings, collisions, etc. Since bending moments are greater at midships and the largest stresses are on the deck plating, the condition of the ship deck near midships and specially the areas between cargo holds are of great importance during surveys since buckling may occur. Figures no. 26 depict a damage due to overload of the bulbous bow structure due to heavy weather, where due to heavy pounding the structure buckled.

Figure 26 - Bulbous damages due to slamming (Overload)

5.5.3.3 Fractures/Cracks

Cracks are one of the most noticeable damages that can be found on bulk carrier structures. It is very important to timely repair any observed fracture since if left unattended and not repaired immediately, it can grow and continue to propagate with dangerous consequences.

In most cases, fractures are found at locations where stress concentration occurs. Stress concentrations occurs where there is a geometrical discontinuity in a section and where there is surface roughness such as blow holes, undercutting, etc. caused during the construction phase. The intensity of the stress concentration is mainly a function of the abruptness of the discontinuity. Some of the areas of stress concentration that the attending surveyor should look out for are

1) Hard Spots/point,
2) End of bracket toes and stiffeners,
3) Points at which there is a change of section,
4) Areas of misalignment,
5) Areas where there is a change of thickness,
6) Openings,
7) Points where three planes meet (Knuckles).

Figures no. 27 provide an example of a crack that initiated at a cut out in way of a web frame and a longitudinal stiffener and propagated into the hull creating water ingress.

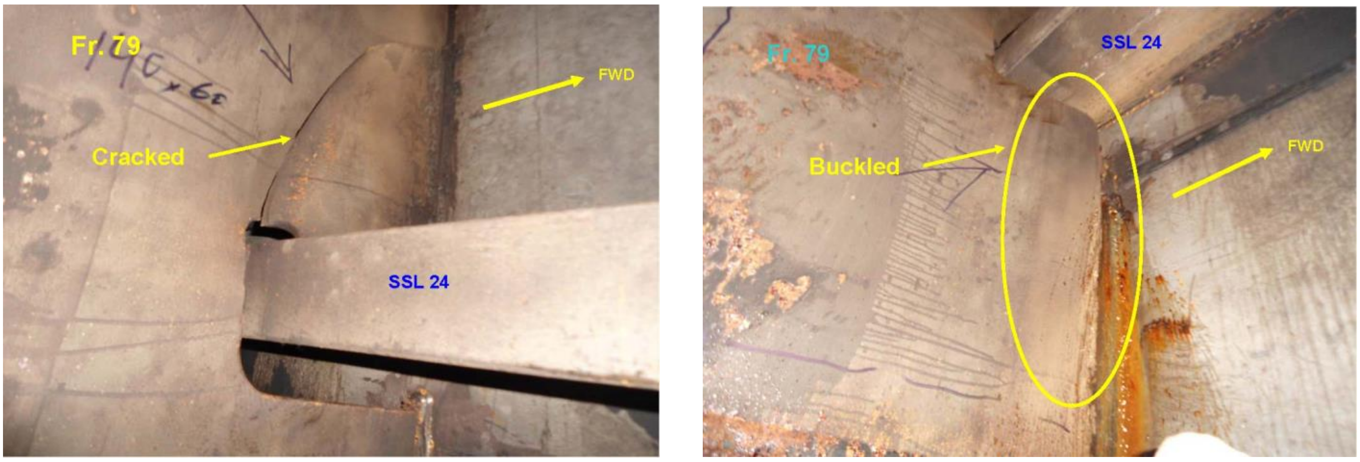


Figure 27 - Examples of crack that propagated into the hull

If fractures/cracks occur due to cyclic repetitive loads (induced by wave forces) which are below the yielding stress of the material, these fractures are called fatigue fractures. In addition, fatigue fractures can also be a result of vibration forces introduced by vessel main engine and/or propeller, especially in the aft part of the hull (aft peak tank).

5.5.3.4 Normal Operational Damages (Wear and Tear)

The normal operational handling of cargo during loading and unloading of bulk carriers tend to cause different damages to the structure mostly in way of deformation and indentations on the cargo hold region. Most of these deformations and indentations take place during the loading (cargo drop) and unloading (grabs, bulldozers) operations of a bulk carrier, where the tank top of cargo holds, lower bracket of hold frames, sloping bulkheads, and lower portion of transverse bulkheads are usually affected by the cargo or the loading/unloading equipment used.

5.5.4 Survey Execution

5.5.4.1 Thickness Measurements & Diminution Tolerances

Due to the great importance of the thickness measurements in assessing the hull girder strength by evaluating the extent of the corrosion/wastage, measurements are to be carried out in a systematic manner. The measurements shall be carried out on locations that adequately represent on average the condition of any corrosion or wastage found on the measured hull structure. The thickness measurement team should not only focus on simply recording and reporting wall thickness information but also visual observations should be made of any defects such as fractures, holes, knife edging, grooving, pitting, etc. Random verification of correctness of measurement results by check measurements performed by the attending surveyor himself or by the measurement firm in the surveyor's presence is to be carried out.

Since very few ships are constructed in series and its majority are individually designed, this makes the creation of general guidance on diminution tolerance a challenge. During the construction of a vessel, the thickness of the different hull structure element may vary depending on the different class societies rule requirements applicable at the time of the newbuilding and special requirements that might be given by the initial owner. Thus, nowadays, the specific values for diminution tolerances (corrosion margin) may vary from ship to ship depending on its strength criteria; however, general guidance’s developed by the different classification societies do exist. The diminution tolerances depending on the vessel length are included on the guidelines.

5.5.4.2 Examination of Hatch Covers & Weather Tightness Integrity Test

The careful inspection of hatch covers during annual surveys is extremely important since the weathertightness integrity of a bulk carrier depends on their good condition. Sea loads due to waves and green water on deck are normally greatest at the forward portion of the vessel, special attention should be given to the hatch covers located in the forward part of the vessel (one quarter (¼)) forward ship's length).

The effectiveness and condition of sealing arrangements are to be carefully inspected and tested either by a combination of chalk and fire hoses test or by using ultrasonic hatch tightness testing equipment. During the hose test, the surveyor should make sure that no leakage inward to the cargo holds take place with the use of the water pressure greater than 250 Kn/m^2 with a nozzle of 12.5 mm diameter. Figure no. 28 presents a hose testing being carried out.

Figure 28 - Hose Test (Source: SS Marine Surveyors)

When hose testing, if the water jet cannot be applied directly to the gasket or compression bar connection then hose test would not be suitable, and weathertightness test should be carried out with the assistance of an ultrasonic equipment with a multidirectional transmitter. Figure no. 29 presents an ultrasonic hatch testing being carried out.

Figure 29 - Ultrasonic Hatch Testing (Source: Damco Survey AB)

5.5.4.3 Examination of Tanks & Protective Coating

Inspections inside tanks and void spaces are perform to find of defects or anomalies relative to the condition of the corrosive protection system, corrosion, deformations and fractures. The surveyor visual examination should consist of overall examination, close-up examination of suspect and critical areas and a condition assessment of the protective corrosion system (Protective coating and anodes). Adequate lighting in the tanks and void spaces are critical the inspection work, safety and for identifying deformations or surface dents. Immediately on entering the enclosed space OMCS CLASS Surveyor can determine overall the tank's condition; taking into consideration the condition of ladders, paint coatings, overall corrosion levels and by closely observing areas susceptible to corrosion such as near the weld joints. This overall inspection will give the attending surveyor an impression of the degree of rigour and carefulness required for inspection.

The condition of the protective coating system inside tanks is to be evaluated and documented in connection with the different inspections to be carried out to the hull structure and ballast tanks, it is important that the focus on the different areas where coating damages are prone to such as:

- ✓ areas difficult to effectively protect with coating,
- ✓ restricted access for surface preparation and coating application,
- ✓ welds,
- ✓ sharp edges.

Coating damages can take the form of coating cracking, blistering, rust, and flaking depending on different factors. OMCS CLASS surveyor should document and record the condition of the protective coating inside the tanks. The condition of the coating is evaluated based on the type of coating damage, causes of coating failure and extent (percentage) of the area damaged. The condition shall be judged over 'larger' areas with one rating for the complete tank.

Table no. 6 states the criteria that surveyors should base themselves in order to classify the condition of the coating.

Table 6 - Classification of Protective Coating inside Ballast Tanks ((IMO), International Code on the Enhanced Programme of Inspections During Surveys of Bulk Carriers and Oil Tankers, 2011 (2011 ESP Code), 2011)

Hull Condition	Remarks
GOOD	Condition with only minor spot rusting;
FAIR	condition with local breakdown of coating at edges of stiffeners and weld connections and/or light rusting over 20% or more of areas under consideration, but less than as defined for POOR condition; and
POOR	condition with general breakdown of coating over 20% or more of areas or hard scale at 10% or more of areas under consideration.

5.5.5 Areas of Concern for Cracks, Deformations and Corrosion

In order to assist OMCS CLASS field surveyors with a better visualization of the most typical defects/damages found specifically on OMCS CLASS bulk carriers and their areas of concern, a segregation of the bulk carrier structure into seven (7) main structural regions was performed. Pictures and drawing depicting the areas of concerns and the type of defects are included on the guidelines. These areas of concern and defects were gathered from the review of the survey history of ten (10) single skin bulk carriers classified by OMCS CLASS. The table no. 7 summarizes the different defects found on OMCS CLASS bulk carriers segregated by the seven (7) main structural regions:

Table 7 - Defects found on OMCS CLASS bulk carriers segregated by main structural regions

Side shell plating / Vertical frames & Brackets
Cracks in side frames at lower / upper bracket connection
Corrosion of side frames and lower brackets –detached brackets
Grab damage and side shell contact damage
Fatigue cracks at the connection of independent brackets to shell frames.
Fatigue cracks at the toe of the shell frame top and bottom brackets
Grooving at the weld connection to the shell plating
Bottom & Inner Bottom Plating, Longitudinal Stiffeners & Girders
Cracks in inner bottom plate in way of knuckle to hopper tank
Crack / Corrosion of floors –girders in ballast tanks
Indents of inner bottom plate due to cargo handling
Fractures in longitudinal stiffeners at floor/transverse web frame or bulkhead
Pitting/Erosion Corrosion below bell mouth suction heads
Bilge keel terminations – crack in hull plating

Deck
Cracks in deck plate at end of longitudinal hatch coaming
Cracks in deck plate in way of hatch corner
Buckling of deck between hatches (cross deck section)
Buckling on deck due to green water or over pressure of topside tanks
Transverse Bulkheads
Heavy corrosion in lower stool diaphragms
Heavy corrosion at mid height and lower part of corrugated bulkhead plating & weld connections
Wastage and Cracks in way of the connection of the bulkhead and stool (Shedder plating)
Fracture/Crack in way of the connection of the upper stool and topside tank sloping plate
Fracture/Crack in way of the connection of the lower stool and hopper tank sloping plate
Shear buckling of corrugated bulkhead due to excessive corrosion
Topside Tanks (Web frames, Longitudinal Stiffeners, Deck & Side Plating's)
Web Frame buckling deformation due to overpressure of ballast tank
Fatigue cracks in lower side longitudinal stiffeners
Heavy corrosion topside tank deck & side plating and their longitudinal stiffeners
Excessive corrosion/wastage in lower part of the slopping plate, upper supporting brackets and lower side and slopping plate longitudinal stiffeners
Hopper Tanks
Cracks in way of knuckle line between hopper tank sloping plate and inner bottom plate
Crack in web frame in way of the connection with longitudinal stiffeners.
Excessive corrosion at web frame corners
Hatch Coamings, Hatch end Corner Brackets & Covers
Cracks in hatch coaming corners and hatch end corner brackets
Cracks in hatch longitudinal coaming (mid of cargo hold)
Excessive corrosion on hatch end corner brackets, hatch coaming plating inside cargo hold, topside tank plating vertical strake and covers

6 CONCLUSIONS

The hardship that bulk carriers endure during its operational life due to their cargo loading and unloading operations and type of cargoes coupled with loads and stresses induced by the marine environment make the hull structure of these vessels prone to the development of structural defects which requires well planned and detailed inspections.

Due to the great dimensions of the bulk carriers' hull structures, the dangers and difficulties to access the different elements, the commercial pressure inherited in the maritime operations and the very short time allocated make the hull inspection on board bulk carriers very challenging. These facts highlight the importance for a classification society to have standardized and detailed procedures and guidelines for hull condition assessment surveys of bulk carriers. The extent, importance and complexity of the hull condition assessment surveys have been highlighted on this thesis and on the propose guidelines developed exclusively for Overseas Marine Certification Services (OMCS CLASS).

The opportunity given by OMCS CLASS to perform my internship, to grant access to the survey history of its single skin bulk carrier fleet and to attend to different on field surveys exposed the common and critical problems that old bulk carriers currently face considering that the design life span of most of these vessels were for twenty (20) to twenty-five (25) years. The fleet of bulk carriers certified by OMCS CLASS is mostly of advanced age and of relative small size, handysize bulk carriers. Mainly due to the age of the vessels and to the unforgiven effect of corrosion; the hull structure is prone to many defects. Most the defects found on board OMCS CLASS vessels were related to corrosion and fractures on the different parts of the hull structures and mostly located on the structure elements in way of the cargo hold area (tank top and sloping plating and vertical frames) and the supporting structure inside topside tanks.

Several new regulations have been enacted on the last couple of years which should improve the conditions of the new bulk carrier when they will age, specially the requirements of the application of protective coating to ballast tanks and cargo holds during new building and the better enforcement of the regular inspections required by the ESP Code 2011.

Procedures to enhance and better enforce the transfer of class agreement (TOCA) in order to obtain all the necessary and relevant information of the vessels that are transferred to OMCS CLASS is vital. Mainly to ensure that the vessel is transferring to the gaining society in not doing so to avoid compliance of the regulations under the losing class society.

The propose guidelines developed as the result of this thesis could be of great assistance to the different office technical and field surveyors' personnel and we encourage the top management to share this information as they consider fit. A similar study is recommended to be performed on the Oil Tanker fleet of OMCS CLASS that is also subject to the requirements of the ESP Code 2011 and the results to be adhered to these propose guidelines.

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8 REFERENCES

(CCRS), C. C. (2011). Steel Corrosion in Ships. Kaohsiung, Taiwan: China Corporation Register of Shipping.

(IACS), I. A. (2001). *Formal Safety Assessment of Bulk Carrier Fore-end Watertight Integrity*. London: International Association of Classification Societies (IACS). Retrieved 2016, from http://www.iacs.org.uk/document/public/Publications/Other_technical/PDF/FSA_Bulk_Carrier_Annex_02_pdf438.PDF

(IACS), I. A. (2006). *Common Structural Rules or Bulk carriers*. London, United Kingdom: IACS. Retrieved October 2016, from http://www.iacs.org.uk/document/public/Publications/Common_rules/PDF/CSR_Bulk_Carrier_Consolidated_PDF_File_pdf774.pdf

(IACS), I. A. (2015). *Guidelines For Coating Maintenance & Repairs For Ballast Tanks And Combined Cargo/Ballast Tanks On Oil Tankers*. London: IACS.

(IACS), I. A. (2015, March). Hull Surveys of Bulk Carriers. *Z. 10.2 Hull Surveys of Bulk Carriers*. London, United Kindom: IACS.

(IACS), I. A. (2015). *Rec. 85 Guidelines for Coating Maintenance & Repairs for Ballast Tanks and Combined Cargo/Ballast Tanks on Oil Tankers* (Rev. 2 ed.). London, United Kingdom: IACS. Retrieved from http://www.iacs.org.uk/document/public/Publications/Resolution_changes/PDF/REC_087_Rev2_pdf2592.pdf

(IACS), I. A. (2015). *Rec. 85 GUIDELINES FOR COATING MAINTENANCE & REPAIRS FOR BALLAST TANKS AND COMBINED CARGO/BALLAST TANKS ON OIL TANKERS* (Rev. 2 ed.). London, United Kingdom: IACS. Retrieved from http://www.iacs.org.uk/document/public/Publications/Resolution_changes/PDF/REC_087_Rev2_pdf2592.pdf

(IMO), I. M. (1974, 2016 Consolidated Edition). International Convention of Safety of Life at Sea. In I. M. (IMO), *International Convention of Safety of Life at Sea* (2016 Consolidated Edition ed., pp. Chapter XII, Regulation 1). London, United Kingdom: International Maritime Organization (IMO). Retrieved December 2nd, 2016

(IMO), I. M. (2011). *International Code on the Enhanced Programme of Inspections During Surveys of Bulk Carriers and Oil Tankers, 2011 (2011 ESP Code)*. London, United Kingdom: International Maritime Organization (IMO).

(IMO), I. M. (2011). International Code on the Enhanced Programme of Inspections During Surveys of Bulk Carriers and Oil Tankers, 2011 (2011 ESP Code). *IMO General Assembly - Resolution A.1049(27)*. London, United Kingdom: International Maritime Organization (IMO).

(IMO), I. M. (2013). *Bulk Carier Safety*. London: IMO.

(IUMI), I. U. (2016). Hull Fact Sheet. In I. U. (IUMI) (Ed.), *International Union of Marine Insurance (IUMI)*. Genoa, Italy: International Union of Marine Insurance (IUMI) - IUMI Facts & Figures Committee. Retrieved 2016, from http://www.iumi.com/index.php/committees/facts-a-figures-committee/statistics

Boon, B. B. (1997). *Mechanical properties of aged ship structures, International Conference Ships – the Ageing Process*. London, UK.

C.P. Gardiner, R. M. (2003). Corrosion analysis of bulk carriers, Part I: operational parameters influencing corrosion rates. *Marine Structures*.

CAPPS International Ltd. (2016). *CAPPS International Ltd*. Retrieved from CAPPS International Ltd: http://www.cappsinternational.com/

Caridis, P. (2001). *Inspection, repair and Maintenance of Ship Structures*. Witherby.

Charles Taylor & Co. Limited. (2011, March). Bulk Cargoes - Hold Preparation and Cleaning. *Standard Cargo*. London, United Kingdom.

Chritian Cabos, D. J.-F. (2008). *Condition Assessment Scheme for Ship Hull Maintenance (CAS Project).* Condition Assessment of aging ships for real-time Structural maintenance decision Project, Hamburg. Retrieved November 2016, from http://transport-research.info/sites/default/files/project/documents/20121105_09

Clarksons Research. (2016). *Bulk Carrier Register 2016.* Clarksons Research, London. Retrieved 2016, from http://www.crsl.com/acatalog/bulk-carrier-register-2016.html

Class NK. (2015). *Port State Control Annual Report.* Class NK, Survey Operations Head Quarters. Tokyo: Class NK. Retrieved 2016, from www.classnk.com

Det Norske Veritas (DNV). (2005). *Technical Guideline for Inspection and Repair of Hull and Hull Equipment.* Oslo: DNV. Retrieved 2016

Gonzalez, H. (2013, January 14). *Surveyor Guide Notes for Bilge Keels Survey*. Retrieved from Marine Survey Practice: http://marinesurveypractice.blogspot.com/2013/01/bilge-keels-survey.html

Guttormsen, V. J. (2000). *Critical Areas with Respect to Coating.* Det Norske Veritas (DNV), Hovik, Norway.

IACS, I. A. (2003). *Recommendation 82 (Surveyor's Glossary, Hull Terms & Hull Survey Terms).* London: International Association of Classification Societies (IACS).

International Association of Classification Societies (IACS). (1994). *Bulk Carriers For Guidelines for Surveys, Assessment and Repair of the Shull Structure.* London: International Association of Classification Societies.

International Association of Classification Societies (IACS). (2007). *Guidelines for Surveys, Assessment and Repairs of Hull Structures* (September 2007 ed.). London, United Kingdom: Witherby. Retrieved 2016

International Association of Classification Societies (IACS). (2011). *Guidelines for Approval / Acceptance of Alternative Means of Access.* London: IACS.

International Maritime Organization (IMO). (1995). Guidelines on the Means of Access to Structures for Inspection and Maintenance of Oil Tankers and Bulk Carriers. In M. S. Committe (Ed.), *Maritime Safety Committe.* London: IMO. Retrieved Nvember 30, 2016, from http://imo.udhb.gov.tr/dosyam/EKLER/SOLAS__BOLUM_II_1_EK(18).pdf

International Maritime Organization (IMO). (2015). SURVEY GUIDELINES UNDER THE HARMONIZED SYSTEM OF SURVEY AND CERTIFICATION (HSSC), 2015. *IMO GENERAL ASSAMBLY - Resolution A.1104(29).* London, United Kindom: International Maritime Organization (IMO).

Ivosevic, S. (2015). An Approach to the Corrosion Analysis of Bulk Carrier Hull Structure. *Scientific Journal of Polish Naval Academy*, 30. doi:10.5604/0860889X.1178568

Lloyds Register of Shipping. (2014). Thickness measurement and close-up survey guidance. London, United Kindom: Lloyds Register of Shipping.

Ohyagi, M. (1987). Statistical survey on wear of ship's structural members. *NK Class Technical Bulletin*.

Overseas Marine Certification Services (OMCS CLASS). (2012). Part 1. Rules & Regulations. In O. M. CLASS), *Part 1. Rules & Regulations* (p. 8). Panama: Overseas Marine Certification Services (OMCS CLASS).

UK P&I Club. (2006). *Testing weather-tight integrity of dry cargo vessels' hatchovers.* UK P&I Club, Carefully to Carry Committee – the UK P&I Club's advisory committee on cargo matters. London: UK P&I Club. Retrieved November 30th, 2016, from http://www.ukpandi.com/fileadmin/uploads/ukpi/LP%20Documents/LP_Bulletins/Chinese_Translations/Testing%20hatchcovers%20.pdf

unknown. (2010). *Docking Survey*. Retrieved from Docking Survey: http://docking.ship-doctor.com/8/8_1.html

Wang, e. a. (2009). 17th INTERNATIONAL SHIP AND OFFSHORE STRUCTURES CONGRESS. *Condition Assessment of Aged Ship and Offshore Structures.* Seul.

Yamamoto, N. (2008a). Probabilistic model of pitting corrosion and the simulation of pitted corroded condition. *International Conference on Offshore Mechanics and Artic Engineering*.

Yamamoto, N. T. (2008b). Total Support System during life cycle of LNG Ships. *GASTECH*.

Yanamoto N, I. K. (1996). Study on the degradation of coating and corrosion of ship’s hull based on the probabilistic approach. *Proceedings of the International Offshore Mechanics and Arctic, Volume No. 2*, 159-66. Retrieved 2016

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11 APPENDICES

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OMCS CLASS Guidelines for Hull Condition Assessment of Single Skin Bulk Carriers

11.2 APPENDIX A2

OMCS CLASS Enhanced Survey Documentation

TD-SP-ESP Enhanced Survey Program Procedures

PM-TD25 Guidelines to Ship Owners and Surveyors during ESP Surveys for Bulk Carriers

PM-TD26 Survey Planning Questionnaire for Bulk Carriers

PM-TD27 Survey Program for Bulk Carriers

ESP-BC-SR ESP-Condition Evaluation Report for Bulk Carriers

PM-TD29 Corrosion Protection