Service Experience Gas Carriers – Hull Structures

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Abstract

The world's gas carrier fleet has grown significantly over the last few years. In this growth, the industry has seen newcomers with respect to both newbuilding yards and operators. How will the change in the gas carrier fleet influence the frequency of hull findings on these vessels? What are the main challenges from a hull structural point of view on gas carriers? The paper addresses in-service experience of these vessels with respect to hull structure. Typical gas carrier specific defects reported in class surveys are discussed. Furthermore a comparison of the reported deficiencies in gas carriers compared to logged deficiencies in oil tankers is made.

1 Introduction

The main intention of the paper is to share experience on hull findings in gas carriers. The findings are primarily based on class surveys carried out in the period from 2005 to 2010. The assessment is limited to hull and cargo tank supports, but does not include the cargo tanks themselves. The damage statistics for gas carriers is also compared to finding frequency for oil tankers, also logged in the same time period.
The paper does not give a complete overview of all critical areas of design for gas carriers, and it has not been the intention to list all possible and found damages. Some of the typical damages for gas carriers' hull and supports are included. Some of the findings are presented as finding frequency. Here this is defined as number of findings per compartment per 1000 shipyears.

2 Trends in gas transportation at sea

he world fleet of gas carriers has grown significantly over the last ten years. The number of LNG carriers has increased from 120 to more than 350 since year 2000, whereas the number and also the transportation capacity of LPG carriers world wide has approximately doubled since 1990. With more gas being transported at sea, more ship builders and operators are involved in the gas carrier segment. Some of these players have recently entered the gas carriers' scene.

The size of LNG vessels has increased over the last few years. The standard sized LNG carrier has gone from 135k m3 in 1995 to around 170k m3 in 2010. Since 2007 also operation of the larger Qflex (~216k m3) and Qmax (~250k m3) vessels has commenced. Fig Increased size of LNG carriers

The trading pattern for LNG vessels is also changing. Previously the major routes were from Arabian Gulf to Korea and Japan. These trades are still prevailing but with an increased activity in the Atlantic, where the wave environment is more severe.

These trends may have an impact on the pattern of hull findings in LNG carriers in operation.

For the LPG segment the changes appear less dramatic. The number of vessels has increased steadily over the years noth in the large and smaller LPG segment. The trading pattern for these vessels is more or less as before.

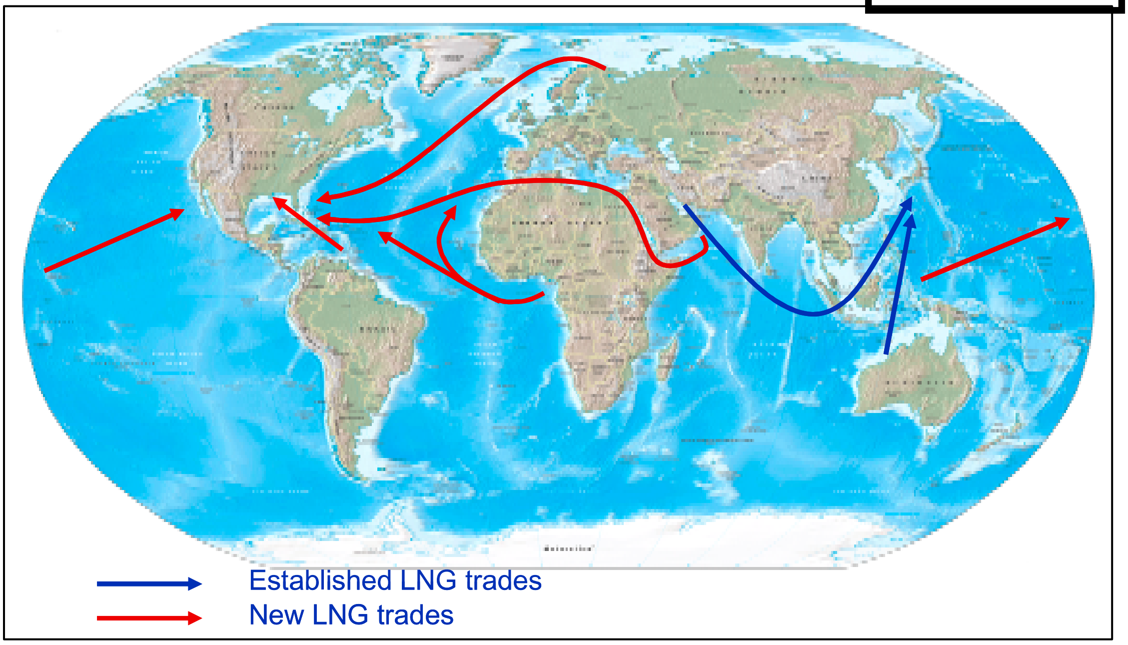

Fig 1 Changes in trading routes for LNG vessels

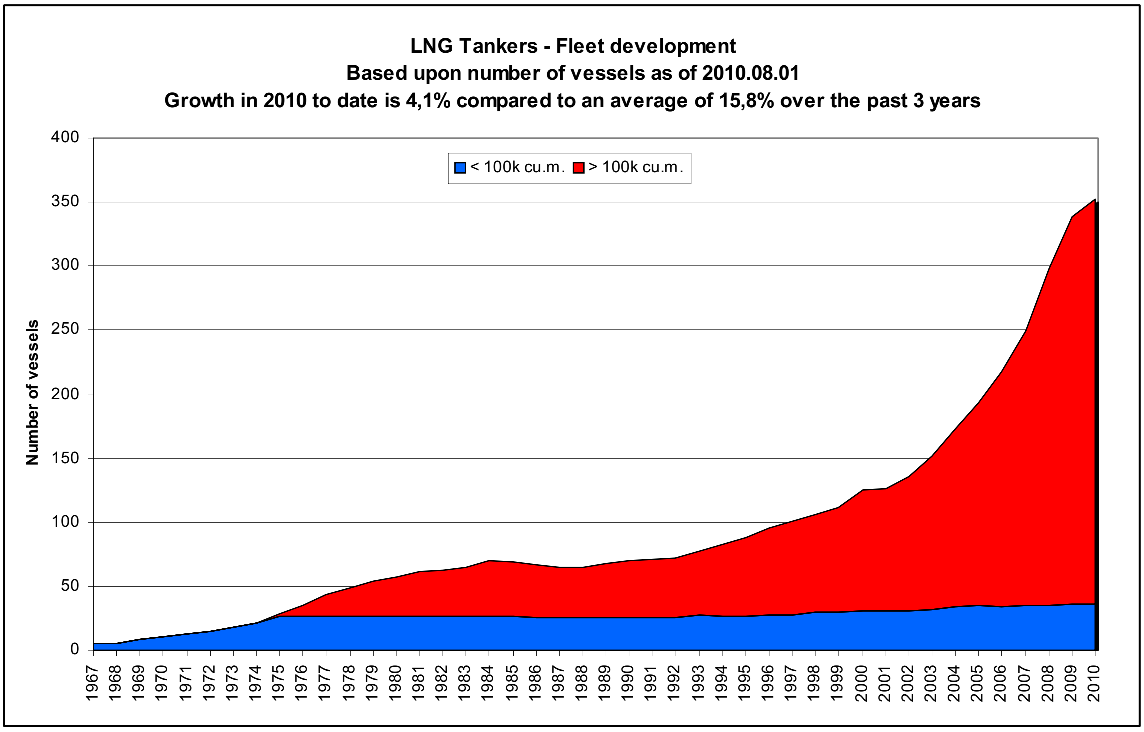

Fig 2 LNG Tankers – Fleet Development (Source HIS Fairplay)

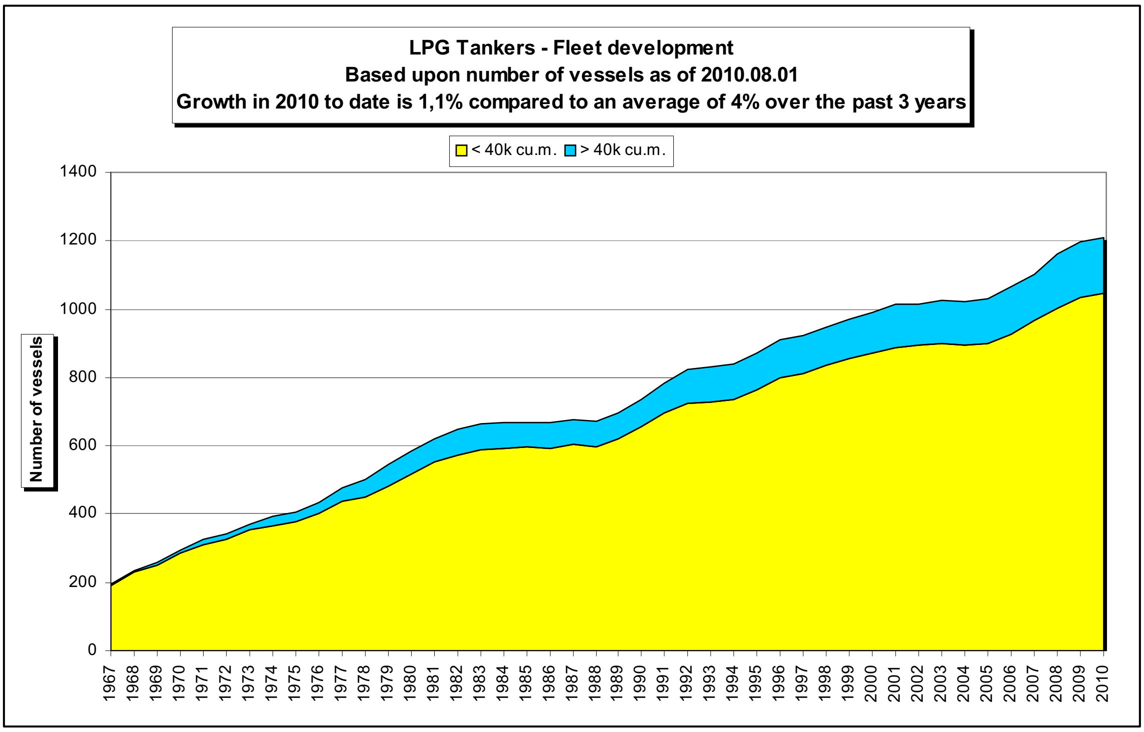

Fig 3 LPG Tankers Fleet Development (source IHS Fairplay)

3 Types of gas carriers

For the purpose of easy reference a short description of the main types of gas carriers on which the paper is based, is included. Findings related to the cargo containment system itself are not included in the study. However, in order to have an easy reference when looking at differences in various types of gas carrier ships, reference to the type of cargo containment has been done.

For LPG carriers we refer to two main categories of ships. The smaller gas carriers are equipped with pressure vessels for cargo containment designed for 3-18 bars, typically with a cargo capacity in the range of 8.000 to 22.000 m3 carrying cargoes like LNG, Ethylene, Propane, Butane, Ammonia and Propylene Oxide.

The larger LPG carriers are based on a design pressure of 0.25bars, have a minimum design temperature of -50degrees C, and hold a cargo capacity between 20.000m3 and 85.000m3. The most common cargoes carried in this shiptype are propane, butan and ammonia.

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For transportation of LNG the most frequently used cargo containment systems as per today are the spherical tank and the membrane tanks (NO and Mark systems). Also in operation for LNG transport is the IHI independent prismatic tank, but ships equipped with this cargo containment system will not be further addressed here, as no gas carriers with the prismatic B-tank concept are included in the selection of vessels analysed.

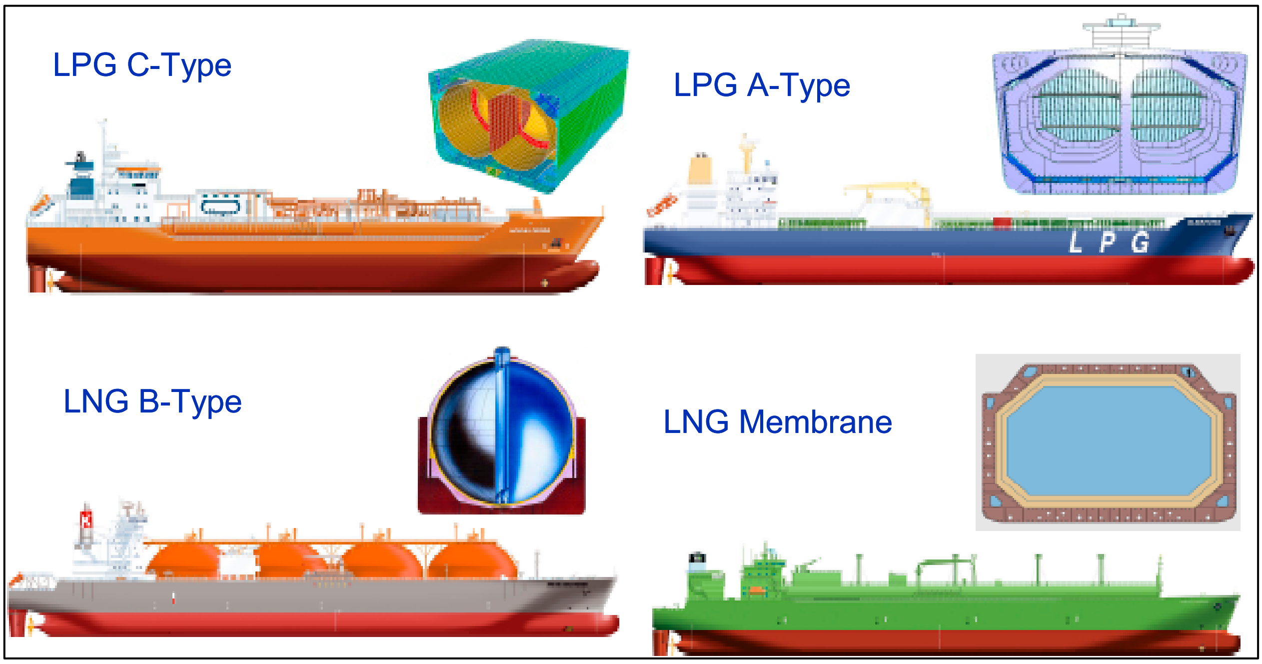

Fig 4 Gas carrier types studied

4 Hull Statistics

Basis for statistics

Findings from SiO class surveys have been organized and evaluated. Both LPG and LNG vessels are included. The statistics is based on surveys carried out in the period from 2005 to 2010,hence the results are fairly dependent on the number of vessels available for each category of ships assessed. The number of vessels included in the basis for statistics is larger for LPG carriers than for LNG carriers and the age distribution and hence the numbers on the LPG carriers gives a better basis for an evaluation. The LNG carriers included are both B-type (spherical tanks) LNG carriers and Membrane carriers, however, many of the spherical type vessels assessed are older vessels, more than 20 years (some also more than 30 years old) whereas the membrane carriers analysed are mostly younger vessels, less than 10 years old. Because of this difference the damage statistics for these two vessel types are not comparable, but may be used as basis for identifying some of the typical damages for these vessels.

Furthermore, the findings for the gas carriers are compared to tankers. The number of ships and surveys for the tankers is significantly higher than that of the gas carriers. This should be taken into account when comparing the damage statistics for the vessel types.

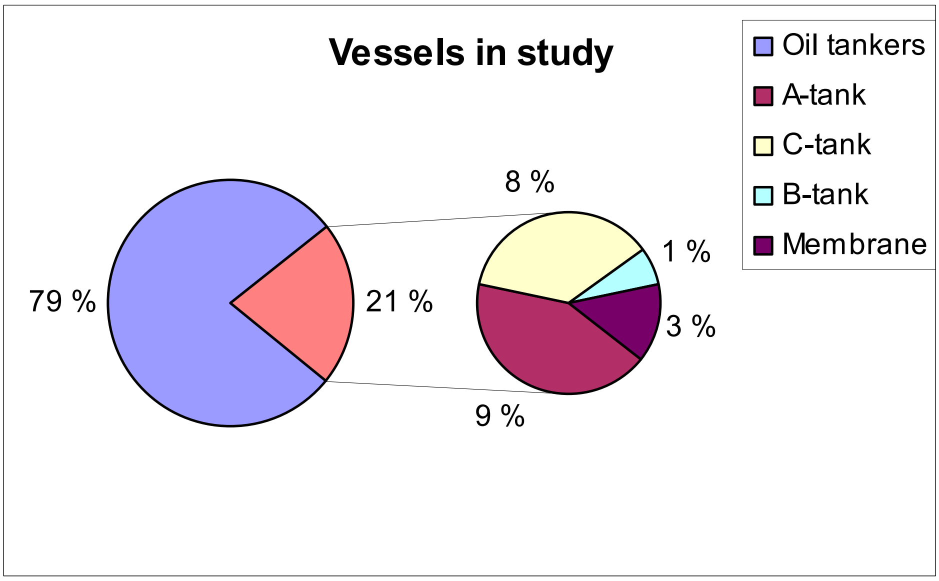

Fig 5 Distribution of vessels assessed

Findings per age group

In Table 1 the distribution of the age of the compartments analysed is shown. Table 2 gives an overview of the distribution of hull findings per age group for each ship type assessed.

Table 1 Distribution of age of compartments assessed per ship type

Age Group (Years)	Tank Type A (%)	Tank Type B (%)	Tank Type C (%)	Tank Type Membrane (%)	Oil Tankers (%)
0-4	39	11	49	79	31
5-9	13	0	8	19	22
10-15	4	6	10	2	14
15-19	13	22	8	0	14
20-24	3	0	5	0	8
>24	29	61	20	0	11
Grand Total	100	100	100	100	100

Table 2 Distribution of number of hull findings per age group per ship type

Age Group (Years)	Tank Type A (%)	Tank Type B (%)	Tank Type C (%)	Tank Type Membrane (%)	Oil Tankers (%)
0-4	0	0	0	17	1
5-9	2	0	0	83	3
10-15	0	2	9	0	13
15-19	23	20	22	0	48
20-24	9	0	14	0	23
>24	65	78	55	0	13
Grand Total	100	100	100	100	100

Finding frequency per ship type incl tankers

The frequency of findings for gas carriers is less than for oil tankers.

Corrosion and cracks are the most frequently reported damages for both oil tankers and gas carriers. The frequency of cracks is approximately at the same level for oil tankers and gas carriers. Corrosion is occurring more frequently in oil tankers than in gas carriers. The reported number of cracks is at the same level in LPG vessels of tank type A and C. For the LNG vessels the age distribution of the vessel types included is so different that a comparison is not relevant.

Table 3 No of findings per ship type

Ship type	No of findings	No of compartments	Frequency
Gas carriers	1796	8366	42,9
Tanker for Oil	11375	26468	86,0

Table 4 Reported damages in Tankers vs Gas carriers 2005-2010

	Tanker for oil			Gas Carrier		
Finding category	No of findings	No of compartments	Frequency	No of findings	No of compartments	Frequency
Buckling	104	26462	0,8	3	8366	0,1
Corroded	6173	26462	46,7	926	8366	22,1
Crack	3104	26462	23,5	540	8366	12,9
Deformation	1108	26462	8,4	155	8366	3,7
Pitting	461	26462	3,5	40	8366	1,0

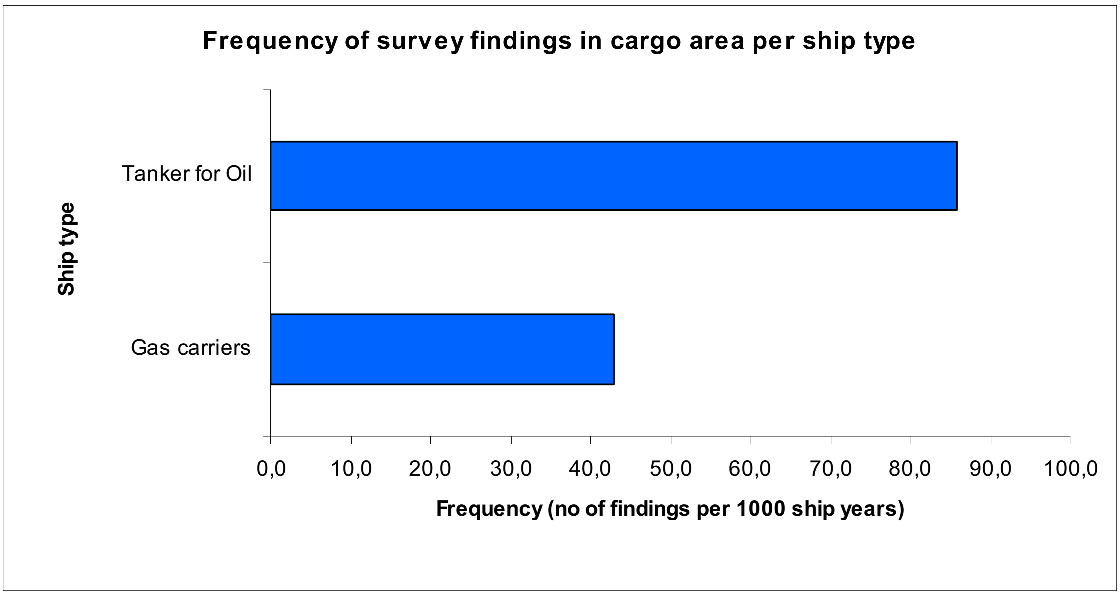

Fig 6 Frequency of survey findings in cargo area

Findings pr compartment type

The reported damages in ballast tanks are more frequent in oil tankers than in gas carriers. The damage frequency for oil tankers is almost twice that of gas carriers. In gas carriers the pattern of the findings in the ballast tanks show same trend as that of the oil tankers;

The compartments with the most frequent findings are top wing tanks, hopper tanks and side tanks, where as the number of findings in the double bottom tanks is significantly lower.
For cargo tanks the frequency of findings is low for gas carriers, only a fraction of that of oil tankers.
As many of the gas carriers in the study are vessels with independent cargo tanks, the frequency of findings in voids are more significant than that of oil tankers.

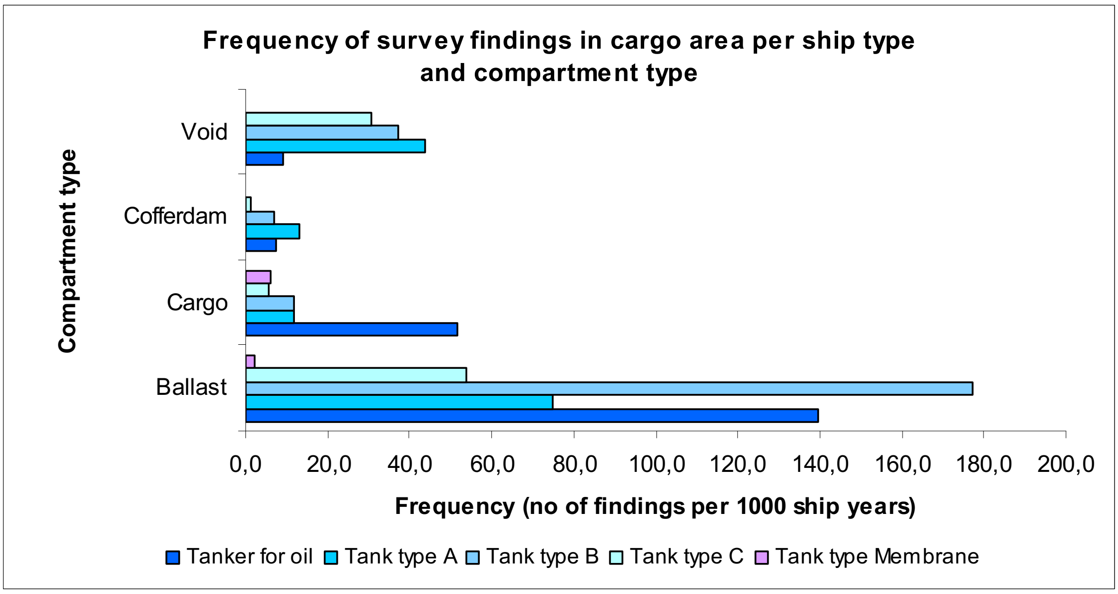

Fig 7 Frequency of findings in cargo area per shiptype and compartment type

Based on the data assessed, it appears that for some gas carriers (tank type A) cracks are as normal findings as corrosion. For tankers the number of findings related to corrosion is more than twice that of cracks. This trend is the same for most gas carrier types. The finding frequency related to corrosion for the B-tank type vessels appears high. It should be noted however that a significant contribution comes from vessels more than 30 years old. With the relatively smaller number of vessels analysed, the impact on the statistics from a few vessels is significant, compared to similar effects on the group of tankers, A-tank vessels and C-tank vessels, where the data base is larger.

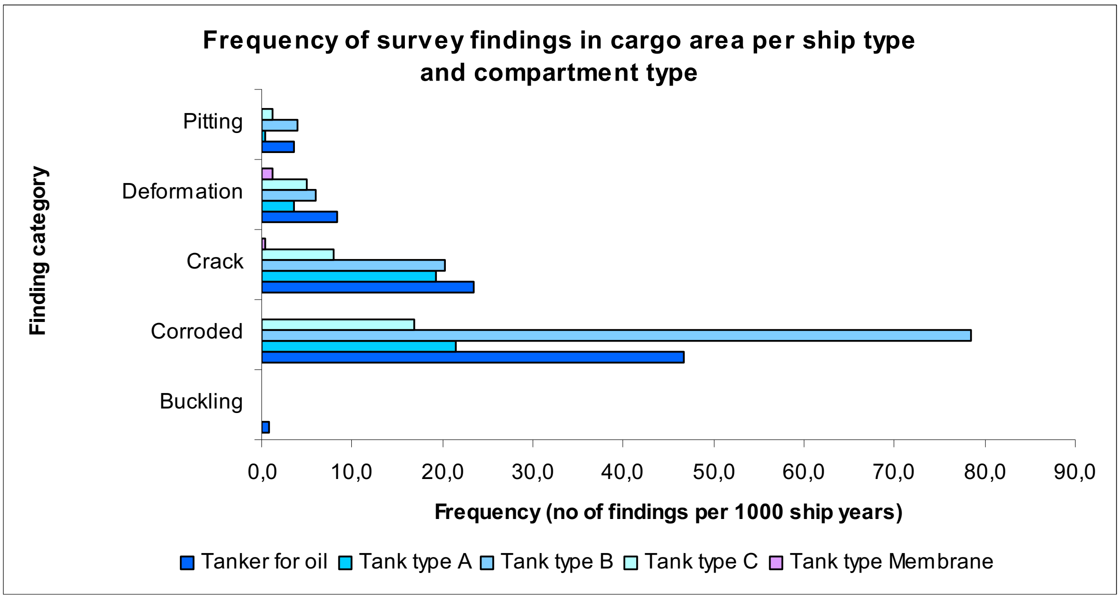

Fig 8 Frequency of findings in cargo area per ship type and damage category

5 Typical hull damages

In this section a set of typically reported damages are described. As the selection is made to be gas carrier specific, the most frequent hull related findings may not necessarily be included in the examples. Focus has been addressing the typical findings of the gas carrier, other than that of the typical tanker. Examples of corrosion in topwing tanks, side tanks etc are not included here, as these findings are not considered special for gas carriers, compared to oil tankers. Such damages will however be found also in gas carriers.

5.1 LPG vessels

5.1.1 LPG Hull Findings, vessels with Tank type A

Crack in side frame web at connection to lower/upper bracket

A typical finding on LPG carriers of type A, is cracking in vertical side frame at the connection to lower and upper bracket. Cracks are observed at both upper and lower end of the bracket.

The dynamic loads from the sea are taken up by the side plates supported by the vertical side frames and load is transferred to the upper and lower brackets. This gives peak of bending moment and shear in way of the lower bracket connection. At the lower termination of the bracket the sniped termination of bracket flange creates a local tress concentration, which may lead to developing cracks from the toe of the bracket. At the connection between the lower bracket and side frame high bending stresses in the flange and stress concentration due to weld increase the rsik of fatigue cracks.

As the cracks develop, the lower end fixation of the side frame is reduced, causing higher bending moments at the middle of the frame. Some of the load will then be carried by the adjacent frames. If the crack has gone through the stiffener the beam will be simply supported at the lower end and the profile may buckle at mid field.

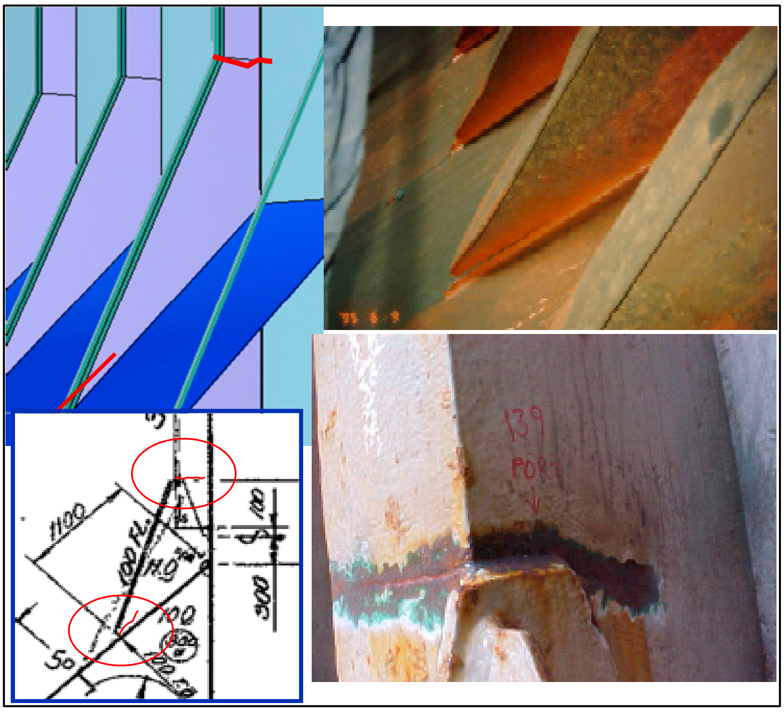

Fig 9 Cracks at side frame web connection to bracket

Cracks in way of stoppers at deck level

Cracks have been reported in connection with anti rolling supports at deck level. These cracks normally propagate from brackets connected to the top of the tank or deck. In addition to design pre-cautions taking into account the large effect of temperature on the tank side, alignment and gap control are significant issues under fabrication to avoid such cracks.

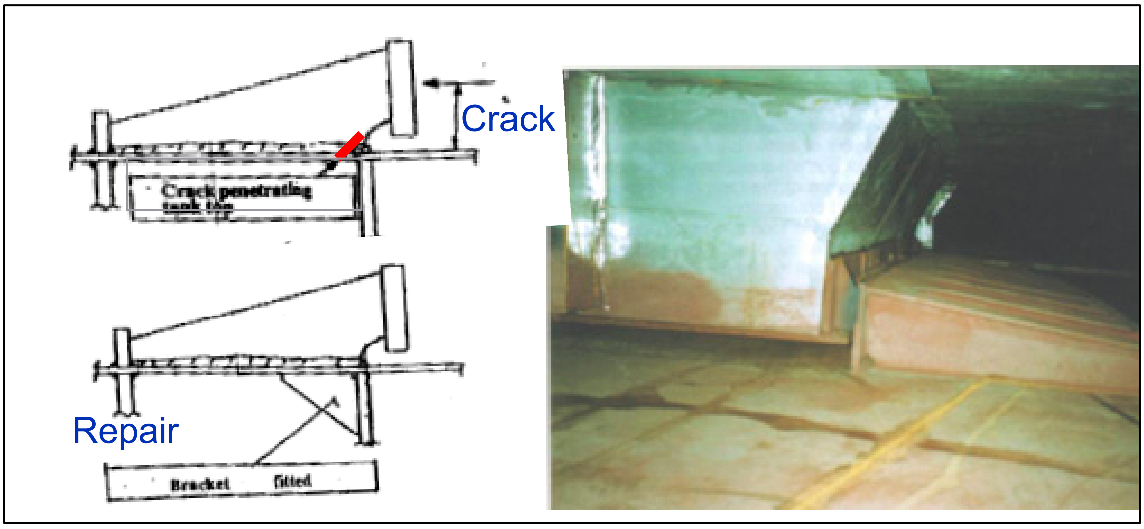

Fig 10 Cracks in anti rolling supports

Cracks in deck plate at openings of domes/deckhouse

Cracks are reported in deck plates in way of opening of domes and deckhouses, deck attachments and deck piping penetrations. In particular it should be noted the occurrence of cracks in way of gas dome and liquid dome.

Other typical damages reported in gas carriers of tank type A are cracks in hopper area/ hopper knuckle, cracks in longitudinal connection at Transverse Bhd, In double bottom the most frequent damages are corrosion of floors and girders in ballast tanks. Repeated findings are also cracks at vertical beams supporting transverse bulkheads.
In some vessels cracks in way of vertical supports at inner bottom is reported.

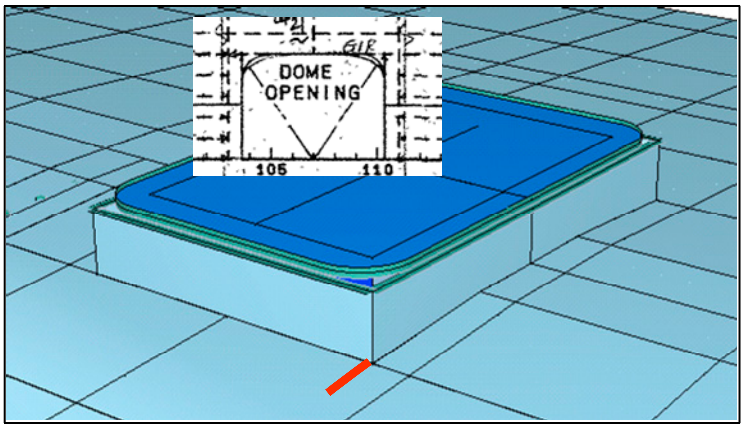

Fig 11 Crack in deck plate at dome opening

5.1.2 LPG Hull Findings, vessels with tank type C

Crack in Side frame lower brackets

As for the A-tank design, the connection between side frames and innerbottom is considered critical. Cracks are found in these connections.

Fig 12 Connection between side frame and inner bottom.

Corrosion inner bottom

For C-tank hold spaces, there is no requirement to inerted atmosphere, but the air in the space to be dry. A number of vessels are reported with corrosion at bottom of hold space and at connection between side frames and bottom, following lack of proper control of the atmosphere in the hold space.

Foundations

Lack of moisture control in the hold space has also caused problems with the isolating wood between cargo tank and cargo tank support. In loaded/cold condition ice may accumulate on the supports. For some designs using non-impraegnated wood in the support saddle, the wood may swell and get distorted.

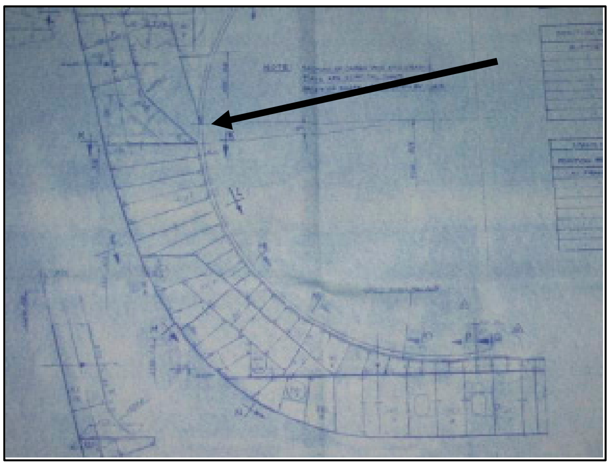

Fig 13 Location of swelled wood

Fig 14 Damaged wood

5.2 LNG Vessels

5.2.1 LNG Hull findings, vessels with tank type B

Deck connections in way of cargo tank covers

For an LNG carrier of spherical type a re-occuring finding is cracking of the connection between cargo tank cover and deck. The crack along the deck is loosening up the tank dome connection. If these cracks penetrate to deck it could become a longitudinal strength issue.

Fig 15 Cracks in deck connection in way of cargo tank covers

Delamination in structural transition joint between tank and foundation/skirt

At the skirt intersection between cargo tank aluminium and the steel for the hull structure delamination has been reported in some vessels.

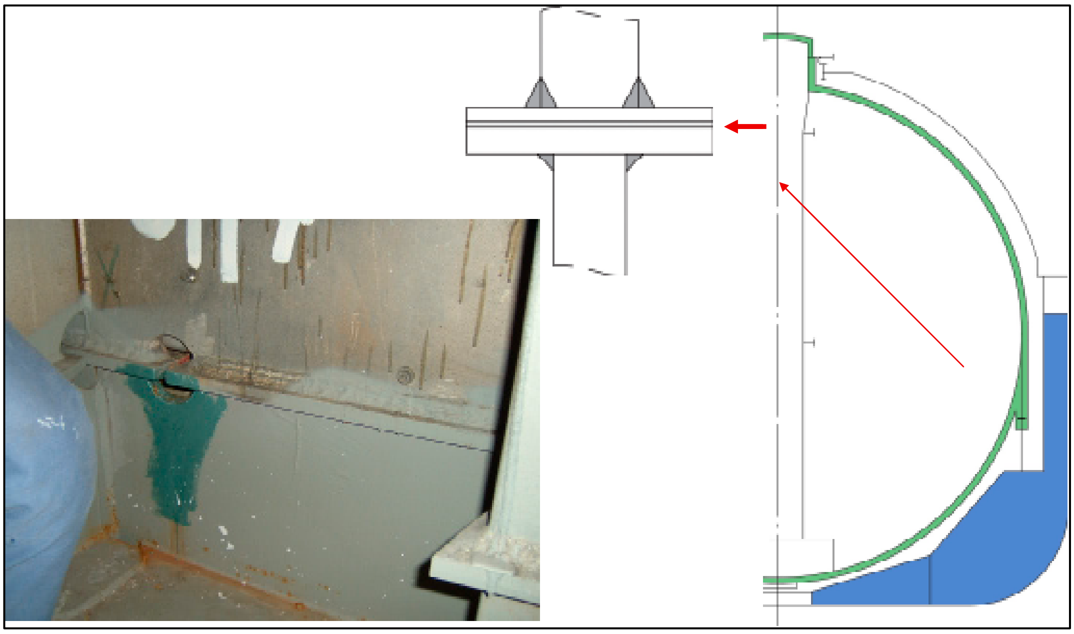

Fig 16 Structural transition joint

Crack in deck underneath drip tray

Damages to drip trays may lead to spilling of LNG onto the deck plate. The deck, not being designed for low-temperature application, will in such cases experience severe brittle fracture. This a critical situation for the longitudinal strength of the vessel.

Corrosion in cross tanks

A characteristic damage to the transverse bulkhead is corrosion in way of the cross tank. Corrosion in lower stool tank and in the diaphragm in particular will give increase shear stress level and possible development of shear buckling or cracks. In case of excessive corrosion, the buckling strength may be reduced and the support of the cargo tanks may be weakened.

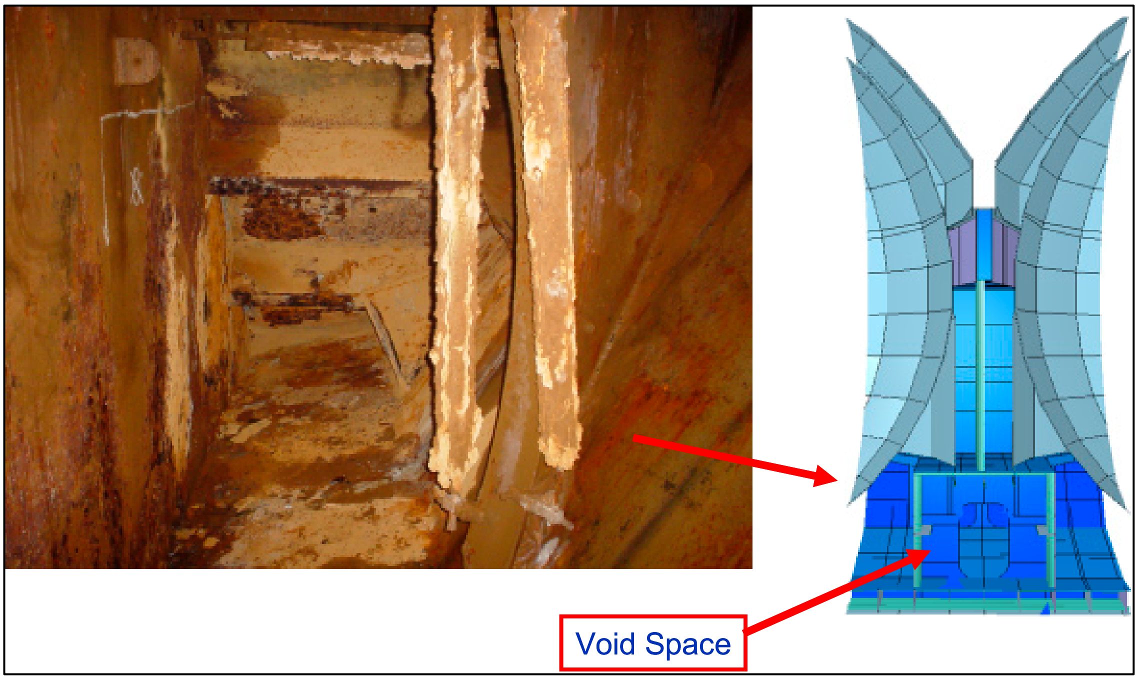

Fig 17 Corrosion in cross tanks

5.2.2 LNG Hull findings, vessels with tank type membrane

Most of the findings for this ship type are considered general hull findings, not particular or special for the shiptype. The findings include cracks, deformation and corrosion. Excluding findings related to the cargo containment system, no details on findings on membrane carriers will be elaborated further in this paper.

An additional challenge on the membrane carriers is the fact that the cargo containment system is directly adjacent to the hull inner structure, meaning that any repair in the hull structure may influence on the cargo containment system. For this reason the focus on fatigue is important. Ingress of water from the ballast tanks in the double hull to the barrier spaces in the membrane will be critical and may lead to lengthy and costly lay-offs.

6 Conclusion

The assessment shows that the frequency of hull findings on gas carriers are in general lower than on oil tankers. Distribution of findings has a slightly different trend on gas carriers than on oil tankers, where for some carriers cracks are, relative to findings on corrosion, closer in frequency to that of oil tankers.

For gas carriers, with a significant presence of ships with independent tanks, many of the many findings are related to the tanks supports and the void spaces in which the tanks are located, in addition to the more traditional tanker findings in the ballast tanks.

For LNG carriers the trends in the world wide operation of the vessels may lead to changes in the damage observed in inspections.