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LOCAL STRUCTUAL ANALYSIS FOR CONTAINER SHIPS

Adrian Presura
University "Dunarea de Jos" of Galati,
Faculty of Naval Architecture, Galati, 111
Domneasca Street, 800201, Romania,
E-mail:adrian.presura@ugal.ro

VictorMihai
University "Dunarea de Jos" of Galati,
Faculty of Engineering, Galati, 111 Domneasca
Street, 800201, Romania,
E-mail:victor.mihai@ugal.ro

ABSTRACT

Container ships present highly stressed local structures under the corners of containers stack, which need rigorous analysis from rigidity and stress point of view. High value concentrated forces require the use of high strength steels or thick structural elements, for their analysis in this article, it was used the FEM analysis with volume elements. An inland navigation barge was used as a case study and 40 ft containers were considered in order to analyze the situation with the greatest forces at the feet of containers. The investigated solutions for containers foundation are applicable for new ships and also for modernization of existing vessels. Technological and strength aspects were compared for different types of solution, that have to comply with specific Rules and need to satisfy production constrains of the Shipyards.

Keywords: structural analysis, container, inland navigation

1. INTRODUCTION

This paper aims to investigate different structural solutions for containers foundation that can bring real improvements in Shipyard production and also in long-term operating of container vessels.

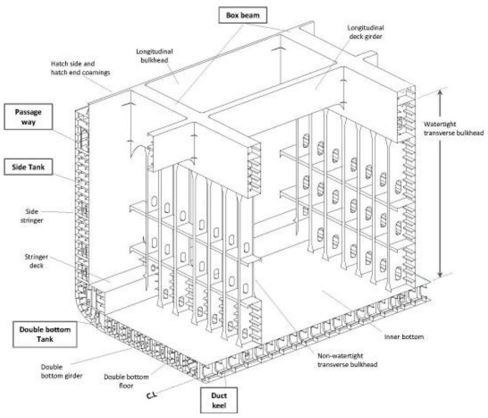

Fig.1 – Typical cargo hold configuration for a container ship [1]

The vessels able to transport containers are divided in two categories:
- specialized ships that can carry only containers (see figure.1)
- general cargo vessel that are equipped for transport of containers.

The first category, of specialized ships are designed from the beginning according to specific Rules for the purpose of transporting containers and they are built with particular foundations that are optimized to take the concentrated forces from the legs of the containers and to dissipate them in the adjacent structure. Thus, the cargo holds of this specialized ship will not be suitable for transport of other types of cargo.

The general cargo vessels need to be fitted with flat bottom cargo holds so as to facilitate loading/unloading and transport bulk, bale, or other general cargoes and also to permit loading of containers when needed. In consequence, the entire container foundation and additional supporting structure must be positioned under double bottom, so as not to impede the functionality of the holds for general cargo.

Basically, the foundations for containers, in the case of general purpose ships, consist of reinforced area of the double bottom shell and the necessary stiffeners placed under the double bottom to dissipate the concentrated loads from the legs of the containers.

The local reinforced double bottom shell can be performed as an increased thickness plate, a solution easy to be applied for new building ships, or as a doubler plate over the existing shell, a more suitable solution for modernization or repairing the existing ships. In the case of existing ships, the application of a doubler plate brings considerable technological and economic benefits, such as:
- drastically reduces labour and execution time
- easier welding process
- does not affect the structure below
- involves less added material.

Considering the obvious technological advantages of the doubler plate, in the following there will be presented a comparative analysis from a strength and rigidity point of view between the two solutions: increased thickness plate versus doubler plate.

2. STRUCTURE AND LOADS CONSIDERATIONS

For the case study, it was considered the structure of a river barge for general cargo that was adapted to container transport, selecting for the FEM model the local structure under a container leg situated at the intersection of the double bottom with the double side (see figure2).

The analysed structure has the following characteristics:
- double bottom thickness 10 mm
- web frame thickness 8mm
- transversal profiles under container leg - L profile 150x75x15
- reinforced double bottom shell under container leg in two variants with the identical overall thickness:
  - 25mm increased thickness
  - 15mm double plate welded above existing 10 mm plate.

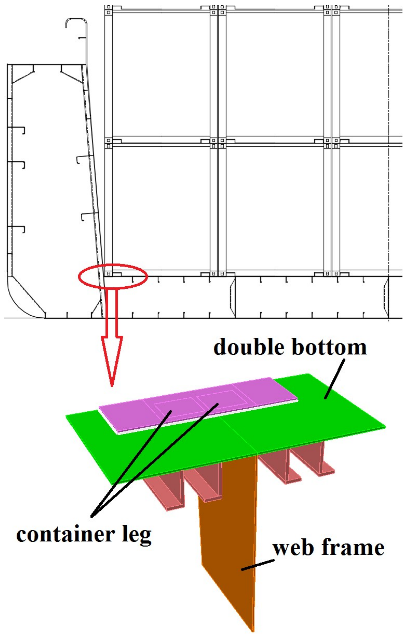

Fig.2 – Local structure under container leg

A fine mesh with volume elements, with average 5mm element size, was used for generating the calculation grid of the local structure.

Also, the 5mm fillet welding between doubler plate and double bottom shell was modelled with volume elements, and bonded type contact were defined between the welding and the adjacent plates.

The boundary conditions used in FEM calculation were (see figure3):
- symmetry condition on double bottom shell at fore, aft and from centre line edges
- X and Z blocked displacements and Ry blocked rotations at double side edge
- X and Y blocked displacements and Rz blocked rotations at bottom side of the web frame

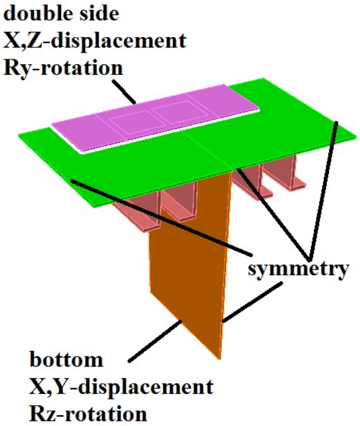

Fig.3 – Boundary condition

The total force acting on the container foundation was calculated at 500 kN, taking into account a vertical stack of 3 standard containers [2] of 40 ft and the vertical acceleration according inland navigation BV Rules [3].

3. FEM ANALYSIS OF CONTAINER FOUNDATION

The FEM analysis was performed with ANSYS Static Structural module. Standard grade A steel properties were considered for al structural elements.

A total of three analysis were conducted for the double bottom structure under container leg:

- Case1 - 25mm increased thickness
- Case2 - 15mm double plate welded above existing 10 mm plate, with no friction between the double plate and the double bottom plate (hypothetical case)
- Case3 - 15mm double plate welded above existing 10 mm plate, with 0.15 friction coefficient between the double plate and the double bottom plate.

In the following, there are presented the total displacement, equivalent stress (von-Mises), normal stress along principal bending direction and shear stress in vertical plane for the three analysed cases.

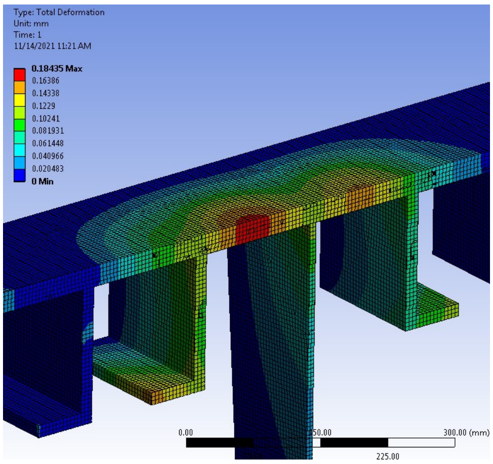

Fig.4 – Total deformation – Case1 - increased thickness 25mm

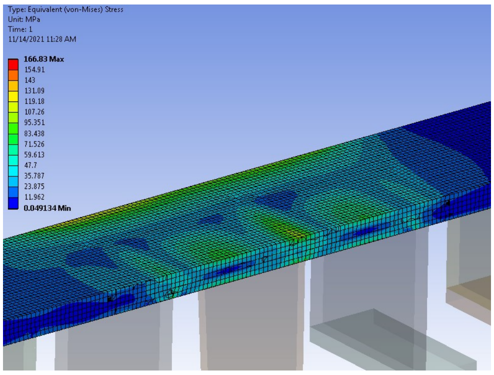

Fig.5 – Von-Mises stress – Case1 - increased thickness 25mm

For all the analysed cases the total deformation (see figure 4, 8 and 12) is between 0.18 and 0.30 mm, such small values can be neglected.

For case 1 the maximum equivalent stress is 167 MPa (figure5), less than maximum 219 MPa allowable stress for fine mesh FEM analysis according BV Rules [3].

The maximum normal stress (figure 6) occurs in the external fibres of the increased thickness plate along main bending direction (X axis) and has a value of 92 MPa for stretched fibre and 125 MPa for compressed fiber.

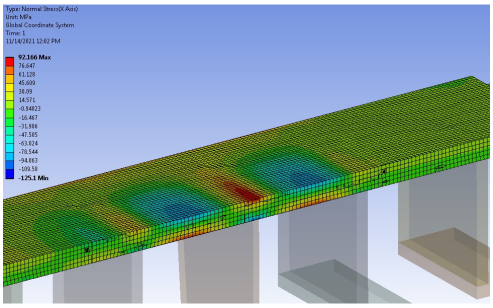

Fig.6 – Normal stress (X axis) – Case1 - increased thickness 25mm

The shear stress map (figure 7) reveals a 50 MPa shear stress in vertical plane adjacent to transversal L profile positioned under the double bottom shell.

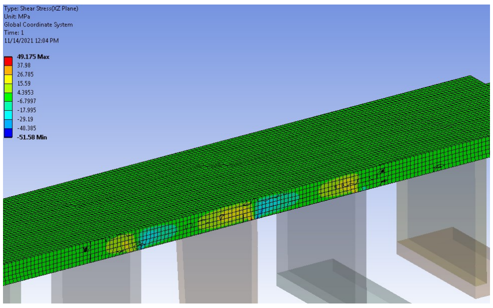

Fig.7 – Shear stress (XZ plane) – Case1 - increased thickness 25mm

The maximum equivalent stress of 167 MPa and the low stress areas in the middle part of the increased thickness plate, as shown in figure5, can lead us to the conclusion that the 25 mm thickness of double bottom can be reduced.

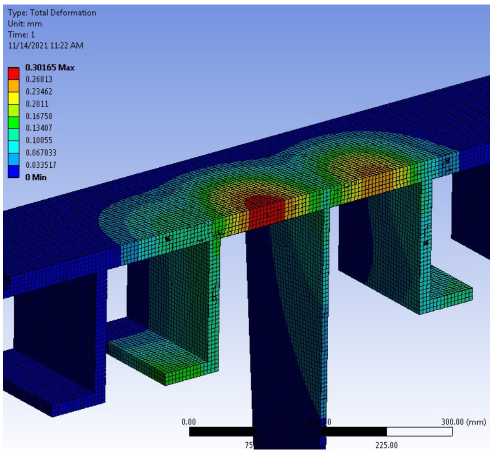

Fig.8 – Total deformation – Case2 – doubler plate 15mm – no friction

For case 2 the maximum equivalent stress is 228 MPa (figure 9), with 37% larger than Case1 and slightly larger than maximum 219.4 MPa allowable stress.

The maximum normal stress (figure 10) occurs in the external fibres of 15mm doubler plate and of 10 mm double bottom plate along main bending direction (X axis) and has a value of 223 MPa for stretched fibre and 237 MPa for compressed fiber, which represents an increasing with 90-140% compared to Case1.

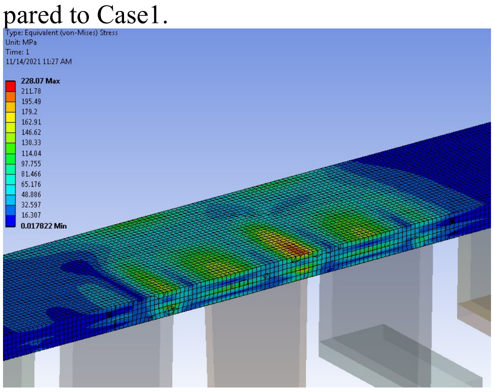

Fig.9 – Von-Mises stress – Case2 – doubler plate 15mm – no friction

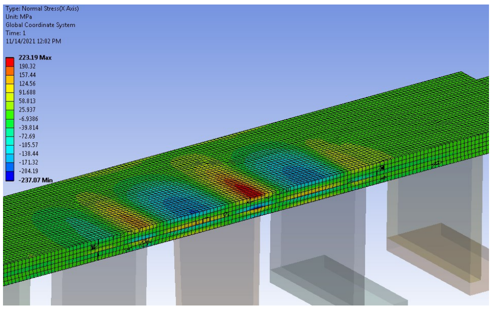

Fig.10 – Normal stress (X axis) – Case2 – doubler plate 15mm – no friction

The shear stress map (figure 11) reveals a 64-78 MPa shear stress in vertical plane adjacent to transversal L profile positioned under the double bottom shell, which represents an increasing with 30-56% compared to Case1.

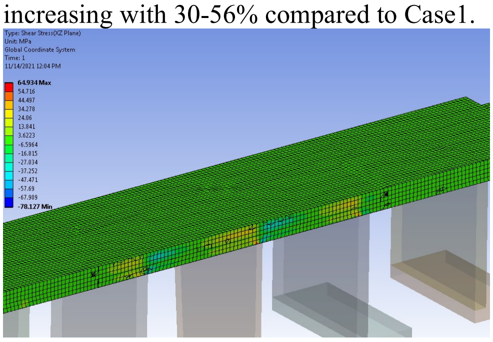

Fig.11 – Shear stress (XZ plane) – Case2 – doubler plate 15mm – no friction

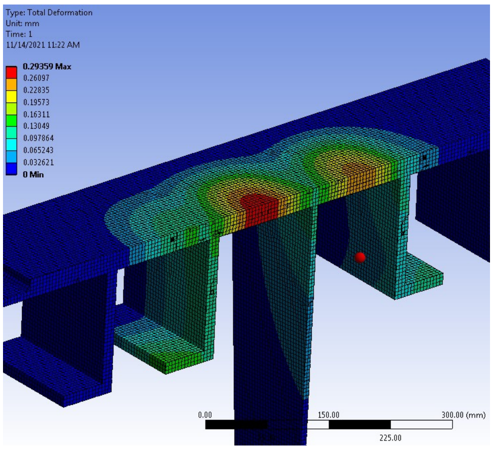

Fig.12 – Total deformation – Case3 – doubler plate 15mm – friction coefficient 0.15

For case 3 the maximum equivalent stress is 208 MPa (figure 13), with 25% larger than Case1 and less than maximum 219.4 MPa allowable stress.

The maximum normal stress (figure 14) occurs in the external fibres of 15mm doubler plate and of 10 mm double bottom plate along main bending direction (X axis) and has a value of 213 MPa for stretched fibre and 216 MPa for compressed fiber, which represents an increasing with 73-132% compared to Case1.

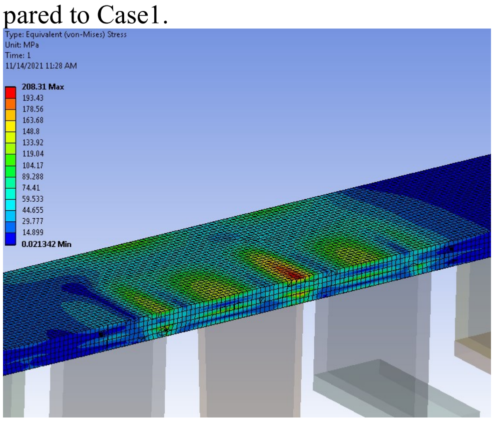

Fig.13 – Von-Mises stress – Case3 – doubler plate 15mm – friction coefficient 0.15

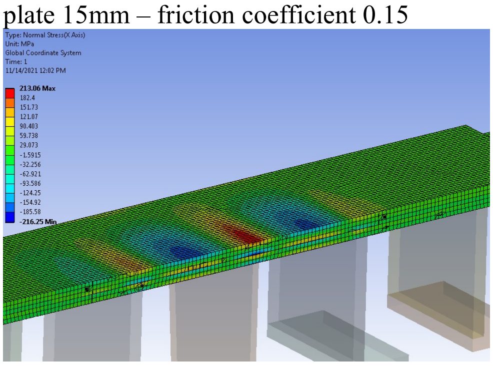

Fig.14 – Normal stress (X axis) – Case3 – doubler plate 15mm – friction coefficient 0.15

The shear stress map (figure 15) reveals a 62-75 MPa shear stress in vertical plane adjacent to transversal L profile positioned under the double bottom shell, which represents an increasing with 30-56% compared to Case1.

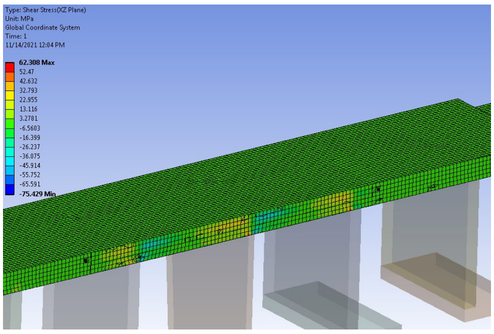

Fig.15 – Shear stress (XZ plane) – Case3 – doubler plate 15mm – friction coefficient 0.15

A summary of the results obtained for all FEM analysis cases is presented bellow:

	vonMises [MPa]	Normal Stress-X [MPa]	Shear Stress-XZ [MPa]	Computing time [minutes]
C1	167	+92 -125	+49 -52	5.1
C2	228 +37%	+223 -237	+64 -78	75.38
C3	208 +25%	+213 -216	+62 -75	68.1

Case 2, with no friction between the doubler plate and the double bottom plate, is an hypothetical situation and it was analysed only for comparison purposes.

The only notable difference between case 1 and case 3 refers to the von-Mises tension, 25% difference, which is mainly due to the bending along the X axis, significantly lower bending in the case of the increased thickness plate of 25mm.

4. CONCLUSIONS

This paper proposed to present a comparative analysis between the two strengthening solutions for double bottom shell: increased thickness plate and doubler plate.

Comparing the behaviour of the two solutions under the action of the concentrated force from the container legs, the following conclusions can be drawn:
- the total deformation of the double bottom shell is negligible, so both solutions can be considered similar,
- the equivalent stress (von-Mises) is higher for the doubler plate solution with 25% in Case3, when friction was considered,
- the frictional contact used for doubler plate affects significantly the computing time.

As a general conclusion of the analysis presented in this paper, it can be stated that the solution with doubler plate confers similar strength with an increased thickness equivalent plate, and due to the technological advantages it is more suitable in modernization or repair of existing ships.

Acknowledgements

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