Structure Defects on Double Hull Tankers

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Abstract

Abstract - Double Hull tankers built in the past have experienced certain structural deficiencies. The statistics indicate that a significant number of defects, especially fractures, occurred in double hull tankers less than 10 years old. The statistical data presented illustrates the type of defects known to occur in the early double hull tankers by the application of Rules prior to the IACS Common Structural Rules (CSR) and hence where the prior Rules could have been improved. The intent of the CSR is to provide a more robust structure with a view to enhance the structure so these known defects are addressed by application of the CSR. Thus the presentation will review the work done during the development of the CSR and intends to include the data known to the other Class Societies that are members of TSCF.

1 Introduction - History of Double Hull Tankers

The International Maritime Organization (IMO) through the Marine Pollution Convention made double hull tankers mandatory by Regulation 13 F adopted in 1992. Thus the United States requirement of the Oil Pollution Act of 1990 mandating double hull tankers effectively became the world standard. The initial view of the Tanker Structure Cooperative Forum in the publication "Guidelines for the Inspection and Maintenance of Double Hull Tanker Structures" (TSCF DH Manual) published in 1995 identified locations that may be prone to fracture in double hull oil tankers. These locations are selected from experience from the number of double hull oil tankers operating at that time, and also from other types of vessels in operation with similar structure. These include Chemical Tankers that met IMO Type 2 hull required by the International Bulk Chemical Code, Gas Tankers, Ore/Bulk/Oil Carriers, and Ore or Oil Carriers.

The information in the TSCF DH Manual advised that special attention be paid to areas identified as problematic in existing and older tankers where both corrosion and structural defects have occurred, and also where the analysis shows higher stresses. The TSCF DH manual identified the following areas as ones where defects are more likely:

Cargo Tanks:

1- Under deck vapor spaces in cargo tanks,
2- Termination of primary support structure (webs and stringers)
3- Panel instability where panel stiffeners have not been properly arranged
4- Joints of the inner hull in way of lower hopper and upper shelf construction.

Ballast Tanks:

1- Same locations as cargo tanks
2- Connections of longitudinal stiffeners to web frames, floors and bulkheads
3- Vertical stiffeners on transverse bulkheads to deck, horizontal stringers and inner bottom.

The additional guidance contained in TSCF DH Manual indicated that due consideration be given at the design stage to reduce the risk of fatigue cracking. This gave industry some early insight into the problems that may occur in double hull tankers.

2 Profile of Double Hull Tankers

The world fleet of double hull oil tankers with a length of 150 Meters, or more, has grown from about 180 in 1990 to over 3000 in 2007 since the IMO requirement entered into force. Prior to the IMO requirement the world fleet of existing double hull oil tankers had been, about one third Panamax, Aframax and Suezmax. These three sizes now account for about half of the world fleet of double hull oil tankers. Table 1 indicates the age profile of double hull oil tankers.

The rate of construction of double hull oil tankers has been greatest in the last five years. The increase in the double hull oil tankers over this period has been influenced by a number of factors but the most probable influence has been the action of the European Community to require a phase out of single hull tankers earlier than the date mandated by MARPOL. The current double hull oil tankers less than 5 years old make up about one third of the world fleet of oil tankers (4282 from Clarkson 2007 Tanker register) in service. Thus it is expected that the Common Structural Rules (CSR) could have an impact on up to one half of the world oil tanker fleet over the next 10 to 15 years.

Table 1 Age Profile of Double Hull Oil Tankers

Age	Product	Panamax	Aframax	Suezmax	VLCC	ULCC	Total
36 - 50	4						4
31 – 35	11			1			12
26 – 30	11	1		2			14
21 – 25	33	9	4	1			47
16 – 20	51	13	24	14			102
11 – 15	125	21	94	48	47		335
6 - 10	243	31	136	78	129		617
0 - 5	568	219	282	99	179	8	1355
Total	1046	294	540	243	355	8	2486

The existing world fleet of oil tankers (single and double hull) is over 4200 ships (April 2007) with approximately 500 under 150 Meters in length. Thus there are about 1000 single hull oil tankers that will require replacement over the next decade. Most of these will be built to the CRS of IACS which came into force for contracts signed after 1 April 2006.

Table 2 World Fleet of Double Hull Oil Tankers

Deadweight Range	Size Category	World Fleet
< 50K	Product	1046
50K – 80K	Panamax	294
80K – 120 K	Aframax	540
120K - 160K	Suezmax	243
160k – 320K	VLCC	355
>320K	ULCC	8
		2486

3 Service History of Double Hull Oil Tankers

During the development of the CSR for Oil Tankers above 150 Meters in length the service history of existing double hull oil tankers has been reviewed. The records of the ships in Table 2 have been analyzed to establish the type of defects occurring in the fleet of double hull oil tankers. The defects have been categorized as “cracks”, “wastage”, “deformed” and “other”.

The results are shown by age in Table 3 for common sizes of oil tanker.

Table 3 Age of Ship at Incident

Age	Product	Panamax	Aframax	Suezmax	VLCC	TOTAL
5 years and less	3.5%	1%	3.3%	9.2%	6.6%	23.6%
6 to 10 years	2.5%	2.6%	8.8%	13.9%	9%	36.8%
11-15 years	7.8%	1.1%	6%	5.8%	1%	21.7%
16-20 years	4.5%	1.3%	0.5%	5.4%		11.7%
21-25 years	0.1%			0.4%		0.5%
25 years and over	5.4%			0.4%		5.8%

It is noted in Table 3 that most defects have been found in ships with an age of 15 years or less. This may be due to one or more of several causes including:

1- limited sample size, or
2- designs for the first double hull oil tankers were subjected to new design loads, and new fabrication methods were adopted in their construction, or
3- the owner, class and the yard did not work together in an integrated manner to address the challenges associated with designing for the demands of the service that double hull oil tankers would endure, or
4- the diligent attention applied during the early design evolution of the first double hull oil tankers in regard to design and construction did not continue in subsequent designs. (In the construction of a new structural configuration there is generally greater interaction between the designer and fabricator in the search for a balance between design and fabrication demands.)

Whatever the cause for the defects found in the double hull oil tankers, the effort in developing the CSR for Oil Tankers has resulted in a uniform methodology for fatigue assessment of double hull oil tanker structures, and also a more transparent requirement for the operator in regard to steel renewal. These requirements when applied should have the desired effect of providing a more robust structure for oil tankers. Thus many of the problems noted in the reported service history of the double hull oil tankers designed to various requirements of the classification societies should be eliminated in the oil tankers built to the CSR of IACS.

4 Location of Reported Defects

Table 4 reports defects in the location on the ship as either forward, cargo area, aft or not stated. The defects reported have been mainly in the cargo block of the vessel. In fact over 80% of those in the sampled reports have been in the cargo area of the vessel.

Table 4 Location of Reported Defects by Region of the Ship

Location	Product	Panamax	Aframax	Suezmax	VLCC	Total
Forward	2%	0.3%	2.4%	1.9%	3.5%	10.3%
Cargo Area	18.4%	5.3%	15.6%	31.5%	12%	82.8%
Aft	2.8%	0.3%	1.7%	1.7%	1%	6.4%
Not stated	0.5%					0.5%
Total						100%

The majority of the defects found, over 80%, have been in the cargo block of the ship. The defects have also been examined by type of space either ballast tank, cargo tank, other or not stated. This has been further examined as to the type of defect as cracked, wasted, deformed or not stated. The results are in Table 5. The defects found have been distributed about equally in the cargo tanks and ballast tanks in the cargo block of the ship.

Table 5 Defects by Type and Type of Tank

Tank Type	Cracked	Wasted	Deformed	Not Categorized	Totals
Ballast	24.5%	16.1%	3.6%	1%	45.3%
Cargo	34.7%	4.1%	0.9%	2.1%	41.8%
Other	2.4%	0.3%	0.3%		3%
Not stated	6.3%	2%	1.4%	0.3%	10%

5 Damages Found in Double Hull Oil Tankers

The reported service results indicate that defects occurred in the areas as shown in Table 6. The defects have also been reported by type in Table 6. This shows that crack type defects and wasted type defects account for over 80% of the reported defects. The wasted type defects reported are approximately 20% of all the defects found in the sampled reports. This clearly indicates the need to address wastage in new designs. The wasted type defects can be controlled by improving the protection of steel. Since 1998 this has been regulated for ballast tanks by SOLAS in Regulation 3-2 of Chapter II-1 by requiring an efficient corrosion prevention system, such as hard coatings. IACS has incorporated the latest SOLAS ballast tank coating requirements in the CSR to be applied to new contracts after 8 December 2006. Also IMO is currently considering requiring an efficient corrosion prevention system for cargo tanks and void spaces. Therefore the wasted type defects have been, or will be, addressed by both IMO in SOLAS and IACS in CSR. IACS has furthered addressed corrosion in the CSR by defining when renewal must occur as the margin for corrosion is clearly defined at the design stage so the owner/operator and others know the diminution permitted for the structure.

The majority of the defects, almost 70%, found in the sampled reports are crack type defects. Therefore it is important to evaluate these closely to determine the probable cause. Cracks in the deck account for about one third of the crack type defects. The attention to detail for both longitudinal connection to transverse webs and transverse bulkheads and deck outfitting will be necessary in order to minimize, or eliminate, the reported crack type defect found in deck structure. The crack type defect found will be further discussed in section 6.

Table 6 Location in the ship

Location	Cracked	Wasted	Deformed	Not Categorized	TOTAL
Upper deck plate & stiffeners	21.2%	3.8%	0.7%	0.2%	25.9%
Side shell plate & stiffeners	11%	6.3%	3.1%	0.2%	20.6%
Transverse bulkhead plate & stiffeners	11.1%	1.9%	0.5%	1.2%	14.7%
Longitudinal bulkhead plate & stiffeners	8.4%	3.4%	0.3%	0.1%	12.2%
Inner bottom plate & stiffeners	5.8%	3%	0.1%	0.5%	9.4%
Bottom shell plate & stiffeners	3.4%	3.6%	0.3%	1.3%	8.6%
Vertical web plate in double side	1.6%				1.6%
Inner hull longitudinal bulkhead plate & stiffeners (including hopper)	0.5%	0.5%		0.1%	1.1%
Vertical web and face plate of longitudinal bulkhead	0.9%				0.9%
Vertical web and face plate of transverse bulkhead stringers	0.5%		0.2%		0.7%
Web and face plate of deck transverse	0.1%				0.1%
Floors	0.5%		0.2%		0.7%
Other	2.4%		0.5%		2.9%
Not stated	0.6%		0.5%	0.1%	1.2%
	67.4%	22%	6.4%	3.7%	~ 100%

Many of the cracks reported are in locations indicated as crack prone areas by the Tanker Structure Cooperative Forum in the TSCF DH Manual. As the development of the CSR has been done in an open environment with input from both the design yards and operators, the recommendations in the TSCF DH Manual have been considered. The design requirements for fatigue in CSR for the critical hopper corner joint, which received considerable attention at the last Shipbuilders meeting in Tokyo 2000, are more onerous than the pre-CSR requirements in the relevant classification society's rules. This, and the attention given in the development of the CSR to fatigue details for connection of longitudinal stiffeners to webs and bulkheads, addresses the findings of the in-service history of the double hull oil tankers in operation. The findings other than fatigue are due to either loss on material through corrosion, or contact damage. Having defined thickness when renewal is required will provide the operator and class advice from the start of operation on where action is required to maintain a suitable structure for successful operation of the double hull oil tankers of the future.

Table 7 Defect Type

Defect	Product	Panamax	Aframax	Suezmax	VLCC	Totals
Cracked	11.5%	3.6%	13%	27.6%	12.3%	67.9%
Wasted	11.3%	1.7%	3.5%	5.3%	0.6%	22.5%
Deformed	0.6%	0.2%	2.0%	1.5%	1.9%	6.2%
Not categorized	0.4%	0.5%	0.1%	0.7%	1.8%	3.4%

6 Damages Found for the Upper Deck Plate and Stiffeners

The data for the upper deck and stiffeners in Table 6 is noted to be greater than that for either the inner bottom or bottom shell plate and stiffeners. As a consequence there have been questions regarding the cause since the damage to upper deck and bottom should be closer than the ratio 6 (21.2%/3.4%~ 6) in Table 6 from the records sampled from the service history of double hull oil tankers. Discussion with those that assembled the data reveals many of the defects are in plating due to outfitting details and do not involve the end connections of longitudinal to either the web frame, or transverse bulkhead. As many of the defects reported for the upper deck plate and stiffeners are due to details, where outfitting has not provided appropriate supports for the above deck structure, or has selected poor details for construction, or has been located on soft plate. Thus this is an additional location where attention is required by the ship yard, owner and classification society not previously identified by the TSCF DH Manual. When the defects other than the end connections are eliminated, the defects for end connection of deck longitudinal are similar to that reported for the bottom longitudinal. The number of defects occurring in the longitudinal and stiffener connections located on the side shell, longitudinal inner skin, inner bottom and transverse bulkhead are found to be the highest. Thus fatigue assessment is required at these locations and the CSR directs the designer to focus attention on the end connection details.

7 Detail Design and Outfitting

The service history of existing double hull oil tankers has revealed the fact that outfitting details are not to be neglected. Since about 5 in 6 defects found in the upper deck plate and stiffeners were cracks due to outfitting, shipyards and others must consider developing the appropriate design standards to avoid such failures in the future double hull oil tanker. The outfitting details selected for design must eliminate structural hard spots, and consider the loads to be imposed by the connection at the deck.

Although the shipyards generally consider the support of structure above deck, the physical location may move during construction so even where proper back up structure has been designed it can actually be installed such that it is ineffective in eliminating hard spots in way of the above deck structure. Therefore, this should be checked and confirmed during construction. Another cause for defects found from outfitting is late receipt of design information from the different outfit staffs. The lesson for all is to verify that suitable structural details are in fact selected and properly installed.

8 Future Double Hull Oil Tanker Designs

The effort by the International Association of Classification Societies has documented that past designs of double hull tankers have had defects. These defects have mostly been in the hull structure in way of the cargo block of the vessel. The majority of these defects can be attributed to fatigue of details and these can be improved. The earlier work of the TSCF has also advised that these details would be a cause of defects if not adequately evaluated during design. The lessons to be applied for the next flight of double hull tankers designed and built to the IACS

CRS is to verify the details selected for the hull structure have suitable fatigue performance and that they are fabricated proficiently. The change in the CSR for fatigue has in fact increased the requirement compared with those in the prior rules of individual societies. Therefore, details in future double hull oil tankers should be more robust and result in improved service performance.

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