Structures strength verification of 40,000 DWT double hull product tanker.

J. M. Szpiek[a] & A Jazukiewicz[b]
[a]*Division of Hull Structure Design of Szczecin Shipyard SA, Poland.*
[b]*Ship's Theory & Basic Design Department of Szczecin Shipyard SA, Poland*

Abstract.

The present work outlines structural strength verification procedures used for construction of double skin 40,000 DWT product tanker being built in Szczecin Shipyard S.A. The verification has been based on following computational procedures required by Lloyd's Register Classification Society and Owner's:

1. Procedure '*ShipRight Structural Design Assessment*' [1]:
   - Analysis of hull cargo part strength using finite element method,
   - Local analysis of hull parts strength.
   - Analysis of cargo tanks strength under stresses caused by liquids sloshing in partially filled tanks ('*ShipRight Sloshing Loads and Scantling Assessment*' [2]).
2. Procedure '*ShipRight Fatigue Design Assessment*' [3].

1. General description of the hull.

Principal dimensions of vessel are the following :

Length over all	183.0 m
Length between perpendiculars	172.4 m
Breadth	32.2 m
Height	17.6 m
Draught	12.0 m
Speed	14.5 kn.

It is a ship of double hull tanker-product carrier having longitudinal stiffeners layout with 0.85 m spacing and transverse framing with 3.4 m spacing. Cargo tanks are divided by vertically corrugated centreline bulkhead. Horizontally corrugated transverse bulkheads are supported by vertical web frame located in the middle of bulkhead span.

2. ‘ShipRight Structural Design Assessment’ procedure.

2.1 Verification of hull global strength.

The basic numerical model used to verify hull strength properties was a 3-D model of three midship cargo tanks. Analysed part of the model was reduced to an insert spanning over one and a half tanks using a transverse symmetry concept, Fig. 1 [6]. Moreover, it was assumed that geometrical characteristics of the ship are constant along length. The basis for numerical model preparation was design documentation of ship cargo section prepared according to Lloyd's Register requirements [1]. The model was built using a finite elements library of programs NISA-II/DISPLAY III [16,17].
The statistics of course mesh of finite element model were following:

11 628	nodes
14 103	3-D general shell quadrilateral elements / 4 nodes per element
103	3-D general shell triangle elements / 3 nodes per element,
3850	3-D general beam elements / 2 nodes per element
485	3-D general spar elements / 2 nodes per element.

Model boundary conditions were assumed taking into account cross-section lateral symmetry, end section support conditions and limitations of model motions as a rigid body.

Loads were determined as linear combinations of hull hydrodynamic loads (internal - caused by cargo pressure and external - caused by pressure of water) and tension/compression loads due to hull bending on still water and waves. Pressure distribution was modelled as a function of scalar pressure field. Loads perpendicular to hull section were determined assuming linear stress distribution along the depth of the hull. Maximum hogging and sagging moments on still water within loading range and maximum wave moment values have been assumed [1,4].

Numerical calculations were performed and then obtained results were analysed and compared against admissible limits of stresses, deformation and buckling coefficient. Design (and the FE model) was modified wherever it proved to be necessary, and calculations cycle was repeated until criteria defined by SDA procedure were met.

According to Classification Society requirements detailed strength analysis results from the last cycle were presented in a report being the basis for an approval of design documentation.

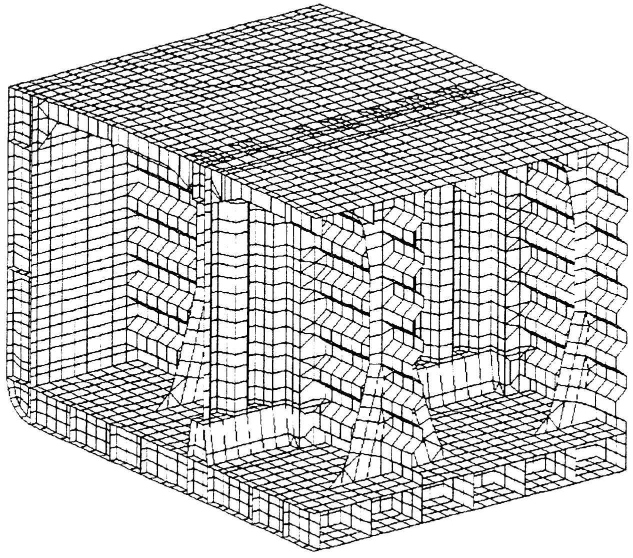

Fig. 1. Coarse mesh of 3-D FE Model of Hull Structure.

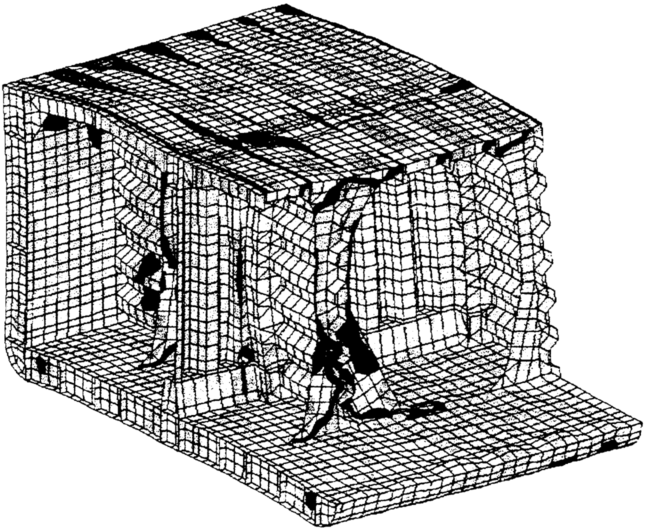

Fig.2. Von-Mises Stresses Results (LoadCase1).

The report contained [6]:

1. Descriptive part presenting the procedure, assumptions taken, the model and analysis results.
2. Graphical presentation of stresses distribution in primary members for successive loading states.
3. Graphical presentation of primary members displacement distribution for successive loading states.

2.2 Verification of local hull construction strength.

According to SDA procedure requirements additional calculations of local 2-D and 3-D models were performed in areas of high stress concentration or wherever important structural details were omitted in the model (e.g. lightening holes, communication cut-outs, scallops).

Mentioned FE models were prepared by extraction of global model part and repeated subdivision into fine mesh of appropriate density being an exact representation of actual structure geometry, Fig. 3 and 5.

The loading of so prepared models were displacements of their boundary nodes extracted from the global model area in question. The displacements of additional boundary nodes created in the process of mesh refinement were calculated by means of linear interpolation. Local loads acting on the sub-model surface (cargo, ballast, water pressures) were also taken into account.

So defined local hull strength verification was applied to :

- Transverse web frame, Fig. 5. [8].
- Vertical frame supporting transverse corrugated bulkhead, Fig. 3, [7].

Moreover, verification of following construction joints strength was carried out:

- Joint of CL crane pedestal with adjacent deck structure [10].
- Joint of bow stopper with adjacent deck structure, Fig.4 [15].
- Cargo and bunker manifolds supports [13].
- Double bottom structures under docking loads [12].
- Deck of superstructure [14].

Numerical calculations were performed and then obtained results were analysed and compared against admissible limits of stress. Design (and the model) was modified wherever it proved to be necessary, and then calculations cycle was repeated.

Same as before, detailed strength analysis results from the last cycle were presented in a report being the basis for an approval of design documentation.

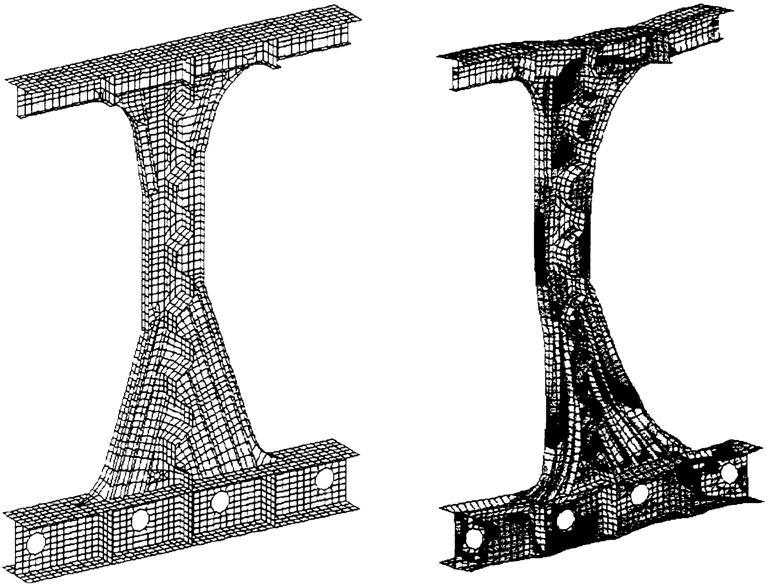

Fig.3. Bulkhead Web Frame Fine Mesh Model and Von-Mises Stresses.

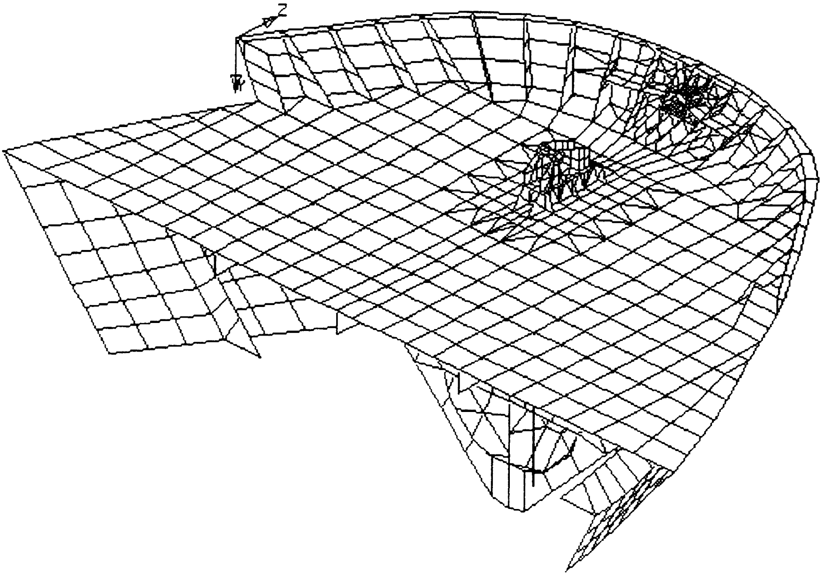

Fig.4. Bow Region Structure FE Model.

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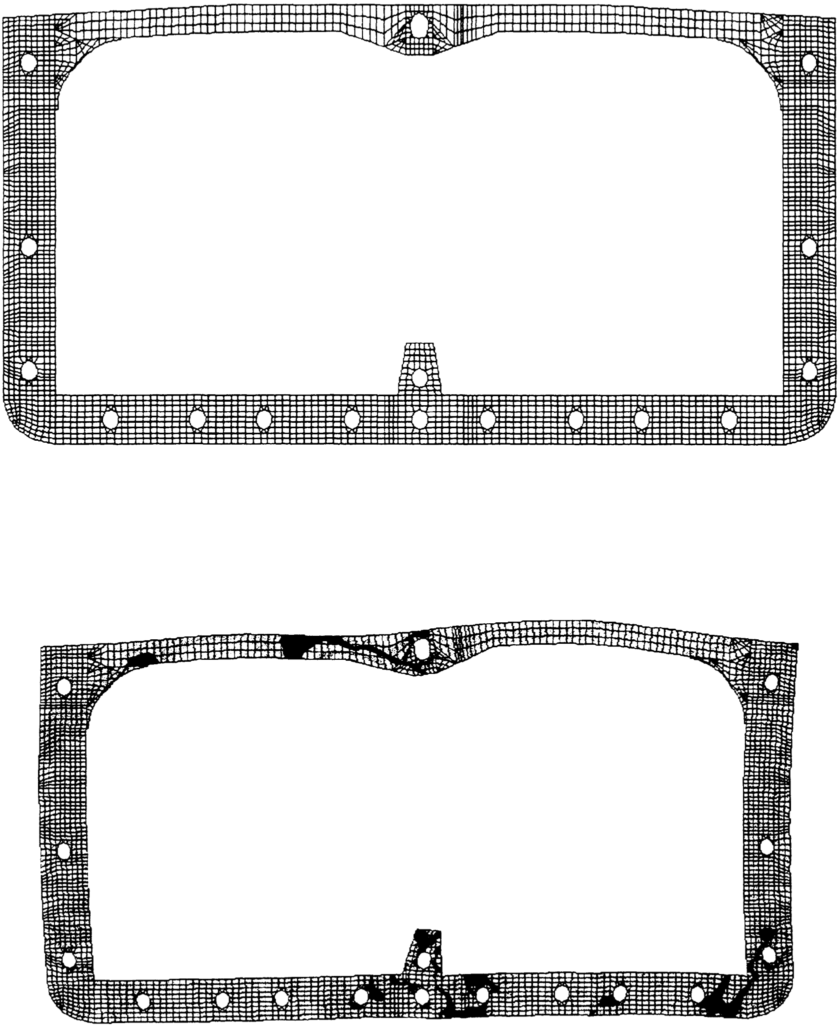

Fig. 5. 2-D Web Frame Fine Mesh Model and Von-Mises Stresses Results.

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2.3 Strength of tank structures due to sloshing pressure in partially filled tank.

Analysis of tanks construction strength in partially filled condition was carried out on the basis of *'ShipRight - Sloshing Loads and Scantling Assessment'* [2]. Analysis was done for tank filling states from 10% to 98%. According to SDA -SLSA it was assumed that liquid motions inside the tank may be a cause of structurally significant impact pressure in following cases:

- where the natural period of the fluid and the ship natural rolling period are within 5 seconds of each other, or
- where the natural pitching period of the fluid is greater than a value of 3 seconds below the ship natural pitching period.

Depending on relation between cargo and ship motion periods different methods are used for calculation of following pressure [9]:

Level 1 - *equivalen*t static pressure,

Level 2 - *equivalent* static pressure adjusted for following tank areas:

- upper and lower hopper tank,
- tank corners,
- accounting for *'funnelling effect'* in tanks of variable cross-section.

Level 3 - distribution of pressure in the tanks for successive filling states calculated on the basis of numerical analysis of fluid oscillating motion and ship's motions, (Fig. 6. program FLUIDS [2]).

Safety factor has been computed using obtained *effective* static pressure as well as panels and stiffeners dimensions data; next, it has been compared with its admissible limit given in [2]. In case of non-compliance, the tank design was modified [9].

3. 'ShipRight Fatigue Design Assessment' procedure.

The fatigue life estimations were calculated using methodology known as the *„maximum life time loads"* approach. The maximum life time loads were calculated on the basis of a 20 year life on the North Atlantic with a probability occurrence of 10^{-8} and ship's service factor 1.0. However, a trading vessel spend a considerable amount of time in less severe conditions, hence a relaxation of the long-term stress history is assumed to conform Weibull distribution having a shape factor of 0.84 (LR's usual procedure for this ship type). The vessel were assumed to spend 50% of its sailing time in ballast and 50% in a full condition. The stress history of the structural detail can be obtained from the load history by application of the life term maximum load to suitable FEM detail model and use of the Weibull distribution. The response at each of analysed details were considered as the summation of the number of effects:

1) primary hull girder response,

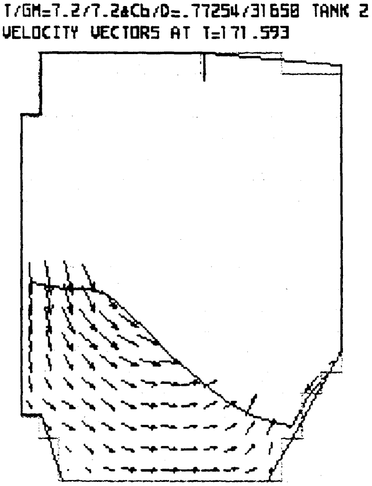

Fig. 6. 2-D Tank Mesh FD Model and Plot of Velocity Vectors.

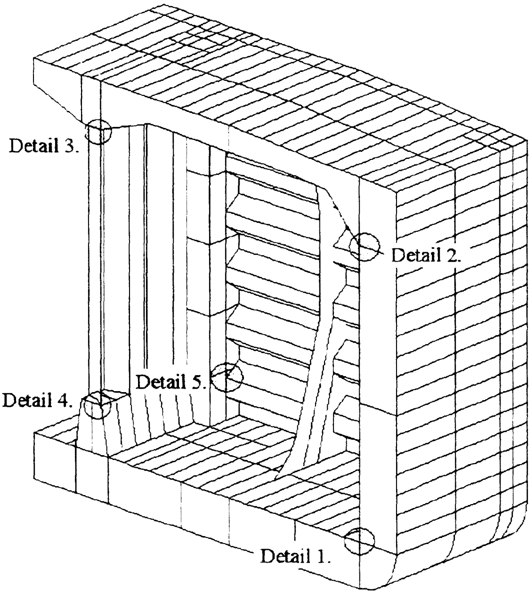

Fig. 7. FE Model Showing Fatigue Analysis Locations.

2) primary structural response due to the effects of ship's motions on cargo and ballast.
3) primary structural response due to the local effects of wave passage.

Finally, fatigue damage were obtained from the stress history by use of the Miner's summation. The Miner's method sums, over the ship's lifetime, the ratios of the number of cycles at each applied stress range divided by the number of cycles at the same stress range on the relevant S-N curve defined by the joint class of the structural detail [5].

The objective of the analysis was to determine whether the predicted fatigue lives of the following structural connections exceed the Owner's specified requirement, Fig. 7:

1) Inner skin bulkhead-inner bottom corner tank.
2) Toe of deck transverse at inner skin.
3) Centreline bulkhead to upper stool (midhold frame and typical location).
4) Centreline bulkhead to lower stool.
5) Centreline bulkhead-transverse bulkhead

The Shipyard prepared a global FE model on the NISA system for SDA stress analysis and this model was imported to MSC/PATRAN P5 by LR [5]. Appropriate boundary parts of the 3-D global model were extracted for the preparation of local fine mesh models, using element mesh size similar to element thickness (TxT) in way of fatigue check points.

Figure 5 shows a section of the model at the midtank, which indicates the locations of fine mesh models 1 to 5. Cargo, ballast, waves and hull bending loads were applied to the global model, to obtain boundary displacements for the fine mesh model. Corresponding pressure loads were then also applied to the fine mesh models, as appropriate for their location.

4. Conclusions.

Strength verification procedure of ship structure were initiate in Szczecin Shipyard during designing process of two product-tanker projects.

The results of verification calculations carried out by Szczecin Shipyard and Lloyd Register indicate a very satisfactory situation with respect to structure safety and fatigue longevity for the details analysed, and the predicted lives are well above the Owner's requirements.

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