SIMPLIFIED PROCEDURES FOR FATIGUE ASSESSEMENT OF SHIP STRUCTURES

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ABSTRACT

Comparison of simplified procedures for fatigue assessment of ship structural details, used by classification societies, is presented. The basics of typical fatigue design approaches are described. In order to illustrate the capabilities and differences of the procedures, comparative study is performed on a bulk carrier built in Croatian shipyard in Split. Fatigue damage is calculated for a few longitudinals in connection with transverse structural elements. Longitudinals are located in the hopper tank, topside tank and double bottom of the bulk carrier. Fatigue damage of critical details is calculated applying current rules and guidelines of the classification societies Bureau Veritas, Germanischer Lloyd and Lloyd's Register of Shipping. The effect of a few input parameters on fatigue life is studied in a parameter variation including the shape parameter of the Weibull long-term stress distribution, structural misalignment and the effect of corrosion.

INTRODUCTION

Over the last decade more than one hundred bulk carriers have been lost, resulting in over 650 deaths. It was concluded that these disasters were caused in all probability mainly by cracking of the side structures (IMO Report, 1995.). A number of structural damages were also experienced, not only on bulk carriers, but also on other types of vessels; particularly VLCCs (Committee III.2, 1997.). Fatigue is recognized as important contributor to these damages. Structural failures may also result from other causes than fatigue (groundings, collisions, etc.) but the majority of structural damages are cracks. Even if the fatigue cracking does not lead to complete failure, the cost of inspections and repairs and the consequences of environmental pollution can be high. Thus, fatigue cracking should, if possible, be avoided or kept at an acceptable level.

Dynamic stress variations experienced during the service period of a ship can initiate fatigue cracks in details which are inadequately designed, constructed or maintained. Subsequent crack propagation may cause failure of primary structural members. It is important to emphasize that fatigue initiation is a localised phenomenon which strongly depends on the structural geometry and stress concentrations. In welded structures, such as ships, cracks are known to initiate at stress concentrations caused by flaws from welding procedures and at cut-outs and plate joints where abrupt geometrical transitions cause a local rise in stress intensity.

The problems related to fatigue cracks have been known for a long time in aged ship structures. However, over the last several years some new facts have emerged – in a number of cases fatigue cracks were discovered on relatively new ships (3 to 4 years old) with highly optimised higher tensile steel structure and without any significant corrosion or wastage (IACS Report, 1997.). This has led the shipping industry to reconsider its attitude towards the fatigue of structural details.

Since the most efficient method for prevention of fatigue cracks is an appropriate design of ship structural details in areas exposed to cyclic loads, it has become essential to give more detailed considerations to the fatigue performance through the application of the fatigue design assessment procedure. Such a procedure should be a practical tool to engineers in the initial design stage (or in the repair process) for evaluation of the fatigue strength of ship structural details. The aim of such a procedure is to ensure that the structure has an adequate fatigue life.

The most of the classification societies have their own comprehensive procedures for assessing fatigue strength of ship structures. During past several years the International Associations of Classification Societies (IACS) made attempts to harmonise these procedures and to develop a unified procedure that would be the guidance for engineers in a ship design process for assessment of the fatigue damage of ship structural details and welded connections. Some progress has been made, but the important issues, such as determination of fatigue loads, selection of stress approach, selection of the S-N curves and correction factors are still left to the discretion of each classification society.

Recently all these procedures have been revised and updated. This paper outlines and summarizes present simplified procedures for calculation of the fatigue damage used by classification societies. The comparison of different approaches as well as the sensitivity of fatigue damage to input parameters is illustrated with examples.

SIMPLIFIED FATIGUE ASSESSMENT PROCEDURE

The basics of the simplified procedure for fatigue assessment of ship structural details will be described. The term 'simplified' stands due to approximation of the long-term distribution of stress ranges with the Weibull two-parameter distribution. This type of fatigue assessment procedure is also referred to as 'deterministic' due to analysis of a large number of specified (deterministic) load cases.

Although simplified procedures for fatigue assessment differ among classification societies they all include four main steps:

- Determination of the fatigue loads
- Calculation of the long-term distribution of stress range
- Determination of the fatigue capacity of structure
- Assessment of the fatigue damage

Determination of Loads

Ship structures are subjected to various types of loads, but in the present procedures only static and wave induced loads are considered to determine the fatigue strength. Static loads include hydrostatic pressure and still water bending moment. Wave induced loads take into account hull girder wave bending moments and forces (global loads) and external hydrodynamic pressures and internal inertia and fluctuating loads resulting from ship motions (local loads). Loads are calculated according to each classification society criteria. The various load components may be combined with different phase angles for different parts of the ship structure, thus providing the most probable extreme stress range. It is recommended that individual load components be determined with respect to a moderate exceeding probability level, e.g. probability level 10^{-3} to 10^{-5} (IACS,1999.).

Fatigue analyses are to be carried out for the representative loading conditions according to the intended operation of the ship. An ocean-going cargo vessel will always operate under at least two different loading conditions, namely a full load and a ballast condition. Often some partial loading conditions should be considered as well. It is necessary that the long-term distribution of stresses is evaluated with due consideration to different loading conditions, and to the time spent in each loading condition.

The fatigue design loads are the most important and also the most difficult to unify. A number of studies were performed by IACS members in order to develop a unified requirement for fatigue design loads, but no conclusion has been made in this regard.

Calculation of the Long-term Distribution of Stress Range

In order to assess the fatigue strength of a ship structure, the long-term stress distribution of the structure is required. Studies of wave loading acting on ships have shown that the long-term distribution of stress range may be represented by a two parameter Weibull distribution:

$$F(S) = 1 - e^{-(S/k)^{\xi}} \tag{1}$$

where k, ξ are the scale and shape parameters respectively.

Defining S_R as the maximum stress range response induced by waves out of N_R cycles, i.e. S_R has a probability of $1/N_R$ being exceeded; the scale parameter can be obtained from:

$$k = \frac{S_R}{(\ln N_R)^{1/\xi}} \tag{2}$$

The stress ranges have to be calculated for one probability of exceedance only.

The effect of the Weibull shape parameter ξ on fatigue damage estimation is significant. The value can only be reliably determined through a spectral fatigue analysis or measurements. The value of parameter ξ varies among different procedures between 0,7 and 1,3 (IACS, 1997.). As a first approximation ξ may be taken as:

$$\xi = 1{,}1 - 0{,}35\frac{L-100}{300} \tag{3}$$

where L is the ship length in meters.

Depending on the kind of stresses used in the calculation, the procedures for fatigue assessment of structural components may be classified into following groups:

- nominal stress approach,
- hot-spot stress approach,
- notch stress approach

These approaches employed for fatigue damage assessment are strongly related to the stress state at the crack tip. The type of stress used for the estimation depends on the problem to be solved and the desired level of accuracy.

The nominal stress σ_n is defined as the stress which can be derived form beam theory or from coarse mesh FEM models based on the applied loads and dimensions of the component. Increase in stresses due to discontinuities in structural geometry and presence of welds is disregarded when calculating nominal stresses. The hot-spot stress σ_{hs} is defined as the local stress at the critical point (hot spot) in structural detail where a fatigue crack may be initiated. In this case increase of stress due to change in the component geometry is taken into account, but the effects from the presence of welds are excluded. The notch stress σ_p is defined as the locally increased stress (peak stress) in a notch, e.g. at a weld toe or at the edge of a cut-out. Notch stress approach is taking into account stress concentrations due to the presence of welds. The three types of stresses are illustrated in Fig.1.

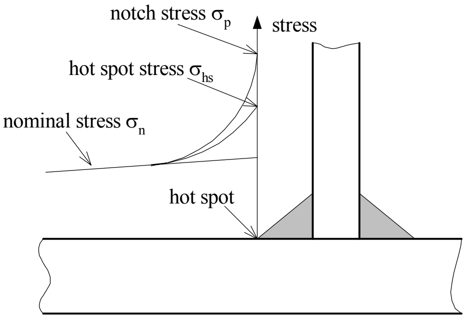

Figure 1: Types of stresses

A connection between different types of stresses may be established through the stress concentration factors (SCF).

$$\sigma_{hs} = K_g \cdot \sigma_n \tag{4}$$

$$\sigma_p = K_g \cdot K_w \cdot \sigma_n \tag{5}$$

where K_g is stress concentration factor due to the geometrical configuration of the connection, and K_w is stress concentration factor which includes effects associated to the weld geometry. The geometric stress concentration factor K_g can be calculated by the finite element method and the values for typical ship details can be found in fatigue guide books. K_w can be calculated by parametric formulas based on the results of finite element analyses and experiments. It is important to use appropriate stresses in the fatigue assessment, since the fatigue life is effectively a function of stress raised to the power more than 3.

Determination of the Fatigue Capacity of a Structure

The fatigue capacity of a welded joint subjected to constant amplitude uniaxial loading is expressed in terms of an S-N curve. S-N curve gives the relationship between the nominal stress ranges S applied to a given sample and the number of load cycles N to failure:

$$S^m \cdot N = C \tag{6}$$

where m and C are constants depending on material and weld type, type of loading, geometrical configuration and environmental conditions.

S-N curves are determined experimentally, and they are defined by their mean fatigue life and standard deviation. The mean S-N curve means that for a stress level S the structural detail will fail with a probability level of 50% after N loading cycles. S-N curves considered in the present procedures represent two standard deviations below the mean lines, which corresponds to a survival probability of 97,5%.

IACS recommends two sets of S-N curves to be used for assessment of the fatigue strength of structural details:

- HSE (Health and Safety Executive) Basic S-N Curves
- IIW (The International Institute of Welding) S-N Curves

HSE set has eight curves, each changes slope at 10^7 cycles and each curve represents a class of welded details. The IIW has established 14 curves for various welded structural details. Slope change for each IIW curve is at $N = 5 \cdot 10^6$. Both sets of curves are well known and described in details (IACS, 1999.).

In the fatigue assessment procedure the appropriate S-N curve must be selected according to the stress approach applied. Traditionally fatigue calculations were based on the nominal stresses and the use of geometry dependent S-N curves. If for a particular detail the S-N curve is specifically tested, then the nominal stress approach can be quite accurate. Unfortunately a large number of ship structural details are different from the details the traditional S-N curves have been derived for. Thus, how to choose appropriate S-N curve can be quite a difficult task when using nominal stress approach.

The hot-spot stress approach significantly reduces the number of S-N curves required. One curve is required for each weld method or type. The stress concentration due to structural geometry is taken into account in the calculation which, while the stress concentration arising from welds is taken into account in the S-N curves. In this approach the finite element mesh has to be fine enough to represent the geometric stress in the region, because the hot-spot stress has to be determined by extrapolation of stresses outside the notch region.

In the notch stress approach only one S-N curve is required for all details. In this case stress concentrations due to structural geometry and weld are considered in the stress calculation. Disadvantage of this approach is that it may be difficult to describe the geometry of the local notch at a weld.

The S-N curves are generally determined in laboratories, which necessitates some modifications to basic S-N curves, keeping in mind that these curves will be used to assess the fatigue strength of actual structures. A number of factors should be considered:

- Corrosion
- Plate thickness
- Weld improvement
- Residual stresses
- Mean stresses
- Workmanship

These adjustments are left at the discretion of each Society.

Assessment of the Fatigue Damage

In order to calculate the fatigue damage, the Palmgren-Miner rule of damage accumulation is adopted by all classification societies. It states that the total fatigue damage experienced by the structure may be expressed by the accumulated damage from individual load cycles at different stress levels. The fluctuating stresses can be divided into k steps of constant stress and equivalent length. Each step is considered independently and the cumulative damage D is given by:

$$D = \sum_{i=1}^{k} \frac{n_i}{N_i} \tag{7}$$

where n_i is the number of cycles of stress range ΔS_i and N_i is the number of cycles to failure at constant stress range ΔS_i.

Based on Palmgren-Miner's approach and assuming the Weibull long-term distribution of stress range and a two-slope S-N curve, the cumulative damage D_i for i-th loading condition can be expressed as:

$$D_i = \frac{\alpha_i N_L}{C} \cdot \frac{S_{Ri}^m}{\left(\ln N_R\right)^{m/\xi}} \mu_i \, \Gamma\left(1 + \frac{m}{\xi}\right) \tag{8}$$

where:

α = factor taking into account time needed for loading/unloading operations, repairs, etc.

N_L = total number of cycles in life time

$$\mu = \frac{1 - \gamma\left(1 + \frac{m}{\xi}, \nu\right) - \nu^{-\Delta m/\xi} \, \gamma\left(1 + \frac{m + \Delta m}{\xi}, \nu\right)}{\Gamma\left(1 + \frac{m}{\xi}\right)}$$

$$\nu = \left(S_q / S_R\right)^{\xi} \ln\left(N_R\right)$$

S_q = stress range at the intersection of two segments of the S-N curve

Δm = slope change of the upper to lower segment of the S-N curve

$\gamma(a, x)$ = incomplete gamma function, Legendre form

$\Gamma(a)$ = Gamma function

Considering two loading conditions, the full load and ballast condition, total fatigue damage is calculated as sum of the damages for each loading condition:

$$D = D_1 + D_2 \tag{9}$$

where:

D_1 = cumulative fatigue damage for the full load condition

D_2 = cumulative fatigue damage for the ballast condition

Table I gives a short summary of simplified fatigue assessment procedures of several IACS members. Some similarities in approaches exist but the variety of combinations of the key issues is very clear. Therefore, numerical example is presented in order to see, concretely, what the difference is in calculated fatigue damage and predicted fatigue life of ship structural details.

Table I: A Summary of Simplified Fatigue Assessment Procedures Used by Classification Societies

Class. Society	Loads probability	Stress approach	S-N curves	Special considerations
ABS	$2\cdot10^{-8}$	nominal, hot-spot	HSE	Corrosion, thickness
BV	10^{-5}	notch	HSE	Mean and residual stresses, corrosion, thickness above 16mm
CCS	n/a	hot spot	HSE	Mean stress, corrosion
CRS	10^{-6}	nominal, hot-spot	IIW	Mean stress, corrosion, thickness
DNV	10^{-4}	notch	Modified HSE^3	Mean stress, corrosion, thickness above 22mm
GL	10^{-6}	nominal, hot-spot	IIW	Mean stress, corrosion and thickness
LR^1	n/a	hot-spot^2	Modified HSE^5	Corrosion, thickness above 22 mm
NK	10^{-4}	nominal, hot-spot	BS^4	Mean stress, corrosion included in the S-N curves
RINA	10^{-8}	nominal, hot-spot	IIW	Mean stress
KR	10^{-4}	hot-spot	HSE	Mean stress, corrosion, thickness above 22mm
RS	10^{-3}	nominal, hot-spot	n/a	Mean stress, corrosion

ABS=American Bureau of Shipping, BV=Bureau Veritas, CCS=China Classification Society, CRS=Croatian Register of Shipping, DNV=Det Norske Veritas, GL=Germanischer Lloyd, LR=Lloyd's Register of Shipping, NK=Nippon Kaiji Kyokai, RINA=Registro Italiano Navale, KR=Korean Register, RS=Russian Maritime Register of Shipping

1 – The procedure is available through the use of the ShipRight program
2 – The weld notch parameters are embedded in the S-N curve
3 – Modified C curve
4 – BS refers to British Standard 5400
5 – Between C and D curve

NUMERICAL EXAMPLE

In order to compare different approaches for fatigue assessment a bulk carrier was analyzed. The ship was built in a Croatian shipyard in Split. The main particulars of the analyzed vessel are given in Table II.

Typical connections of longitudinals to transverse structural elements were selected for the purpose of the comparative study. This was done according to statistical data showing that more than 40% of registered fatigue cracks in ship structures occur in those positions. (Hansen P.F. and Winterstein S.R.,1995., Committee III.2, 1997.). Selected connections are located in the hopper tank Fig.3, topside tank Fig.4, and in the double bottom Fig.5, at the midship section of the bulk carrier. The midship section along with the positions of investigated details is given in Fig.2. The midship section properties are given in Table III.

Table II: Vessel Main Particulars

Length overall	187,60 m
Length between perpendiculars	179,37 m
Rule length	177,95 m
Breadth moulded	30,80 m
Depth moulded	15,45 m
Draught moulded	10,10 m
Block coefficient	0,823
Maximum service speed	14,5 kn
Frame spacing	0,8 m
Floor spacing	2,4 m

Table III: Midship Section Properties

Moment of inertia I_{zz}	383,364 m^4
Moment of inertia I_{yy}	126,904 m^4
Height of neutral axis above base line	7,177 m

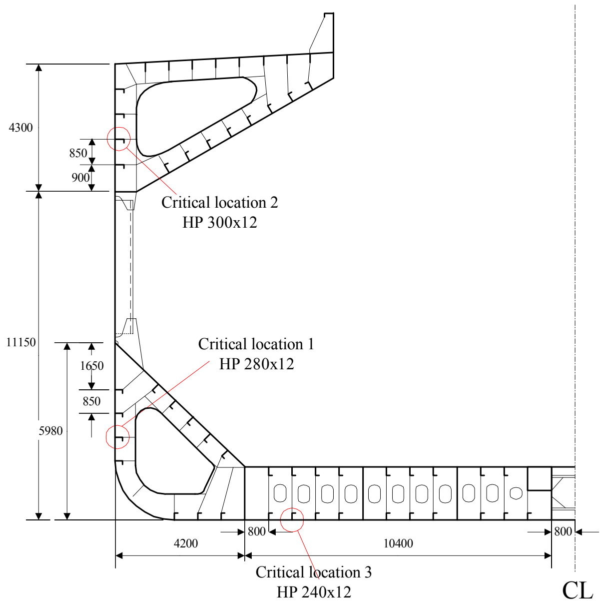

Figure 2: Midship section of the bulk carrier

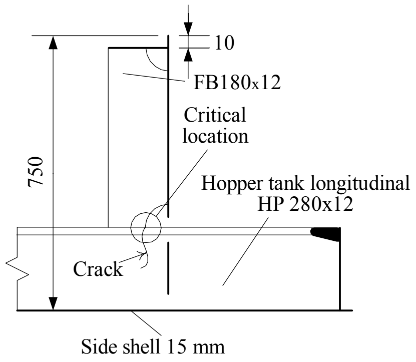

Figure 3: Detail in the hopper tank

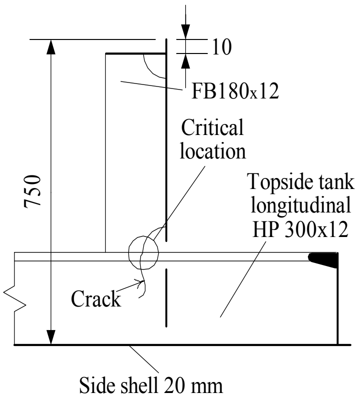

Figure 4: Detail in the topside tank

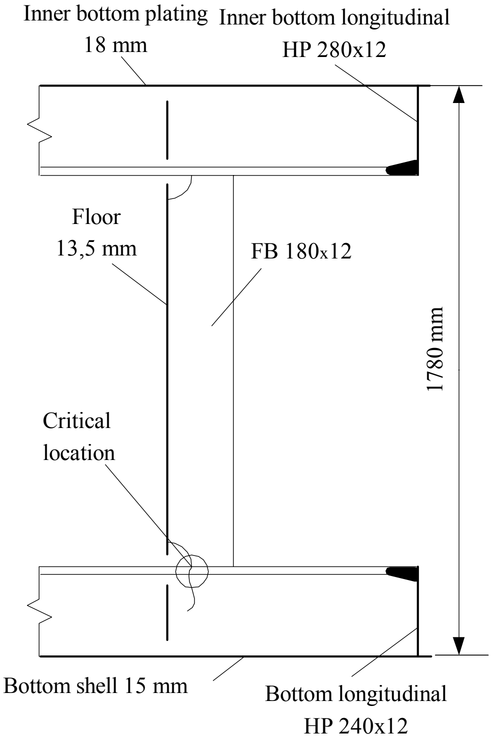

Figure 5: Detail in the double bottom

Three procedures were selected for the comparison:

- The Bureau Veritas (BV) procedure
- The Germanischer Lloyd (GL) procedure
- The Lloyd's Register (LR) procedure

Note: The LR procedure is performed through the use of the ShipRight FDA (Fatigue Design Assessment) program (Lloyd's Register 1996., FDA, 1996.).

Loads

Loads are applied according to each Society Rules (Bureau Veritas, 2000., Germanischer Lloyd, 1998.). For the selected critical locations at the midship, following loads for each loading condition were considered: still water bending moments, vertical wave bending moments, hydrostatic and dynamic sea pressures, static and dynamic cargo and ballast loads.

The vessel is assumed to operate under two loading conditions only - the full load and the ballast condition. Tables IV and V show details for the considered loading conditions.

Table IV: Loading Condition 1 – Full Load

Full load condition	
Max. still water bending moment	61789 tm
GM	6,65 m
Displacement	49772,6 t
Cargo density	2,778 t/m^3
VCG above BL	8,579 m
Draft forward perpendicular	10,739 m
Draft aft perpendicular	10,840 m
Waterplane Coefficient C_w	0,899

Table V: Loading Condition 2 – Ballast

Max. still water bending moment	94957 tm
GM	7,34 m
Displacement	26444,4 t
Cargo density	1,025 t/m^3
VCG above BL	6,190 m
Draft forward perpendicular	6,949 m
Draft aft perpendicular	8,399 m
Waterplane Coefficient C_w	0,870

The parameter α in Eq. (8) is taken:

- α_1=0,6 for the full load condition,
- α_2=0,4 for the ballast condition,

according to the IACS recommendation for bulk carriers (IACS, 1999.).

Stresses

Since the investigated longitudinals are simply clamped beams it was possible to calculate their stresses from the simple beam theory, thus avoiding possible errors resulting from the finite element mesh definition. The geometric stress concentration factors for each investigated detail were taken from tables of details.

In the case of BV procedure fatigue notch stress concentration factor was calculated by formula:

$$K_w = 2\left(\theta/30\right)^{0,5} \qquad (10)$$

where θ is the mean weld toe angle, in degrees. The values of θ are specified by the BV procedure for different types of welds.

The shape parameter ξ of the Weibull long-term distribution of stress range was taken according to Eq. (3) as recommended by IACS. Thus, ξ = 1,0.

S-N curves

In the BV procedure notch stress approach was applied in conjunction with the HSE B curve for all the considered details (Bureau Veritas, 1995). In the case of the GL procedure, the hot-spot stress approach is used, with IIW S-N curve 100 (Germanischer Lloyd, 1998., Fricke W., Petershagen H., and Paetzold H., 1997.). The LR procedure uses hot-spot stress approach with the weld notch parameters embedded in the S-N curve in conjunction with modified S-N curve. (Viollete F.L.M,1998.).

Fatigue damage

The fatigue damage is calculated for each loading condition considered according to Eq. (8). The results are shown at Fig. 6. The expected fatigue life, in years, is given by:

$$\text{Fatigue life} = \frac{\text{Design life}}{D} \qquad (11)$$

for the assumed design life of 20 years.

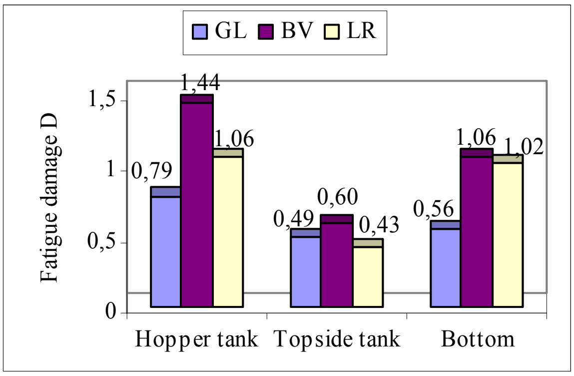

Figure 6: Fatigue damage for the three considered locations

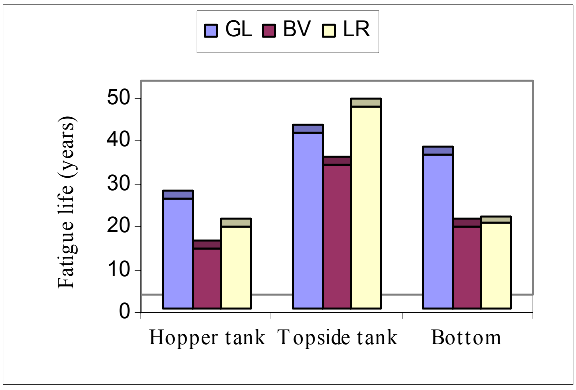

Figure 7: Calculated fatigue life

The largest fatigue damage is observed to occur in the hopper tank longitudinal, where the significant contributor to the fatigue damage is external wave pressure. For the critical detail in the topside tank the fatigue damage is reduced due to the lack of hydrodynamic wave pressure and the increase in section modulus of the longitudinal. Unexpectedly, the calculated damage is very high in the bottom in the cases of the BV and LR procedures. These high values of the fatigue damage obtained for the detail in the double bottom can be partly attributed to the decrease of the section modulus of the longitudinal and the increase of the wave bending moments.

Figs. 6 and 7 show large differences between compared simplified procedures for fatigue damage estimation, which is particularly noted in the locations where the local loads were involved in calculation. However, if each procedure is considered separately, one can notice a consistency in the obtained results: the highest damages are always observed to occur in the area exposed to the high values of the wave pressure (hopper tank in this case), while the lowest damages are calculated in the longitudinal located in the topside tank where no wave pressure exists at all.

To illustrate the importance of determination of fatigue loads, an analysis was performed. The fatigue damages for the three critical locations were obtained by combining the Bureau Veritas fatigue design loads and hot-spot stress approach with IIW S-N curve 100, with all the corrections as given in Germanischer Lloyd procedure. The results are presented in Table VI.

Table VI: Fatigue damage – hot-spot approaches

	GL procedure	BV hot-spot approach
Hopper tank	0,79	1,02
Topside tank	0,49	0,42
Bottom	0,56	0,66

It can be seen from the Table VI that the highest difference of the calculated fatigue damages is in the area where high local loads can be found (below ballast waterline). Calculated damage of the detail located in the topside tank is found to be larger in case when the GL loads were applied; this is due to larger global loads defined by the GL. Thus, definition of fatigue loads, particularly local loads, still remains the primary problem regarding development of the unified fatigue assessment procedure.

Furthermore, the stress approach is also recognized as major contributor to difference in calculated fatigue damages.

Table VI also illustrates the importance of the stress approach applied. When the BV loads were applied in conjunction with notch stress approach the fatigue damage in all locations were significantly larger as shown in Fig.6. This is due to use of fatigue notch stress concentration factor K_w, when calculating the fatigue damage by notch stress approach.

A few assumptions were made prior to calculation of the fatigue damage in the cases of the Bureau Veritas and Germanischer Lloyd procedures: all investigated details are assumed to be representative of standard workmanship and associated constructional tolerance, and are assumed to be properly protected against corrosion. Also, the Weibull shape parameter was taken according to IACS recommendation, Eq. (3), which is not entirely correct because Bureau Veritas proposes fixed values of ξ for different types of ships (Bureau Veritas, 1997.). Therefore, the effects of corrosion, constructional tolerances, and changes of the Weibull shape parameter were investigated.

The Effect of Corrosion

The BV procedure takes the effect of corrosion into account by dividing the coefficient C of the S-N curve by 2 and assuming no change in slope at $N = 0,5 \cdot 10^6$. If there is no adequate corrosion protection, the GL procedure multiplies the fatigue strength reference values $\Delta\sigma_R$ by 0.8 and assumes one slope S-N curve. Fig.8 shows the influence of corrosion on fatigue damage. The fatigue damage is approximately doubled in both approaches for every considered critical location (compared to Fig.6). Thus, the difference in calculated fatigue damage remains large, but the effect of corrosion is well harmonized in different fatigue assessment approaches.

Table VII: Fatigue Damage in the Corrosive Environment

	GL	BV
Hopper tank	1,492	2,874
Topside tank	0,933	1,194
Double Bottom	1,060	2,120

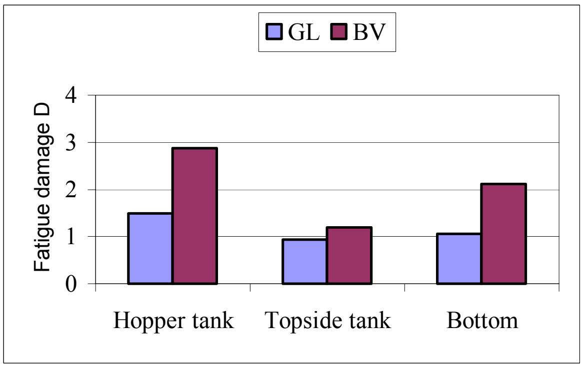

Figure 8: The effect of corrosion

The Effect of the Weibull Shape Parameter

The value of the shape parameter ξ in different fatigue assessment procedures usually varies between 0.7 and 1.3; depending on the type of ship, and particular location of the considered detail in ship. For that range of values fatigue damage was calculated for three locations of the considered bulk carrier. Very large sensitivity of the fatigue damage to the small changes of the shape parameter was found, no matter what part of structure is considered, thus pointing to this parameter as one of the most important issues of the simplified fatigue assessment procedure. Figs. 9, 10 and 11 show the results of calculation. The rise of the fatigue damage due to increase of ξ is clear.

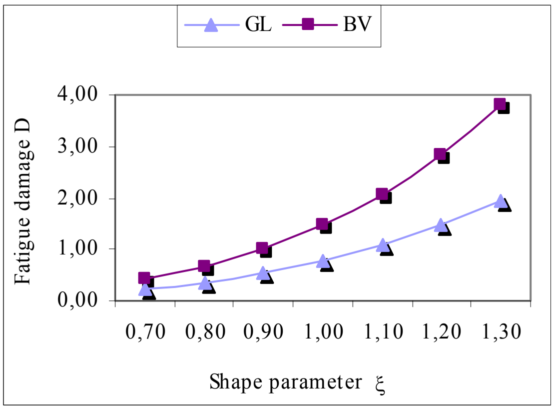

Figure 9: The influence of the Weibull shape parameter on fatigue damage D – location 1, hopper tank

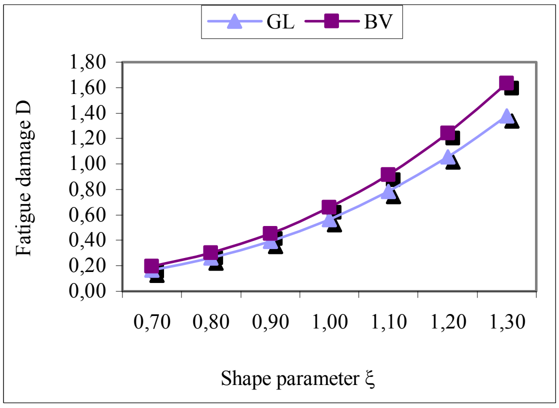

Figure 10: The influence of the Weibull shape parameter on fatigue damage D – location 2, topside tank

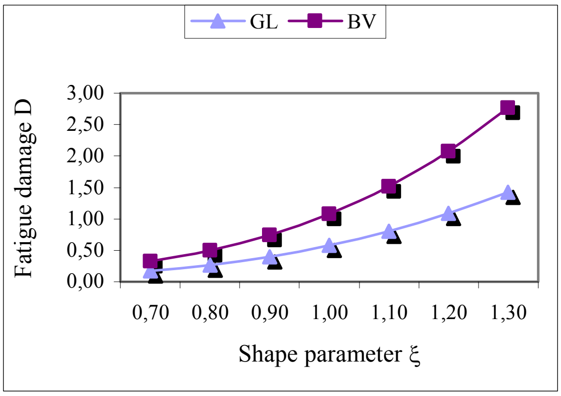

Figure 11: The influence of the Weibull shape parameter on fatigue damage D – location 3, double bottom

Construction Tolerances

The most important factor at construction stage, which affects fatigue life of the structure, is a misalignment of structural elements (Committee III.2, 2000.).

According to the Bureau Veritas the possible misalignment between two abutting members may be taken into account by correcting the stress concentration factor K_{gc} as following:

$$K_{gc} = \left(1 + 3\frac{e}{t}\right) \cdot K_g \tag{12}$$

where K_{gc} is the corrected value of the geometric stress concentration factor; e is the misalignment and t is the thickness of the structural members, both measured in mm.

The analysis was performed for the connection of the stiffener and the longitudinal located in the hopper tank of the bulk carrier. The investigated detail is shown at Fig. 12.

Fig.13 clearly shows the importance of proper fabrication regarding fatigue damage.

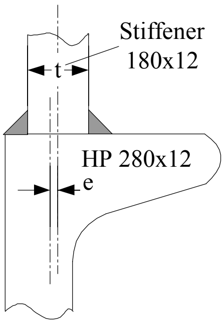

Figure 12: The misalignment of the stiffener and the side longitudinal

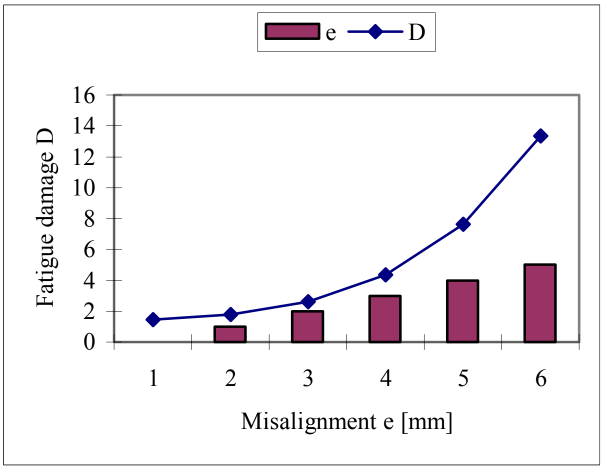

Figure 13: The influence of structural misalignment on fatigue damage

CONCLUSION

Fatigue cracking of structural members is to be expected at some level during the lifetime of a ship. Design tools for the prediction of fatigue lives, of details located at critical points of ships, are therefore important. Relatively simple approaches, proposed by classification societies, are available for such evaluations.

In this paper three different approaches have been compared. Significant differences were found for the calculated fatigue damage. The analyses show that a major part of the differences is due to a different definition of the fatigue loads and stress approaches applied.

The influence of shape parameter of the Weibull long-term distribution of stress range was studied in a parametric variation. Very large sensitivity of the fatigue damage to small changes of the shape parameter was found, regardless of the part of structure considered. The analysis of construction tolerances shows significant impact of structural misalignment on fatigue damage. The effect of corrosion was analyzed and the conclusion was made that this effect should be engaged in fatigue assessment procedure. Also, it was found that different approaches are well harmonized regarding inclusion of the effect of corrosion in the fatigue assessment procedure. However, in spite of the efforts made in order to harmonize various approaches the differences in obtained results are high and the important issues, such as determination of fatigue loads and selection of stress approach still remain the major problem.

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