"Mircea cel Batran" Naval Academy Scientific Bulletin, Volume XVIII – 2015 – Issue 1
Published by "Mircea cel Batran" Naval Academy Press, Constanta, Romania // The journal is indexed in:
PROQUEST SciTech Journals, PROQUEST Engineering Journals, PROQUEST Illustrata: Technology, PROQUEST Technology Journals, PROQUEST Military Collection PROQUEST Advanced Technologies & Aerospace

CONSIDERATIONS REGARDING THE STRUCTURAL MODIFICATIONS OF A 110.000 GRT PASSENGER SHIP IN ORDER TO IMPLEMENT THE ANNEX VI MARPOL REGULATIONS

Adrian POPA[1]
Marian RISTEA[2]
Dragos NEAGU[3]
Mircea PAVEL[4]
[1]Assistant professor dr. ing., "Mircea cel Batran" Naval Academy
[2]Assistant professor dr. ing., "Mircea cel Batran" Naval Academy, marian.ristea@anmb.ro
[3]PhDcing, Marine & Offshore Consultants S.R.L.
[4]Eng, Marine & Offshore Consultants S.R.L.

Abstract: *The new regulations regarding the SOxemissions involves implementation of new technologies onboard ships. This usually means redesigning local structures in order to be able to support the increased loads induced by new equipments.*
The new structure has to be check in order to see if it respect class requirements.
This paper is a good practice example of a structural check for a redesigned structure in order to support new added scrubbers.
Keywords: *Strctural analysis, MARPOL, Class requirements*

Introduction

MARPOL, the International Convention for Prevention of Pollution from Ships is trying to reduce the pollution generated from ships.
Annex VI MARPOL is enforcing regulations regarding the gas emissions from ships.
One of the most important concerns regards the SOx emissions.
Regulations 14 stipulate maximum levels of SOx emissions from ships to be:

- 4,50% m/m prior to January 2012,
- 3,50% m/m after January 2012,
- 0,50% m/m on or after January 2020

Regarding SECAs (Sulphur Emissions Conatrol Areas) Regulations 14 stipulate about the maximum SOx emission levels:

- 1,50% m/m prior to July 2012
- 1,00 % m/m on or after July 2012
- 0,10 % m/m on or after 1 January 2015

In order to reduce the SOx level one of the most used technical solution is to "wash" the exhaust gas in wet scrubbers.
The working principle of a wet scrubber is presented in Figure 1.

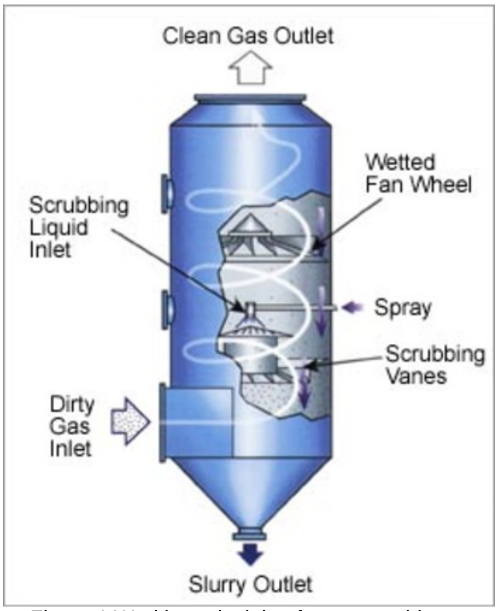

Figure 1 Working principle of a wet scrubber (http://www.indiamart.com/durgapur-environmental/products.html)

Such equipments are heavy and involves structural modifications.

Such modification had to be done during the implementations of these regulations for a 110000 GRT passenger ship.
On this ship were mounted two scrubbers having 8 tonnes each.
After redesigning the structure underneath the two scrubbers, the new scructure is presented in figure 2 and 3

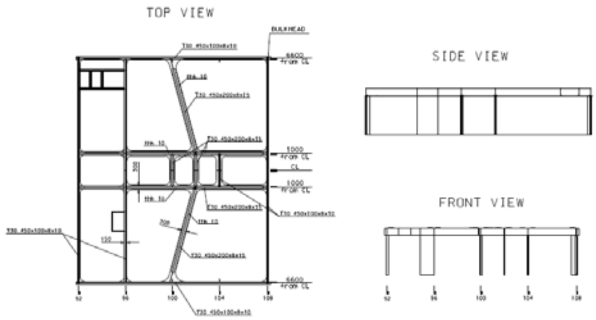

Figure 2 Deck structure view

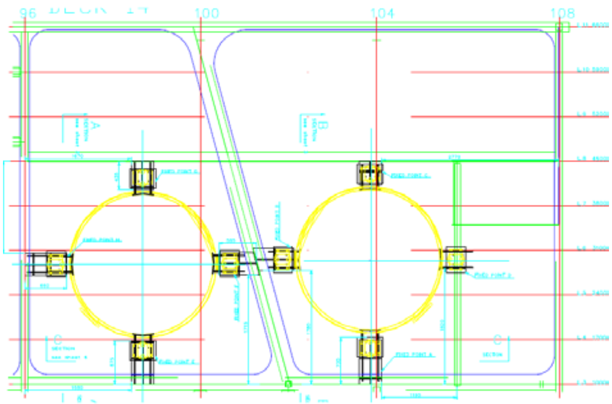

Figure 3.Scrubbers arrangement

In order to respect the class requirements and the client specifications, a structural check using finite element method has to be performed.

1. Units

The following units were used in the FE analysis:
Lengths: millimeter [mm],

- Forces: Newton [N],
- Masses: Kilograms [Kg],
- Accelerations : $\left[\frac{m}{s^2}\right]$

Stresses are therefore expressed in $\left[\frac{N}{mm^2}\right]$, $[MPa]$

2. Analysis

For the analysis was used the ANSYS 12.1 software.

The coordinate system is:

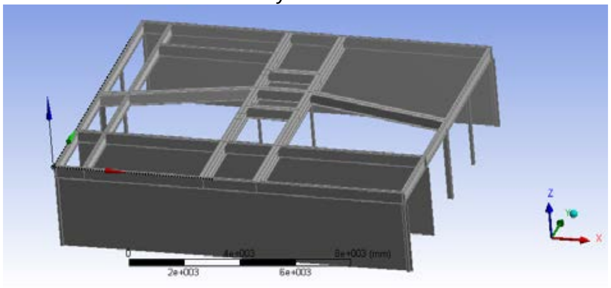

Figure 4 The coordinate system

The material considered throughout the analysis is AH 36 steel. Material characteristics are:

- E= 210000 $\left[\frac{N}{mm^2}\right]$– Young's Modulus
- υ= 0.3 – Poisson's coefficient
- σ_{yield}= 355 $\left[\frac{N}{mm^2}\right]$ (high-strength steel)

The finite element model is:

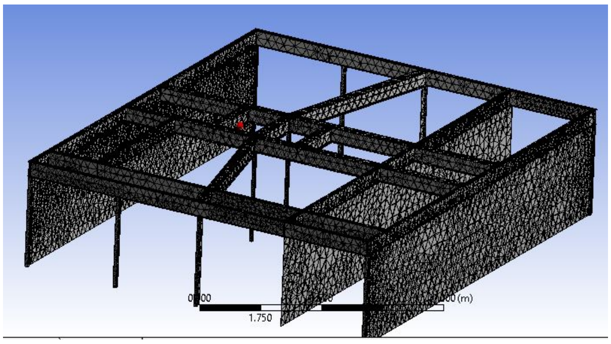

Figure 5. Isometric view of the FE model

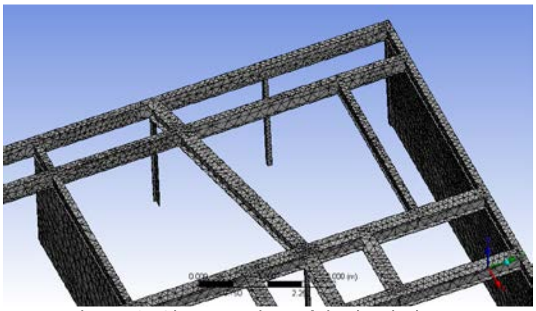

Figure 6. Close up view of the loaded area

The adopted mesh is a fine, unstructured mesh; it's characteristics are presented in table 1.

Table 1. Mesh Characteristics

Object Name	*Mesh*
State	Solved
Defaults	
Physics Preference	Mechanical
Sizing	
Use Advanced Size Function	Off
Relevance Center	Fine
Initial Size Seed	Active Assembly
Smoothing	High
Transition	Slow
Span Angle Center	Fine
Minimum Edge Length	3.6966e-004 m
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Patch Conforming Options	
Triangle Surface Mesher	Program Controlled
Advanced	
Shape Checking	Standard Mechanical
Element Midside Nodes	Program Controlled
Straight Sided Elements	No
Rigid Body Behavior	Dimensionally Reduced
Mesh Morphing	Disabled
Defeaturing	
Generate Pinch on Refresh	No
Automatic Mesh Based Defeaturing	On
Defeaturing Tolerance	Default
Statistics	
Nodes	124479
Elements	62826

According with technicall specifications, the load is induced by the two scrubbers with a 8 tonnes weight each.
The induced forces were distributed on the scrubber's support areas, and were considered to be 20000 N for each individual support and 40000 N for the central beam, as presented in Figures 3 and 7.

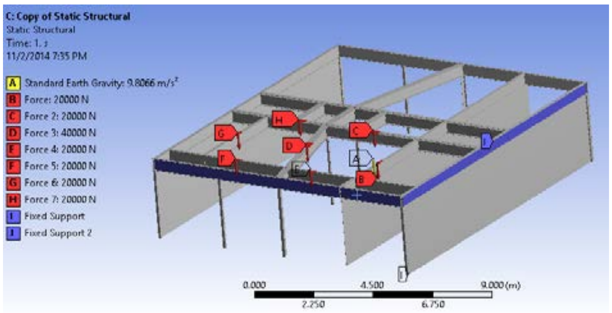

Figure 7. The loads and constraints distribution

In a conservative approach, the allowable stress are :

- according with General informations for the Rules and Regulations for the Classification of Ships, July 2014, Lloyd's Register Part 3Chapter 11 Section 2 the equivalent stress should not exceed 0,8 σ_0. Where σ_0 is the minimum yield stress (355$\left[\frac{N}{mm^2}\right]$);
- according with ref General informations for the Rules and Regulations for the Classification of Ships, July 2014, Lloyd's Register Parte 3 Chapter 13 Section 8 and 9 Allowable stress within the supporting structure of shipboard fittings should not exceed the values presented in Figure 7 (General informations for the Rules and Regulations for the Classification of Ships, July 2014, Lloyd's Register table13.8.6).

	Normal stress, in N/mm^2	Shear stress, in N/mm^2
Allowable stress	$\frac{235}{k}$	$\frac{141}{k}$
where $k = \frac{235}{\sigma_0}$ σ_0 = specified minimum yield strength of the material in N/mm^2		

Figure 7. Allowable stress within the supporting structure of shipboard fitting

After calculus, the stresses within structure should not exceed:

Table 2 Maximum calculated allowable stress

Equiv $\left[\frac{N}{mm^2}\right]$	Normal stress $\left[\frac{N}{mm^2}\right]$	Shear Stress $\left[\frac{N}{mm^2}\right]$
284	355	213

where $k = \frac{235}{\sigma_0} = \frac{235}{355} = 0.6619 \left[\frac{mm^2}{N}\right]$

The boundary conditions were determined for following the conservative approach, by restraining to 0 DOF the lateral beams at deck level and pillars, walls and bulkhead base, situated at the level of Deck 13, as shown in figure 7.
Graphical plots of the results are presented in Figure 8 through figure 15:

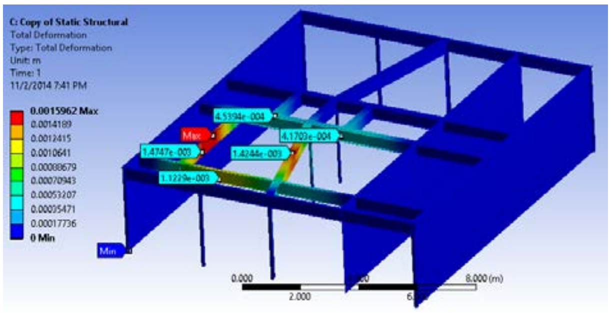

Figure 8. Total deformation

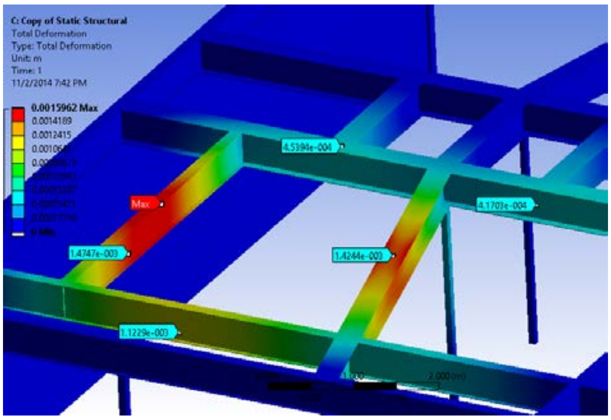

Figure 9. Total deformation detailed for the interest area

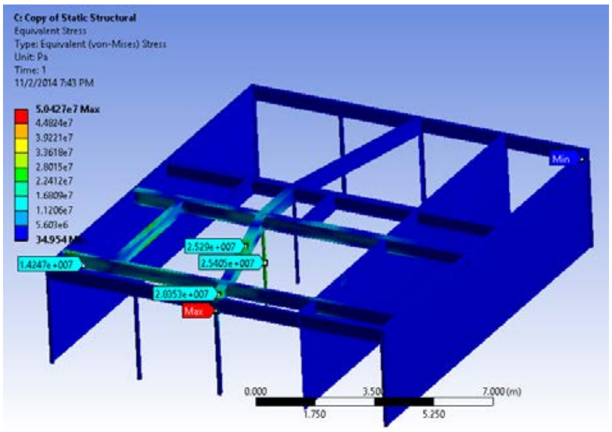

Figure 10. Equivalent stress for the entire structure

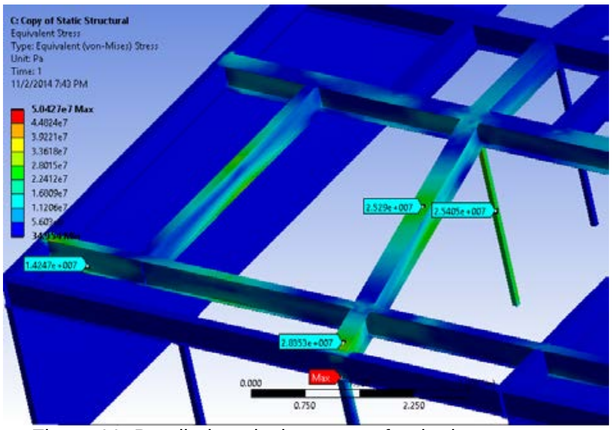

Figure 11. Detailed equivalent stress for the interest area

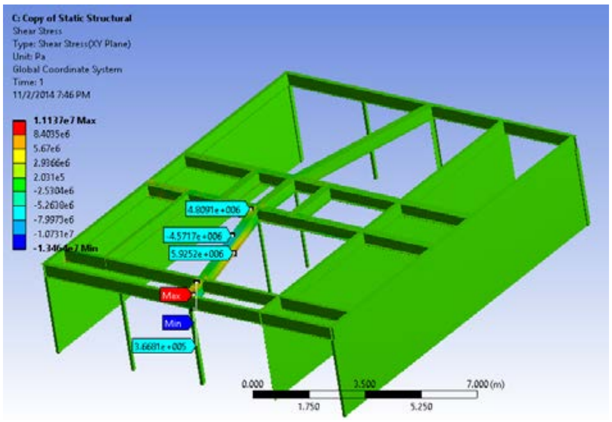

Figure 12. Shear stress for the entire structure

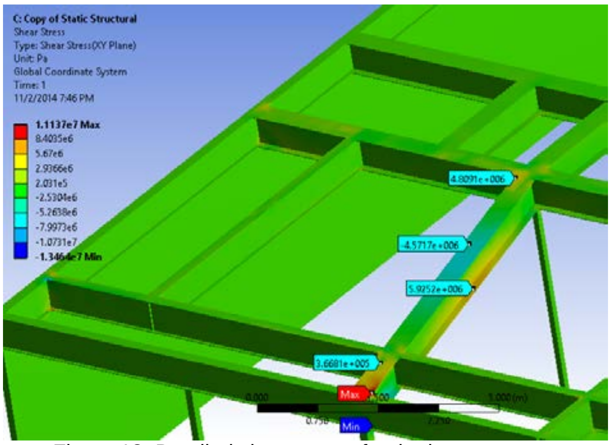

Figure 13. Detailed shear stress for the interest area

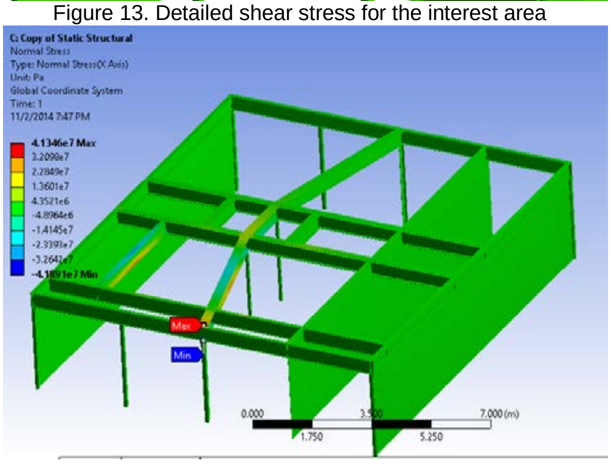

Figure 14. Normal stress for the entire structure

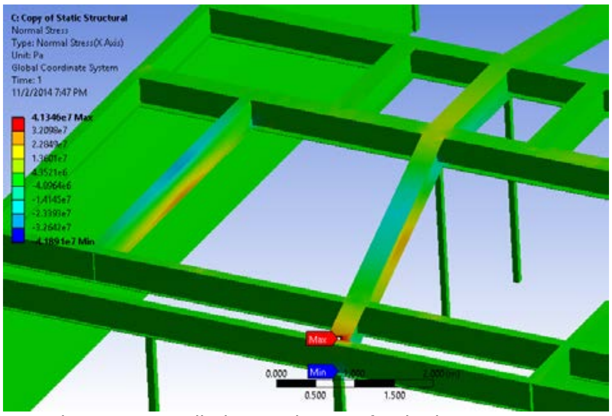

Figure 15. Detailed normal stress for the interest area

After analyzing the resulted values, it was depicted that there are no hotspots in the studied structure as the equivalent, shear and normal stress values are presented in table 3:

Table 3. The calculated stress maximum values

Equivalent stress $\left[\frac{N}{mm^2}\right]$	Normal stress $\left[\frac{N}{mm^2}\right]$	Shear Stress $\left[\frac{N}{mm^2}\right]$
50,427	41,346	11,137

Conclusions

Considering the analysis results all stresses in the structure are found to be acceptable.
This means the structure has been redesigned properly.

Bibliography

[1] General informations for the Rules and Regulations for the Classification of Ships, July 2014, Lloyd's Register
[2]http://www.indiamart.com/durgapur-environmental/products.html