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3D-FEM Strength Analysis for the Influence of Corrosion over Oil Tanker Ship Hull

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Abstract - ***The subject of this study is to identify the influence of corrosion over the hull of a VLCC. Two cases are analysed, as built thickness and the thickness according to measurements after 15 years of service. Strength analysis was perform using 3D-FEM tools over three cargo hold model. Yielding ratio criteria was used as checking criteria.***

Keywords - **corrosion influence, three cargo hold model, 3D-FEM numerical analysis, VLCC**

I. Introduction

The vessel selected for this study is a VLCC (very large crude carrier) with double hull. The main characteristics of the ship are presented in Table 1.

Table 1. Main characteristics of the ship

Length between perpendiculars	L_{BP}	294	m
Breadth	B	60	m
Draught	T	21	m
Depth	D	29	m
Service speed	v_s	16	knots
Displacement	Δ	326000	t
Block coefficient	c_B	0.86	

The size of the selected vessel is justified by the fact that in our days some VLCC are transformed into FPSO (floating production storage and offloading) or FSU (floating storage unit) ships and during conversion the 3D-FEM strength analysis is to be carry out to verify the strength of the hull structure. The structural assessment is to verify that the acceptance criteria specified are complied with.

During the lifetime, ship structure is affected by sea water, a highly corrosive environment. Corrosion represents a constant reduction of thickness which affects the global and local ship strength. According to Bureau Veritas Rules[1] the acceptance criteria stipulate limits of wastage which are to be taken into account for reinforcements, repairs or renewals of steel structure. These limits are generally expressed for each structural item as a maximum percentage of acceptable wastage(W).

$$t_{\min} = \left(1 - \frac{W}{100}\right) \cdot t_{rule}$$

The maximum percentage of wastage is 25 % to the rule thickness. However, when the rule thickness(t_{rule}) is not available, the as-built thickness can be used.

Thickness measurements may be required during annual, intermediate and class renewal surveys. The following table (Table 2) presents the measured thickness[7] after 15 years of service for midship section (Figure.1) .

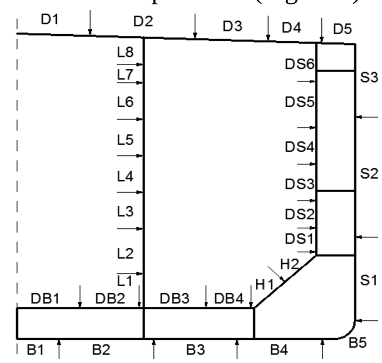

Figure.1. Midship section

Table 2. Thickness measurments for midship section

Panel		As built	15 years	Min thk.
Bottom	B1	19.5	15.7	14.625
	B2	19.5	16.0	14.625
	B3	19.5	16.3	14.625
	B4	19.5	17.0	14.625
	B5	19.5	17.3	14.625
Side Shell	S1	19.5	17.0	14.625
	S2	19.5	15.7	14.625
	S3	19.5	18.2	14.625
Double Bottom	DB1	19.5	17.7	14.625
	DB2	19.5	17.9	14.625
	DB3	19.5	17.8	14.625
	DB4	19.5	18	14.625
Hopper	H1	20.5	18.7	15.375
	H2	19.5	17.9	14.625
Double Side	DS1	17.0	15.8	12.75
	DS2	16.5	14.8	12.375
	DS3	15.5	14.2	11.625
	DS4	14.5	13.6	10.875
	DS5	16.5	15.1	12.375
	DS6	19.5	17.7	14.625
Deck	D1	22.5	18.8	16.875
	D2	22.5	19.3	16.875
	D3	22.5	19.1	16.875
	D4	20.0	18.0	15.000
	D5	20.0	18.2	15.000
Longitudinal Bulkhead	L1	20.0	18.3	15.000
	L2	17.5	15.3	13.125
	L3	17.0	15.4	12.750
	L4	16.0	14.7	12.000
	L5	15.0	13.8	11.250
	L6	16.0	14.7	12.000
	L7	18.0	16.5	13.500
	L8	18.5	16.8	13.875

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II. Methodology

In order to study the strength of the selected vessel the 3 cargo hold 3D-FEM model was built in FEMAP according to CSR Rules[2] for double hull oil tankers. The model extends over three cargo tank lengths about midship. Coarse mesh model has been modelled including all main longitudinal and transversal structural elements.

Hereafter are presented the main steps for the strength analysis[4].

The 3D-FEM mesh of the ship hull structure

The first step of the strength analysis includes the generation of the 3D-FEM hull model. The mesh can be generated automatically, using auto-mesh options that are usual included in the FEM programs or it can be done manually. In the 3D-FEM model all structural members have been modelled according to their original shape using the following types of elements:

- plate element defined by three / four nodes, each with six degrees of freedom;
- bar elements defined by two nodes, six degrees of freedom per node;

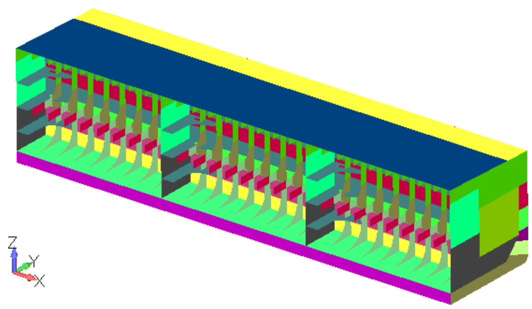

Figure.2. 3 cargo holds 3D-FEM model

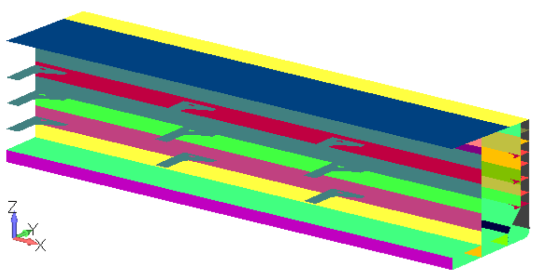

Figure.3. 3D-FEM model: longitudinal structures

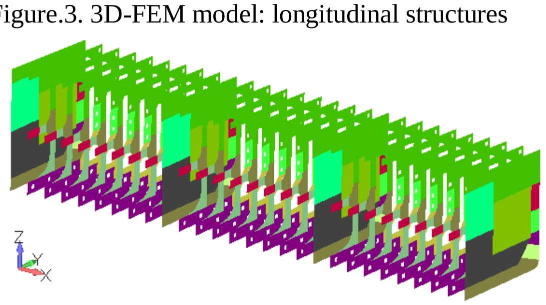

Figure.4. 3D-FEM model: transverse structures

In the Table 3 are presented the characteristics of the materials used for 3D-FEM model

Table 3. Material characteristics

Young modulus		206000	N/mm^2
Poison coefficient		0.3	
Transversal modulus		79231	N/mm^2
Density		7850	Kg/m^3
Yield limit	AH32	315	N/mm^2
	AH36	355	N/mm^2

The boundary conditions of the 3D-FEM model

The next step of analysis includes the generation of the boundary conditions for the 3D-FEM hull model. Due to the symmetry of the ship structure the model was developed only in one side with symmetry conditions in center line.

Two rigid elements (shown in Figure.5) were added at the fore end and the aft end of the model having the master node in the neutral axis of the ship. For all the nodes in center line the symmetry boundary condition is applied.

The boundary conditions applied to the 3D-FEM model are presented in the Table 4. The TX, TY and TZ are the translation along X, Y and Z axis and the RX, RY and RZ are the rotations around X, Y and Z axis.

Table 4. Boundary conditions applied to 3D-FEM model

Boundary condition	TX	TY	TZ	RX	RY	RZ
Center line		X		X		
Aft node	X	X	X	X		X
Fore node		X	X	X		X

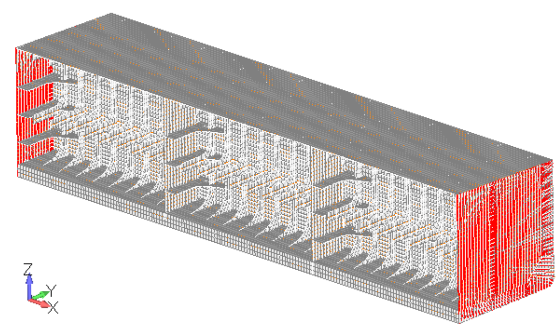

Figure.5. Two rigid elements situated in the aft and fore extremity of the model

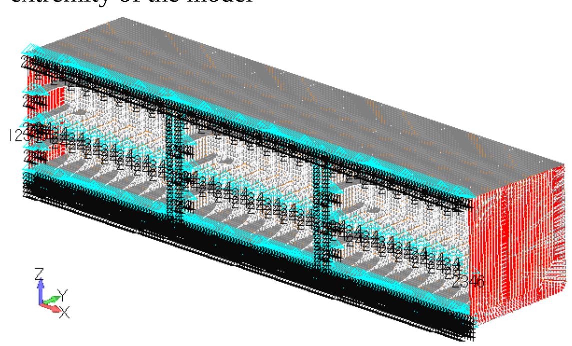

Figure.6. Boundary conditions applied to the model

The loading conditions and the numerical analysis

This third step of the strength analysis contains the modeling of the loading conditions and the effective numerical structure analysis of the 3D-FEM model. Four load cases

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01 Nov. 2014

were selected for this analysis. The model was loaded with still water bending moment (SWBM) and total wave bending moment, SWBM+VWBM, were VWBM represents the vertical wave bending moment, both for sagging and hogging conditions.

The vertical wave bending moment for hogging and sagging conditions are calculated according to Bureau Veritas Rules[1].

$$M_{WV,H} = 190 \cdot F_M \cdot n \cdot C \cdot L^2 \cdot B \cdot c_B \cdot 10^{-3}$$

$$M_{WV,S} = -110 \cdot F_M \cdot n \cdot C \cdot L^2 \cdot B \cdot (c_B + 0.7) \cdot 10^{-3}$$

were:

F_M - represents the distribution factor,

C - represents the wave parameter,

n - represents the navigation coefficient;

The Table 5. contains the values of the moment applied for each analysis case for the two master nodes.

Table 5. Bending moment values for two master nodes

	NDaft [kNm]	NDfore [kNm]
SWBM - Hogging	-6581181	6581180.9
SWBM - Sagging	6022610.9	-6022611
SWBM + VWBM - Hogging	-15678219	15678219
SWBM + VWBM - Sagging	15576171	-15576171

The numerical results evaluation

At this step of the strength analysis based on 3D-FEM model are obtained the stress and deformations, and also the prediction of the higher risk domains.

The yielding ratio was used as checking criteria.

The yielding ratio is calculated according to Bureau Veritas Rules using eigen program codes[3].

$$YR = \frac{\sigma_{VM}}{\sigma_{Master}};$$

$$\sigma_{Master} = \frac{R_y}{\gamma_R \times \gamma_M};$$

$$R_y = \frac{235}{k};$$

$$\sigma_{VM} = \left(\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau^2\right)^{1/2};$$

where k is the material coefficient and γ_R, γ_M are partial safety factors.

III. Numerical results

The numerical analysis is focused on the hull strength of a VLCC ship. Four load cases were selected for this analysis. The model was loaded with still water bending moment (SWBM) and total wave bending moment, SWBM+VWBM, were VWBM represents the vertical wave bending moment, both for sagging and hogging conditions. The yielding ratio is used as a checking criteria, according to chapter II with the yielding ratio smaller than unit the strength criteria is verified.

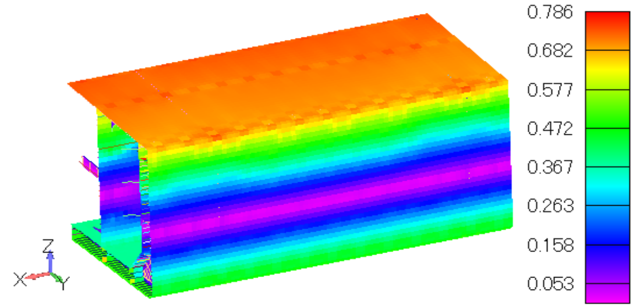

Figure.7. Yielding ratio distribution over central tank of the ship. Envelope for all loading conditons. As built model.

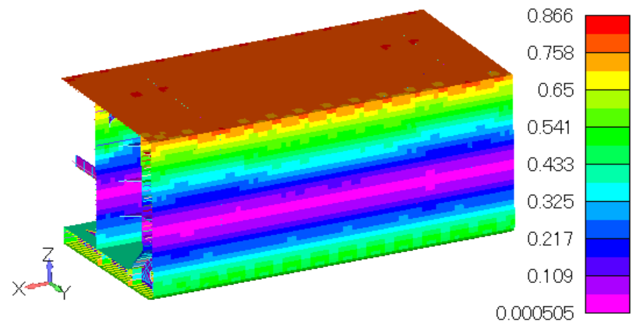

Figure.8. Yielding ratio distribution over central tank of the ship. Envelope for all loading conditons.Corroded model.

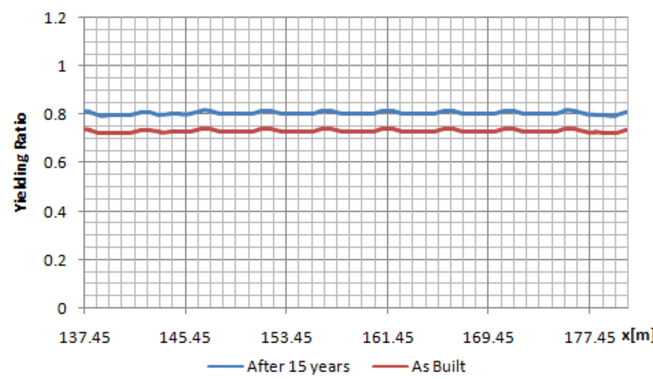

Figure.9. Maximum values for Yielding along the main deck over central tank of the ship. Envelope for all loading conditons.

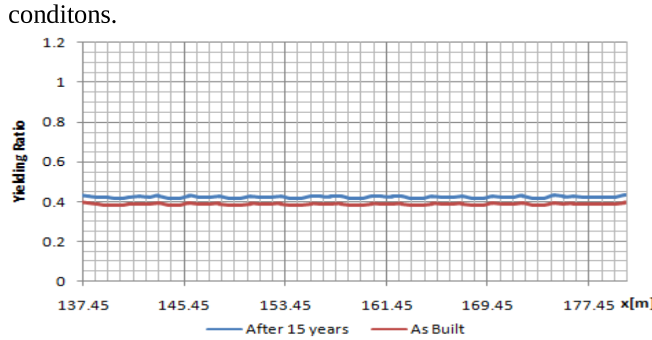

Figure.10. Maximum values for Yielding along the double bottom over central tank of the ship. Envelope for all loading conditons.

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01 Nov. 2014

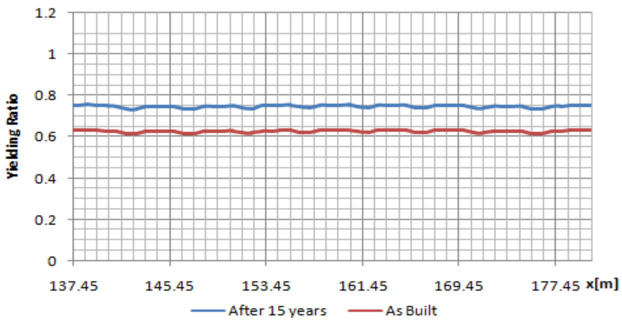

Figure.11. Maximum values for Yielding along the double side over central tank of the ship. Envelope for all loading conditons.

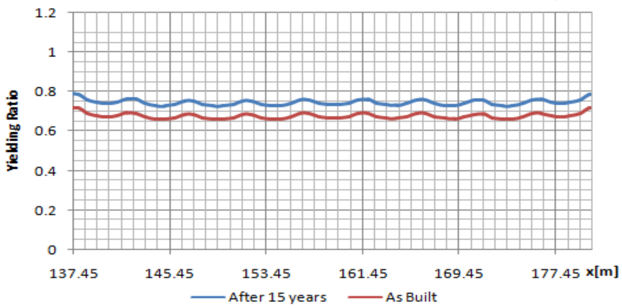

Figure.12. Maximum values for Yielding along the side shell over central tank of the ship. Envelope for all loading conditons.

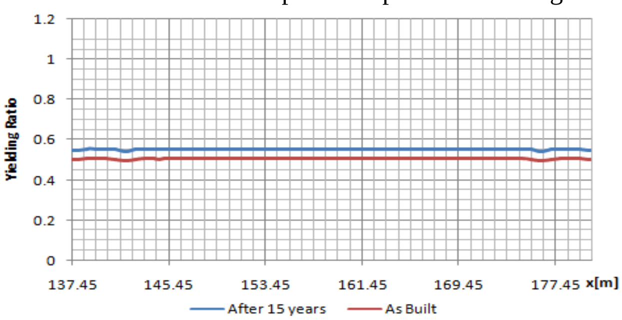

Figure.13. Maximum values for Yielding along the bottom over central tank of the ship. Envelope for all loading conditons.

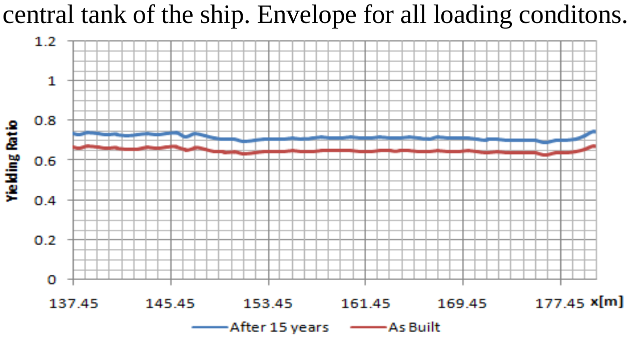

Figure.14. Maximum values for Yielding along the longitudinal bulkhead over central tank of the ship. Envelope for all loading conditons.

Figures Figure.7. and Figure.8. presents the yielding ratio distribution over the middle cargo tank of the ship for as built model and for corroded model.

Figures Figure.9. - Figure.14. presents the distribution along the longitudinal structures (main deck, double bottom, double side, side shell, bottom and longitudinal bulkhead) of the maximum values of yielding ratio for as built model and for corroded model.

For as built model the maximum yielding ratio is 0.786 and for corroded model the maximum yielding ratio is 0.866.

IV. Conclusion

The diminution of the thickness is related to the effect of the environmental corrosion over ship structure Due to the wastage the ship hull the strength was affected. Hereafter are presented the differences over the longitudinal structures of the yielding ratio (YR) between as built model and corroded model.

	YR as built	YR after 15 years	[%]
Main deck	0.731	0.804	9.957
Double bottom	0.384	0.419	9.157
Double side	0.632	0.754	19.273
Side shell	0.666	0.734	10.143
Bottom	0.506	0.553	9.369
Longitudinal bulkhead	0.649	0.713	9.960

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References

i. *BV, Bureau Veritas Rules for Classification of Steel Ships, 2014.*

ii. *CSR, Common Structural Rules for Double Hull Oil Tankers, 2008.*

iii. *Jagite, G.; Domnisoru, L., Ship Structural Analysis with Femap API program codes. Naval Architecture Faculty, Galati, Romania, 2014;*

iv. *Domnisoru, L., The finite element method applied in shipbuilding. Bucharest: The Technical Publishing House,2001;*

v. *Domnisoru, L., Structural analysis and hydroelasticity of ships. University "Dunarea de Jos" Press, Galati, 2006;*

vi. *Hughes, O.F., Ship structural design. A rationally-based, computer-aided optimization approach. New Jersey: The Society of Naval Architects and Marine Engineering, 1988;*

vii. *Thickness measurements report;*

viii. *Bathe, K.J., Finite Elementen Methoden. Berlin: Springer Verlag, 1990;*

ix. *Guedes Soares, C., Special issue on loads on marine structures. Marine Structures 12(3):129-209, 1999;*

x. *Servis, D.; Voudouris, G.; Samuelides, M.; Papanikolaou, A., Finite element modeling and strength analysis of hold no. 1 of bulk carriers. Marine Structures 16:601-626, 2003;*

xi. *Lehman, E., Matrizenstatik. Hamurg: Technischen Universitat Hambourg - Hamburg, 1994;*

xii. *Lehman, E., Guidelines for strength analysis of ship structures with the finite element method. Hamburg: Germanischer Lloyd Register, 1998;*

xiii. *Ioan, A.; Popovici, O.; Domnisoru, L., Global ship strength analysis. Braila: Evrika Publishing House, 1998;*

xiv. *Rozbicki, M.; Das Purnendu, K.; Crow, A., The preliminary finite element modeling of a full ship. International Shipbuilding Progress. Delft 48(2):213-225, 2001;*