THE LEVEL OF CONFIDENCE FOR A SHIP HULL GIRDER

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ABSTRACT

Structural estimation consists in a set of activities done to certificate security and reliability of an existing ship for its residual service life. Depending on ship’s type and damages, there are alternatively evaluation approaches. In this paper it is presented the level of confidence determination for a bulk carrier ship based on approximate methods. Important information can be obtained with special attention on damage factors (corrosion, fatigue). Regarding the ship’s loads, first, it is calculated the still water bending moment, then the wave-induced hull girder bending moment. Once these results being processed, it is possible to determine the structural stress of the ship for any age. The probability to overreach the admissible stress given by classification registers can be calculated, and the potential risk for structure becomes predictable.

KEYWORDS: Level of confidence, bending moment, probability of exceedence.

1. INTRODUCTION

Lately, the probabilistic approach is a preferred tool used for analyzing the ship strength. For most engineering determinations there are used various input data (such as: loads, material and geometrical properties etc.) having different uncertainty levels (probability of exceedence etc.). The uncertainty level of the results is unknown. The fact that knowing the uncertainty level of the results is important for the reliability-based methodology for life prediction of ship structures needs to be accepted. The question is: How much one can trust the obtained results? The level of confidence is a measure of the uncertainty and it is represented by the probability of exceedence of the given limit (for example the admissible stress) or by the probability to be less than the given value. Analytical and approximate methods offer to engineers the possibility of numerical evaluation of the uncertainty of the final calculated results [1]. Once the probability density functions for the input parameters being known, the probability density functions for the results can be determined using the variable distribution formulation. Still, the probability density functions are not always known, also the formulas are valid for simple cases (summing, dividing, and multiplying the input parameters). For complex problems, such as finite element nonlinear analysis of the hull ship, the procedure cannot be used. A solution for this problem can be an approximate method applied to determine the level of confidence for the results directly from the level of confidence of the input parameters. The method is based on a percentage of the input parameters for each probability density function of the input parameters (if there are available) or from the statistics-based analysis of a recording event for the input parameters.

Structural estimation for existing ships represents a major application of this method. It allows obtaining credible information about ship resistance, with special attention on the damage factors (corrosion, fatigue). Corrosion wastage can be treated as a random phenomenon, which affects the panel’s thickness, stiffeners and girders and also affects the geometrical
properties [2, 3]. The method links the uncertainty of the geometric properties to the uncertainty of the ship’s loads. The uncertainty of the geometric properties is calculated using analytical methods and the second one is determined by separate calculus.

First, it is calculated the still bending moment, then the wave-induced hull girder bending moment, and finally, the bending moments are cumulated. Once these results are processed, it is possible to determine the structural stress of the ship for any age. The probability to overreach the admissible stress given by classification registers can be calculated, and the potential risk for structure is predictable [4].

2. LEVEL OF CONFIDENCE.

One can understand this concept by referring to the S-N curves (S - specific stress cycle, N – number of fatigue cycles) for different structures. These curves are based on experimental fatigue tests, for a number of stress cycles applied on a structure. It was demonstrated that the number of cycles has a normal Gauss distribution. It is stipulated that every point of a S-N curve corresponds to a mean value of the number of cycles minus two standard deviations.

![Fig 1. Example of S-N curve [2].](image-url)

<table>
<thead>
<tr>
<th>Main characteristics</th>
<th>Symbol</th>
<th>Full scale ship</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of waterline</td>
<td>( L_{WL} )</td>
<td>220.915 [m]</td>
<td>2.761 [m]</td>
</tr>
<tr>
<td>Length between perpendiculars</td>
<td>( L_{BP} )</td>
<td>217.300 [m]</td>
<td>2.716 [m]</td>
</tr>
<tr>
<td>Breadth of waterline</td>
<td>( B )</td>
<td>32.200 [m]</td>
<td>0.403 [m]</td>
</tr>
<tr>
<td>Draught mean</td>
<td>( T_M )</td>
<td>13.830 [m]</td>
<td>0.173 [m]</td>
</tr>
<tr>
<td>Draught at forward perpendicular</td>
<td>( T_F )</td>
<td>13.830 [m]</td>
<td>0.173 [m]</td>
</tr>
<tr>
<td>Draught at aft perpendicular</td>
<td>( T_A )</td>
<td>13.830 [m]</td>
<td>0.173 [m]</td>
</tr>
<tr>
<td>Longitudinal centre of buoyancy</td>
<td>( LCB )</td>
<td>114.081 [m]</td>
<td>1.426 [m]</td>
</tr>
<tr>
<td>Volumetric displacement</td>
<td>( \nabla )</td>
<td>82626.000 [m^3]</td>
<td>0.161 [m^3]</td>
</tr>
<tr>
<td>Water density</td>
<td>( \rho )</td>
<td>1.025 [\text{t/m}^3]</td>
<td>998.700 [\text{kg/m}^3]</td>
</tr>
<tr>
<td>Water kinematical viscosity</td>
<td>( \nu )</td>
<td>1.18831E-0006 [m^2/s]</td>
<td>1.42667E-0006 [m^2/s]</td>
</tr>
<tr>
<td>Gravity acceleration</td>
<td>( g )</td>
<td>9.810 [m/s^2]</td>
<td>9.810 [m/s^2]</td>
</tr>
<tr>
<td>Block coefficient</td>
<td>( C_B )</td>
<td>0.837</td>
<td>0.837</td>
</tr>
<tr>
<td>Midship section coefficient</td>
<td>( C_M )</td>
<td>0.995</td>
<td>0.995</td>
</tr>
<tr>
<td>Waterline coefficient</td>
<td>( C_W )</td>
<td>0.923</td>
<td>0.923</td>
</tr>
</tbody>
</table>
Fig. 2. Body lines of the 84700 t bulk carrier.

Fig. 3. Scantling parameters of the 84700 t bulk-carrier (generated with Poseidon 2.0)
When S-N curves are utilized one can determine the number of cycles $N_i$ representing the failure of a structural node corresponding to a stress cycle $S_i$, with 97.72% level of confidence. Mathematically this can be written as:

The level of confidence (L.O.C.) [%] = the probability of exceedence (p.o.e.) [%]

(2.1)

Using (2.1), the level of confidence coincides with the given probability of exceedence. If there is interest to know the probability that the structure fails at smaller values of $N_i$, one can conclude that this probability is 2.28%. In this case the level of confidence is:

L. O. C. [%] = 100 - p. o. e [%]

(2.2)

The level of confidence relieves how is possible to reach the corresponding calculated values:
- p.d.f. of $\log N_i$ represents the probability density function of the number of cycles, $N_i$, that corresponds to the cyclically stress having the $S_i$ amplitude;
- c.d.f. of $\log N_i$ is the cumulative density function of the number of cycles, $N_i$, that corresponds to the cyclically stress having the $S_i$ amplitude;
- $\log N_i$ is the mean value of $\log N_i$;
- $\tau$ is the standard deviation of $\log N_i$.

Only the vertical bending case is considered, because it is the most significant still water load case [5].

For calculating the level of confidence there are used only two parameters:
- the still water bending moment, $M_c$;
- the strength modulus on the deck of the hull-girder, $SM_{deck}$.

$M_c = L \cdot O \cdot C \cdot g + m$,

where $m$ is a coefficient depending on $C_B$ [9].

It results that $M_c = 145103$ t.

Statistical analysis of the still water bending moments [6, 7, 8] showed that $M_c$ and $SM_{deck}$ obeys the normal (Gaussian) distribution. During the ship’s operation the probability density function of the still water bending moment depends on the ship’s load. There is a possibility, in practice, that the design values of $M_c$ may be exceeded. This issue is revealed by a special analysis of the ship’s cargo plans (10...30% exceedence relative to the design still water bending moments).

Here the issue is to establish the level of confidence of the bending stress on deck due to the still water bending. For different values of the $SM_{deck}$ it is necessary to calculate only the values of those c.d.f that corresponds to $SM_{deck}$:

$F_{M_c} (M_c) = \int_{-\infty}^{M_c} f_{M_c} (M_c) dM_c$,

(3.3)

where

$f_{M_c} (M_c) = \frac{1}{\tau_{M_c} \sqrt{2 \cdot \pi}} e^{-0.5 \left( \frac{M_c - MC}{\tau_{M_c}} \right)^2}$

(3.4)

is the probability density function and $MC = \text{Mean value of } M_c$.

$\tau_{M_c} = \text{standard deviation of } M_c$.

4. THE LEVEL OF CONFIDENCE FOR THE HULL-GIRDER FLOATING ON WAVES.

The wave-induced hull girder bending moment is determined using the ABS rules. The design wave-induced hull girder bending moment is calculated as:

$M_v [t \cdot m] = 19.37 \left[ 10.75 - \left( \frac{3000 - L}{100} \right)^{1.5} \right] L^2 \cdot B \cdot C_B \cdot 10^{-3}$

(4.1)

$M_v$ obeys the Weibull distribution that becomes, in this case, exponentially and has the following properties:

The c.d.f. of $M_v$:

$F_{M_v} (M_v) = 1 - e^{-\lambda \cdot M_v}$

(4.2)

The p.d.f. of $M_v$:

$f_{M_v} (M_v) = \lambda \cdot e^{-\lambda \cdot M_v}$,

(4.3)

$Q_{M_v} (M_v) = 1 - F_{M_v} (M_v) = e^{-\lambda \cdot M_v}$

is the probability of exceedence, (p.o.e.) of $M_v$.

The classification societies give an approximate p.o.e. of the design $M_v$ as being $10^4$. The $\lambda$ coefficient can be determined from:

$I \cdot 10^{-8} = e^{-\lambda \cdot M_v}$ for $\lambda = 74741.66 \cdot 10^{-9}$

Now it can be determined the p.o.e. of the wave-induced bending moment for an operational life $T=20$ years of the 84700 t bulk-carrier. In figure 4 it is depicted the probability of exceedence for the wave-induced bending moment of the hull girder for an operational life $T=20$ years.

5. CONCLUSION REMARKS

The probabilistic determination of the hull girder stress for an year or for life time period requires the representation of the wave-induce bending moment as a function depending on a given ship operational life.

![Fig 4. p.o.e of the wave-induced bending for T=20 years.](image)
There has to be considered the fact that this mathematical model is based on approximate methods. Satisfactory results will be obtained if there will no more to be used approximate formulation and the values of the wave–induced bending moment will be determined on each section of the ship. This is possible using a computational program based on the point-source method. The results are the non-dimensional transfer function of the wave-induced forces and moments on ship sections.

REFERENCES: