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ANALYSIS OF SHIP STRUCTURAL DETAILS BY A TOP-DOWN METHOD USING RESULTS FROM A MAESTRO ANALYSIS

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Abstract

A method for performing a stress analysis of a ship structural detail using the results from a MAESTRO analysis is described. The method was a top-down procedure where a portion of the MAESTRO model was modelled in considerable detail using a detailed finite element grid with boundary nodes matching the MAESTRO model. The displacements obtained at the boundary nodes from the MAESTRO analysis were applied to the refined model and a finite element analysis was carried out using the finite element program VAST. The comparison of results shows that a MAESTRO analysis alone cannot determine the stress concentrations that occur in a structural detail such as an opening in a deck. When combined with a top-down procedure however, a more accurate assessment of the detail stresses can be obtained.

Résumé

Description d'une méthode d'analyse des contraintes d'un détail de structure de navire en utilisant les résultats d'une analyse MAESTRO. La méthode utilisée fait appel à une procédure allant du haut vers le bas dans laquelle une partie du MAESTRO était modelée à l'extrême dans le détail à l'aide d'une grille d'éléments finis avec des noeuds limites compatibles avec le modèle MAESTRO. Les déplacemants obtenus aux noeuds limites à partir de MAESTRO ont été appliqués au modèle raffiné et une analyse par éléments finis a été effectuée en utilisant le programme VAST. La comparison des résultats indique qu'une analyse MAESTRO seule ne permet pas de déterminer les concentrations de contraintes qui se produisent dans un détail de structure comme une ouverture dans un pont. Cependant, lorsqu'on lui associe une procédure allant du haut vers le bas on obtient une évaluation plus précise des contraintes du détail.

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1 Introduction

The computer code MAESTRO[1] has been developed for the finite element analysis of the global structural behaviour of ship hulls. When used for such an analysis, details such as stress concentrations around openings and other geometries which require fine grids cannot be assessed. MAESTRO can, however, provide boundary conditions for fine mesh models of structural details generated for a general purpose finite element code.

This report describes the process of using boundary conditions from a MAESTRO analysis of a ship, subjected to a sagging condition sea load, to obtain detailed stresses around an opening in the deck. The method used for the process was a top-down procedure where displacements from the MAESTRO analysis were applied to the boundaries of a refined finite element model of the deck. The resulting stresses were obtained using the finite element program VAST[2]. The stress results of the MAESTRO analysis and the top-down method are shown and compared. The top-down method was also used to assess the effect of the model size on the stress results obtained from the refined models.

2 The MAESTRO Model

The MAESTRO model was of the entire ship as shown in Figure 1. The largest entity in the model was a MAESTRO substructure. There were three substructures in the model as illustrated in the schematic of the model in Figure 2. The first was from the stem to frame 34, and the second was the length aft of frame 34. The third substructure was the superstructure which was removed for one of the analyses. Each of the substructures was divided into modules. There are 6 modules in substructures 1 and 2, and 5 in substructure 3. Each module was used to model a portion of the ship structure which maintained approximately the same cross-section shape. They linearly increased or decreased in overall size along the length of the ship over their length. In this way modules were used to define geometry as well as specific components such as superstructure.

The modules were divided into strakes. The strakes stretched from one end of a module to the other. They made up the module cross-section as shown in the midship cross-section in Figure 3. The strakes were of uniform plate thickness and, as in this case, had uniformly spaced identical longitudinal stiffeners smeared into the strake cross-section giving an equivalent cross-section area. The strakes resisted in-plane loads but not lateral loads which cause bending. Girders in the structure were defined as beams running along the edge of the strakes and they provided axial and bending stiffness to resist in-plane and lateral loads.

The strakes were divided along their length by uniformly spaced transverse frames. Longitudinal frame divisions are called sections in which the frames are modelled as beam elements resisting both axial and lateral loads. The frame cross-sections were constant over the width of a strake but were varied as required from strake to strake. The ship model is shown without the superstructure in Figure 4. Module 1 of substructure 2 contained the midship region of the ship which is the area where the study of detailed stresses was made. When generating the MAESTRO model, elements were removed from the weather deck to represent large openings in the structure. The coordinate system for the model, as shown in Figure 2, was a right handed system with the X axis the longitudinal axis placing zero at the forward perpendicular. The Y axis was the vertical axis with zero at the keel. The Z axis was positive to port.

2.1 Model Loading

The model was loaded by a static balance on a wave. Sagging due to a 8 metre wave height was the loading case used. The wave length, wave amplitude (in this case 4 metres), the location of the wave peak and the trim angle were defined. This data was translated into concentrated loads and applied to the MAESTRO element nodes at the frame and strake edge intersections or at explicitly defined nodes. The structural weight was defined by the density of the elements. The non-structural weight was defined at each section interval where it was distributed uniformly over the corresponding cross-section. The static wave balance was obtained by the use of the program TRIM[3].

2.2 MAESTRO Model Results

The longitudinal XX stresses in the deck obtained from the MAESTRO analysis of the model, including the superstructure, are shown as colour fringes for the sagging case in Figure 5. The fringes were obtained by using the VAST Visualiser[4] post-processing program. The box around the model was created by the Visualizer from the process required to remove the superstructure to make the deck beneath it visible. The maximum compressive stress in this case was -138.2 MPa.

The XX stresses in the deck are shown in Figure 6 for the analysis conducted with the superstructure removed, but with its mass included. The stresses of -138.2 MPa for the model with the superstructure and -143.2 mpa without show that the presence of the superstructure reduces the stresses in the deck.

The region of the largest deck opening was enlarged to show the stress colour fringes in greater detail. The maximum compressive stress as seen in Figure 7 was -138.20 MPa. This coarse grid showed the need for a finer model to assess the presence of stress concentrations around the opening.

3 The Detailed Deck Models

A detailed finite element model of the deck (in VAST format and initially covering frame 27 to frame 32.5) was created to investigate the stress concentrations around the deck openings. It was generated from a hull data base obtained by digitizing tranverse section drawings of the ship. The longitudinal structure for the deck was generated from the tranverse data. The program VASGEN[5] was used to combine the individual components into a single structure. The model included the fore and aft bulkheads between decks one and two. The grid was refined in the region of the holes in the deck to account for stress concentrations. The grid was generated from the VAST library of elements, using the general beam, the three-noded triangular plate, and the four-noded quadrilateral shell. The model is shown in Figure 8.

Care was taken in the modelling to match the detailed model boundary nodes with the MAESTRO nodes. There were locations where the number of detailed model boundary nodes exceeded the MAESTRO nodes along the boundary edge, such as in the transverse direction across the deck. The extra boundary conditions required were obtained by interpolation of the MAESTRO nodes boundary conditions. The locations of the detailed model boundary nodes are shown in Figure 9.

To assess the effect of model size three additional models were created. The first of these models was extracted from the large model as the minimum model to examine the stress concentration at the the major hole in the deck. It is shown in Figure 10. The second or intermediate model, as illustrated in Figure 11, was increased in size to include the edge of the deck with two frame stations added forward and three frame stations added aft. In the third of the models, two more frame stations were added at each end as shown in Figure 12. In this case the finite element grid at the fore and aft boundaries was adjusted to match the MAESTRO grid thereby eliminating the need to interpolate the displacements for the extra boundary nodes. The boundary nodes assigned displacements are shown in Figure 13.

4 Top-down Analysis of Deck

Top-down analysis is based on applying the boundary conditions obtained from a previous coarse model analysis, such as a MAESTRO analysis, to a detailed model of a region of the coarse model. The boundary conditions are in the form of displacements at the boundary nodes for each of the degrees of freedom. In the case of the detailed deck models three translations and three rotations were obtained. They were then applied to the VAST detailed finite element models of the portion of the deck as prescribed displacements. The nodes to which the displacements were applied were listed in the VAST stiffness modification file PREFX.SMD. If loads had been present they would have been stored in the VAST file PREFX.LOD. With these conditions set the finite element analysis of the top-down model was carried out.

4.1 Top-down Model Results

The longitudinal XX stresses in the models are presented, for the top-down analysis, in the form of colour fringes for the sagging condition load condition. The XX stresses from the analysis of the deck detail, from frames 27 to 32.5 with superstructure, are shown in Figure 14. The XX stresses from the top-down analysis of thedeck detail from frames 27 to 32.5 without superstructure are shown in Figure 15. The fringes show maximum compressive stresses of

-289.19 MPa and -321.09 MPa respectively. These stresses occurred in a door region in one of the longitudinal bulkheads and were not significant in this analysis as the grid in the door region was not designed specifically to investigate that region. The deck grid was designed to focus mainly on the region of the deck openings with special concentration on the large opening. The largest compressive stress in the port side of the opening was -230 MPa with the superstructure and -239 MPa without the superstructure.

The XX stresses from the top-down analysis of the minimum model of the large opening in the deck, with superstructure, are shown in Figure 16. The most negative stress in this case was -212 MPa.

The XX stresses from the top-down analysis of the intermediate model of the large opening in the deck, with superstructure, are shown in Figure 17 with a largest compressive stress of -231 MPa. This stress occurred at the port side of the deck opening.

The XX stresses from the top-down analysis of the extended model of the large opening in the deck, with superstructure, are shown in Figure 18. The largest compressive stress in this case was -247 MPa which occurred at a door opening in one of the longitudinal bulkheads. The largest negative stress in the deck opening was -228 MPa on the port side.

5 Comparison of the Results from the Models

The results from the models are compared using the XX longitudinal axis stresses. They were obtained for the same point of stress concentration at the port side of the large deck opening. The comparison is shown in Table 1.

Table 1: Comparison of Stresses At Large Deck Opening for the MAESTRO, Top-down and Botton-up Models

Analysis	Model	XX Stresses (MPa)
MAESTRO	MAESTRO Model+Superstructure	-138
	MAESTRO Model-Superstructure	-143
Top-down	Deck+Superstructure	-230
	Deck-Superstructure	-239
	Minimum Model	-212
	Intermediate Model	-231
	Extended Model	-228

The table shows that the MAESTRO analysis did not properly represent the stress concentration around the large opening. It also shows that the intermediate model of the top-down analysis gave the highest stress for the stress concentration at the opening. The large deck model, which was the most representative of the deck, produced the next highest stress. It's value was probably the most accurate of all the stresses. The extended model actually encroached into the area where other holes were present, without including them in the grid, which could account for it's lower stress values. The minimum model was the least accurate in representing the stress concentration being 8 percent lower then the large deck model. It does however have the considerable advantage of being a much more economical model. The effect of the superstructure in lowering the deck stresses, as indicated by the MAESTRO analysis, was confirmed by the detailed analysis.

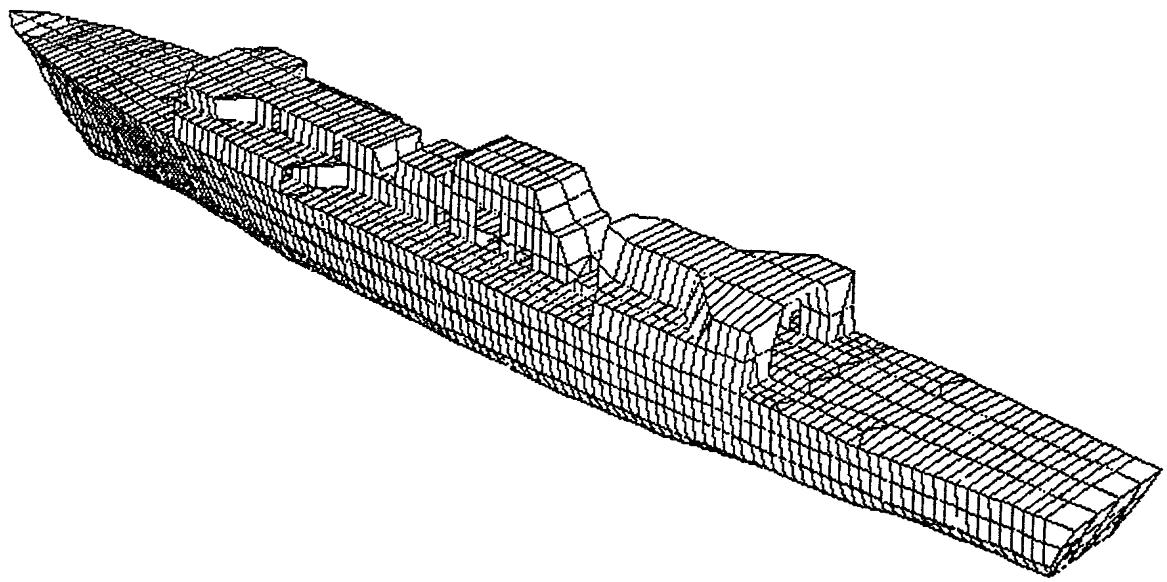

Figure 1: The MAESTRO Model of the Ship

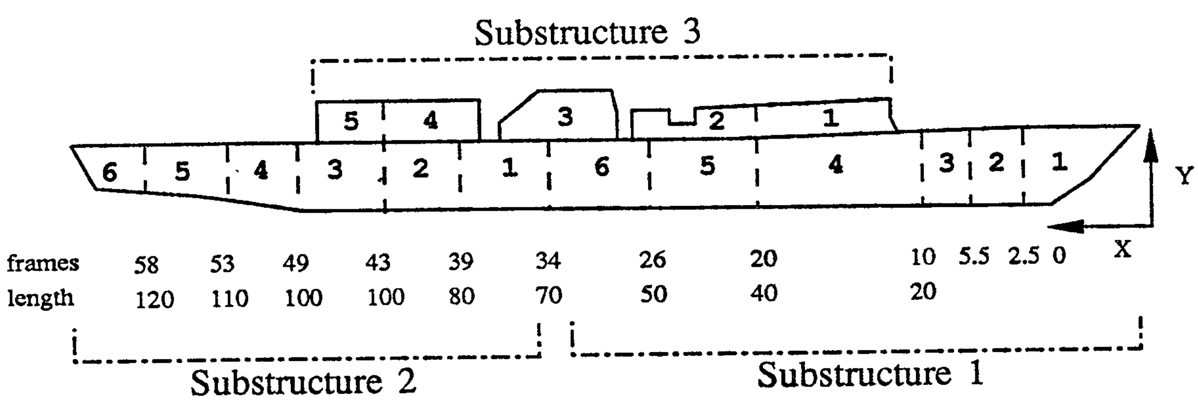

Figure 2: Schematic of the MAESTRO Model Showing the Substructures and the Modules

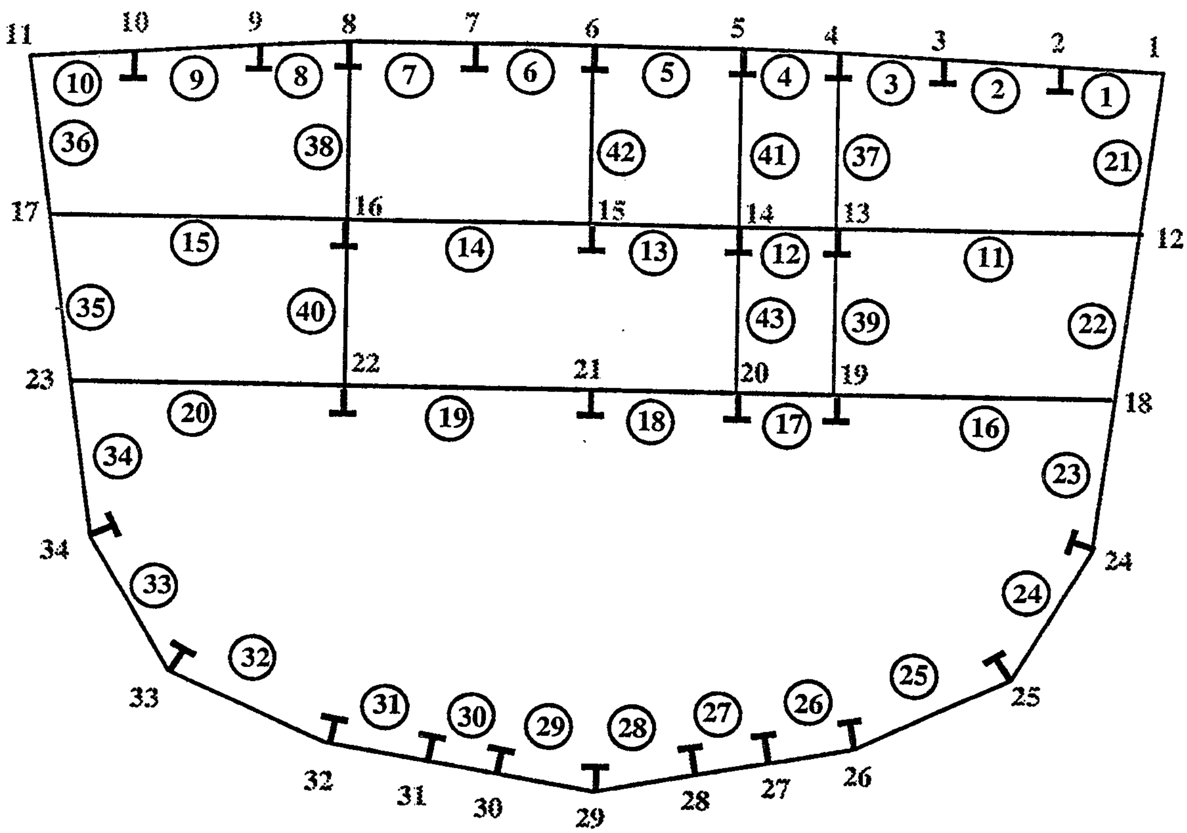

Figure 3: Midship Module Cross-section Showing the Location of the Strakes and Nodes

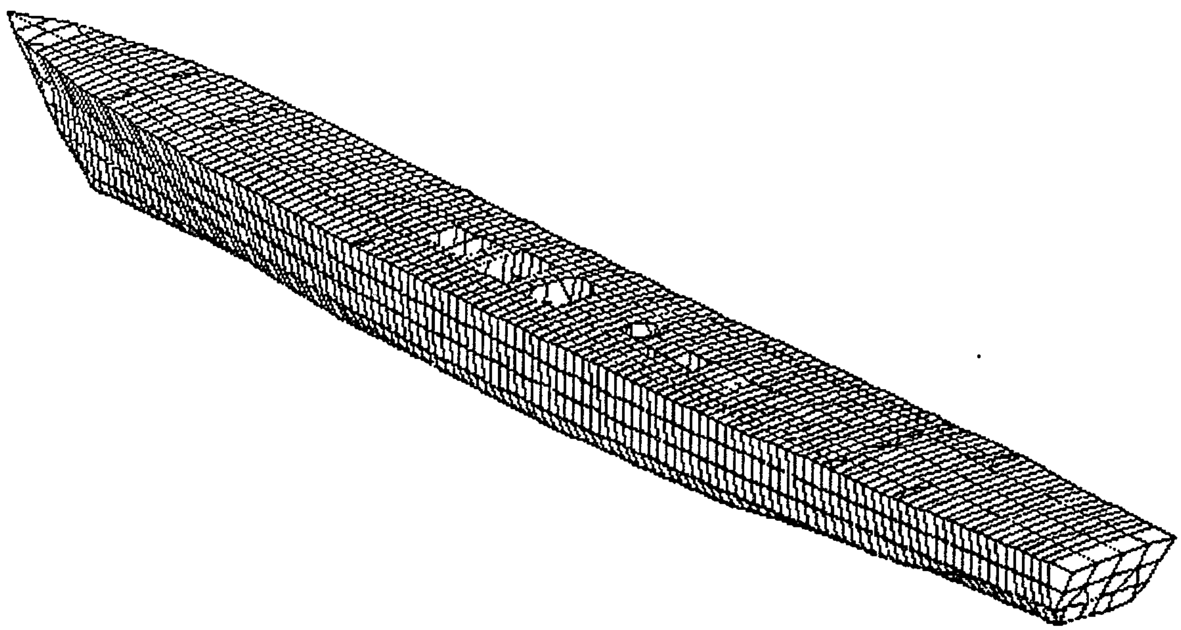

Figure 4: MAESTRO Model with the Superstructure Removed

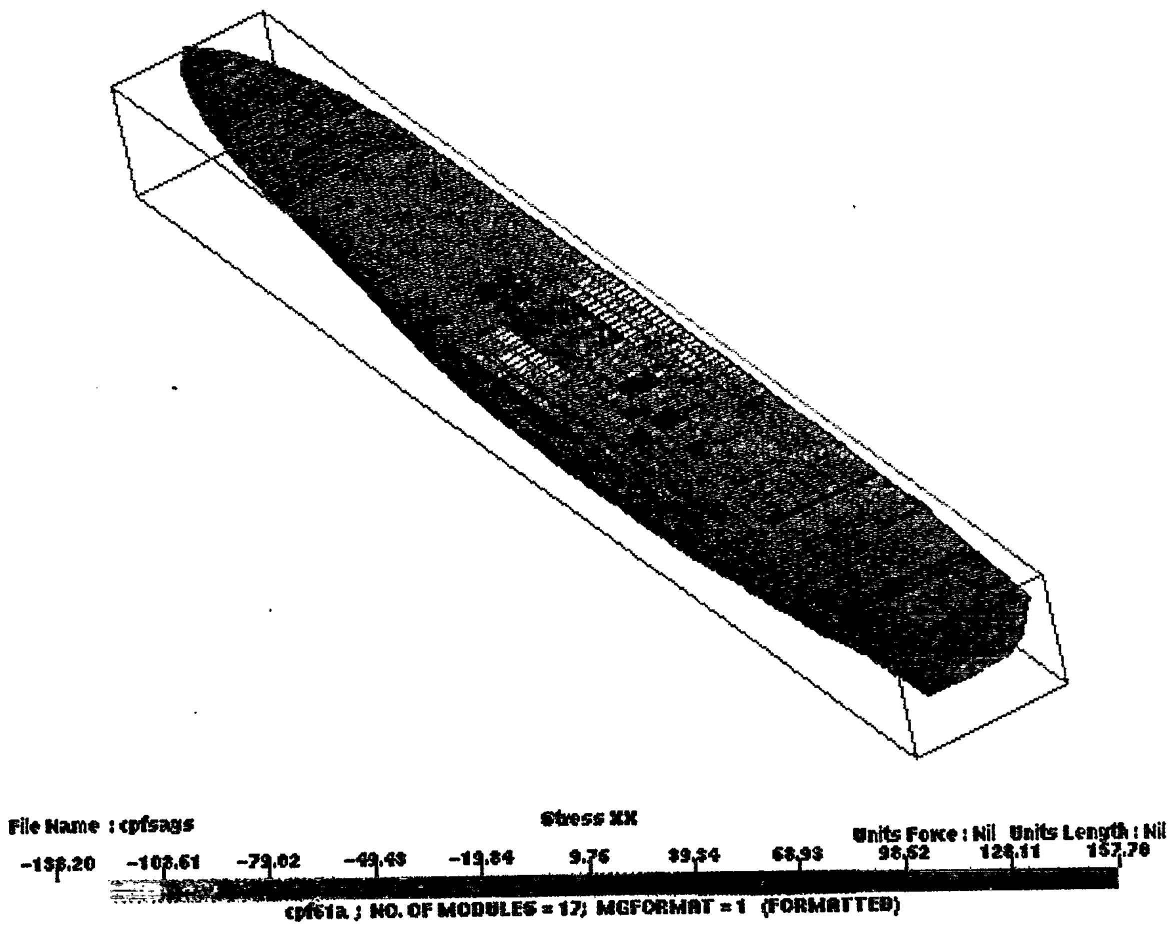

Figure 5: The MAESTRO Model Analysed with Superstructure, Showing XX Stresses in the Deck for a Sagging Load

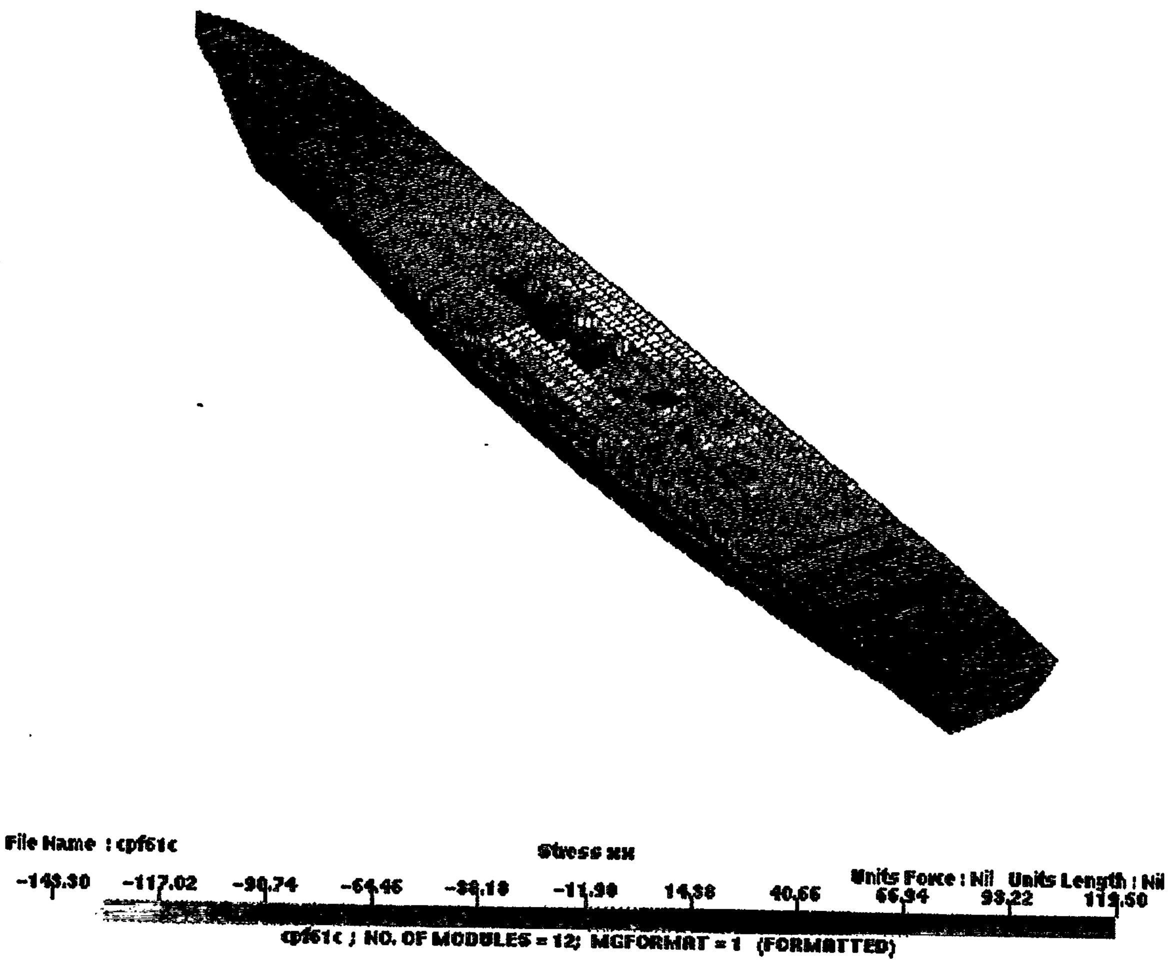

Figure 6: XX Stresses in MAESTRO Model Deck when Loaded without the Superstructure

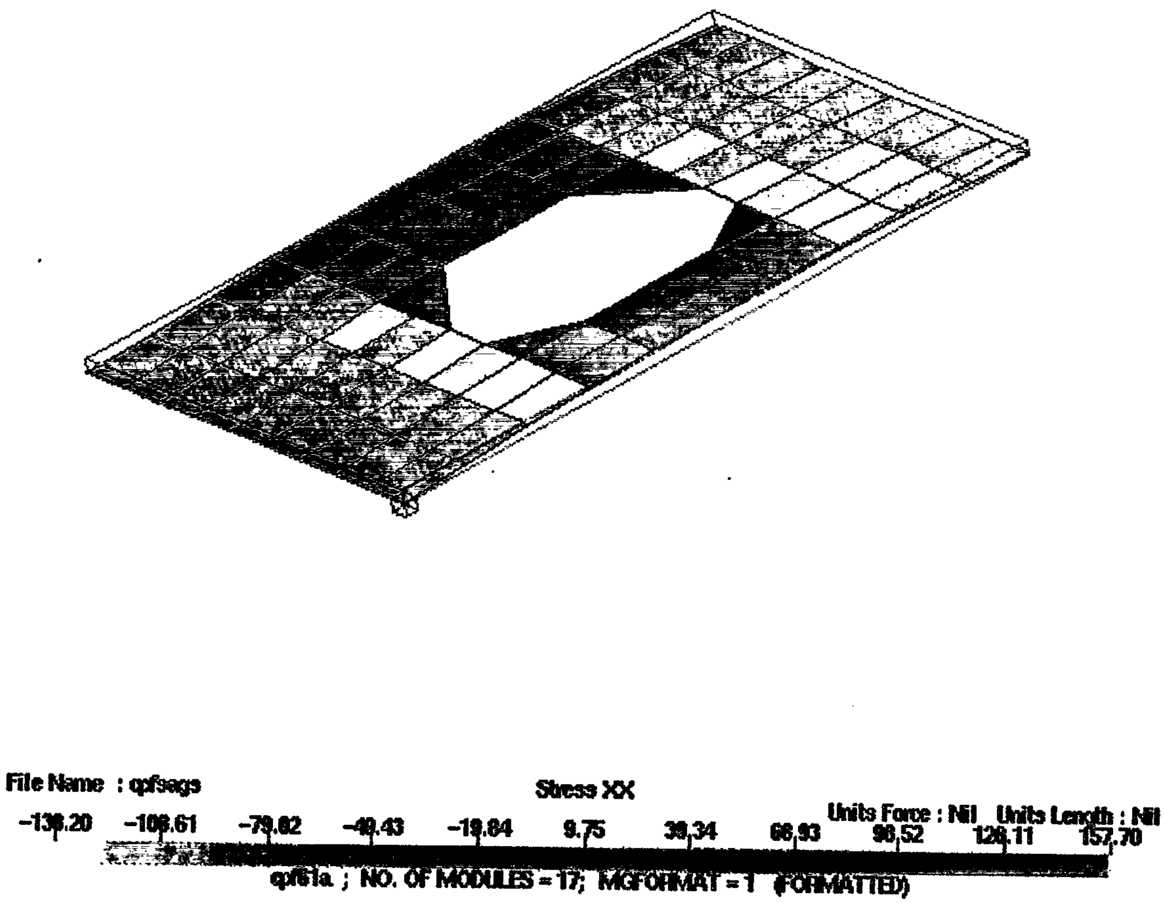

Figure 7: An Enlarged View of the Stresses at the Large Deck Opening in the MAESTRO Model for a Sagging Load

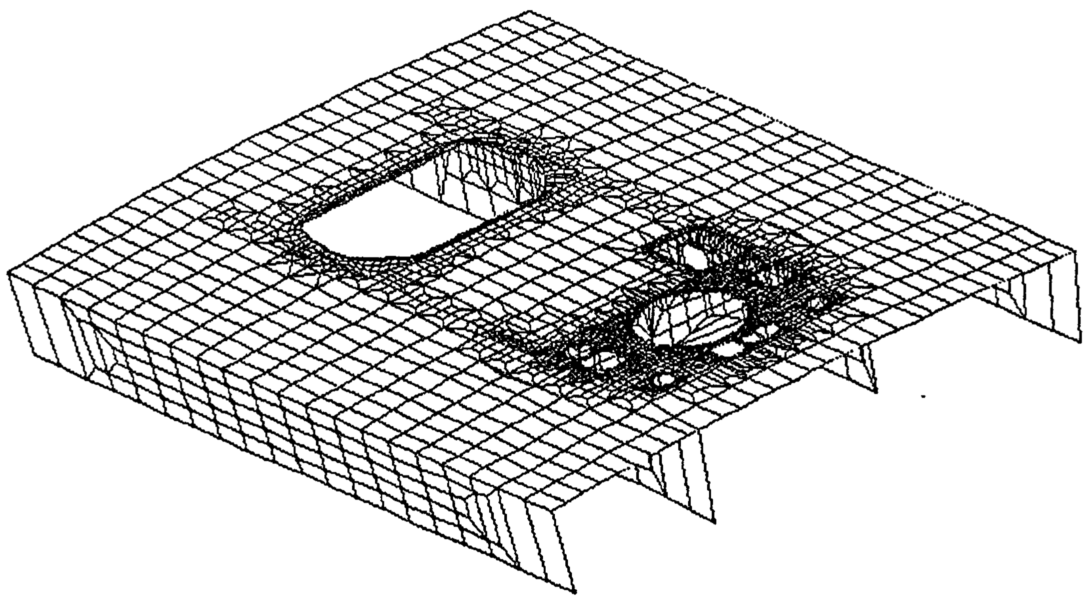

Figure 8: The Refined Grid of VAST Model of the Deck from Frames 27 to 32.5

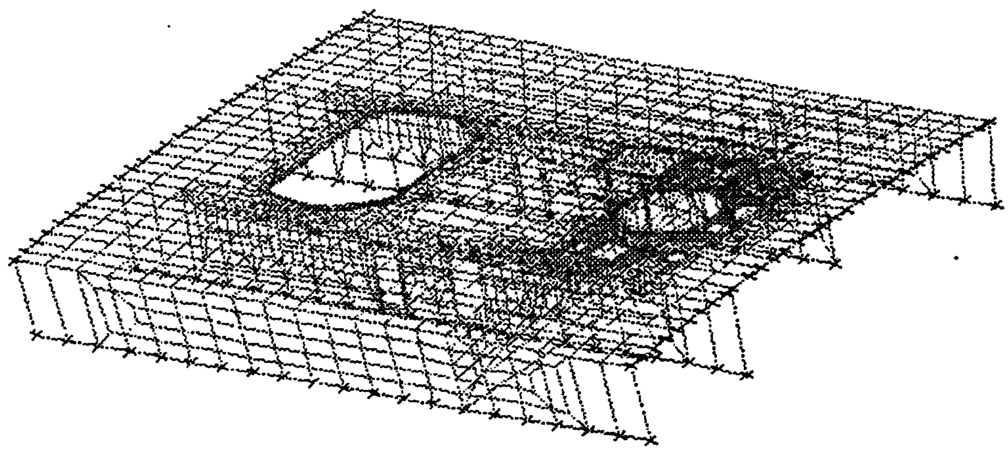

Figure 9: The Refined Grid Model Showing Constrained Boundary Nodes

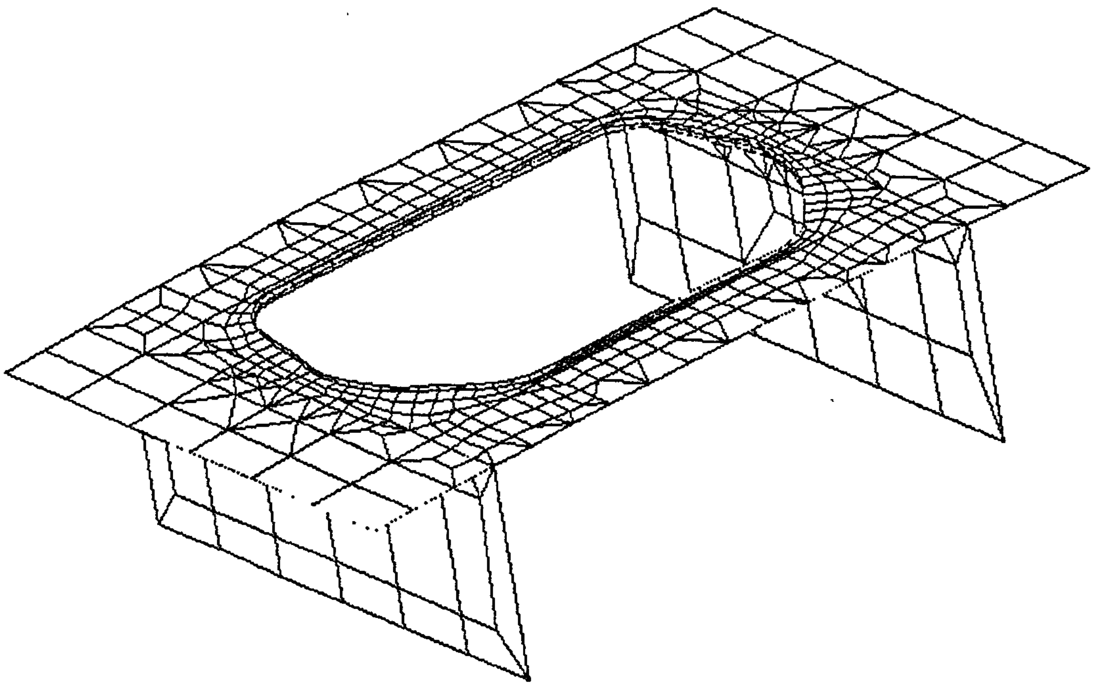

Figure 10: The Minimum Refined Model for Showing the Stresses at the Large Opening in the Deck

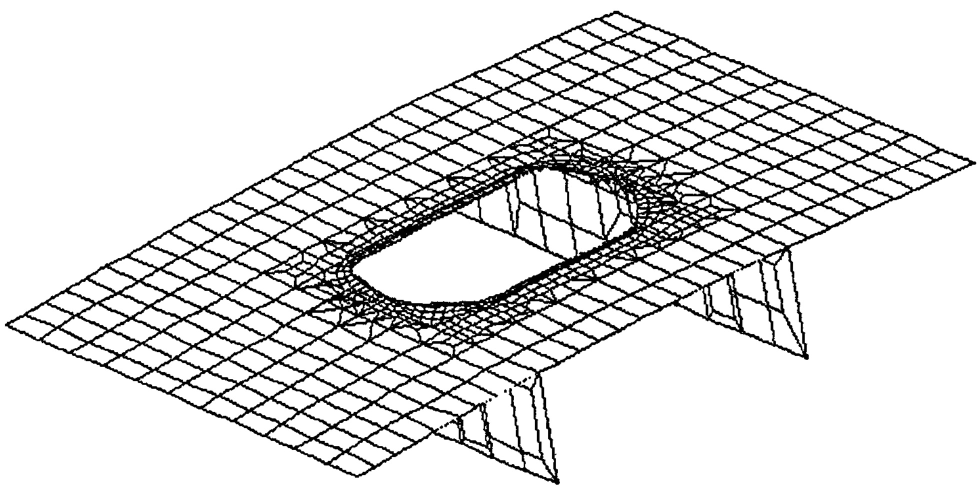

Figure 11: The Intermediate Refined Deck Model for Showing the Stresses at the Large Hole in the Deck

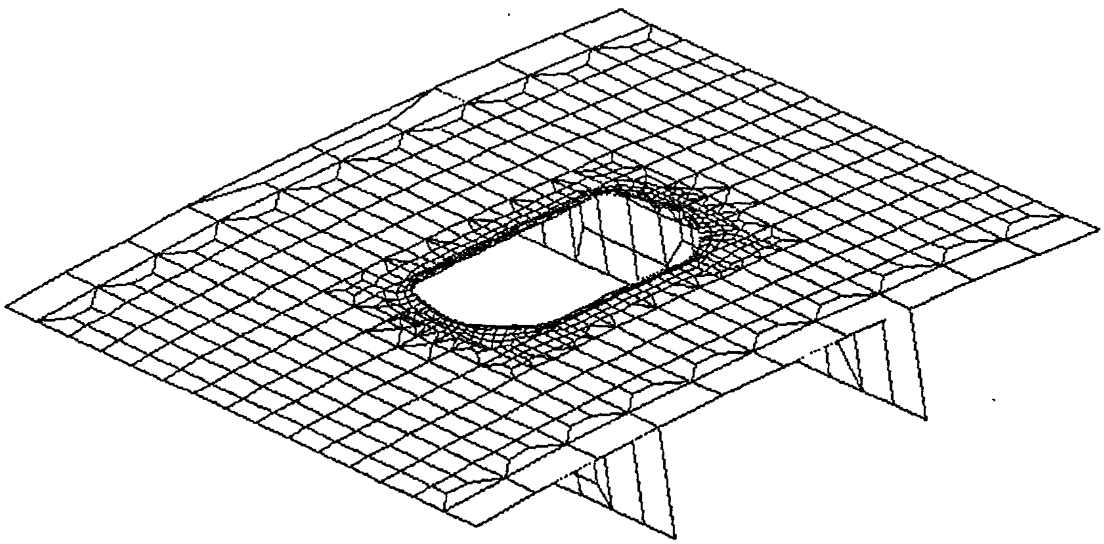

Figure 12: The Extended Deck Model with the Boundaries Nodes Adjusted to Match the MAESTRO Nodes

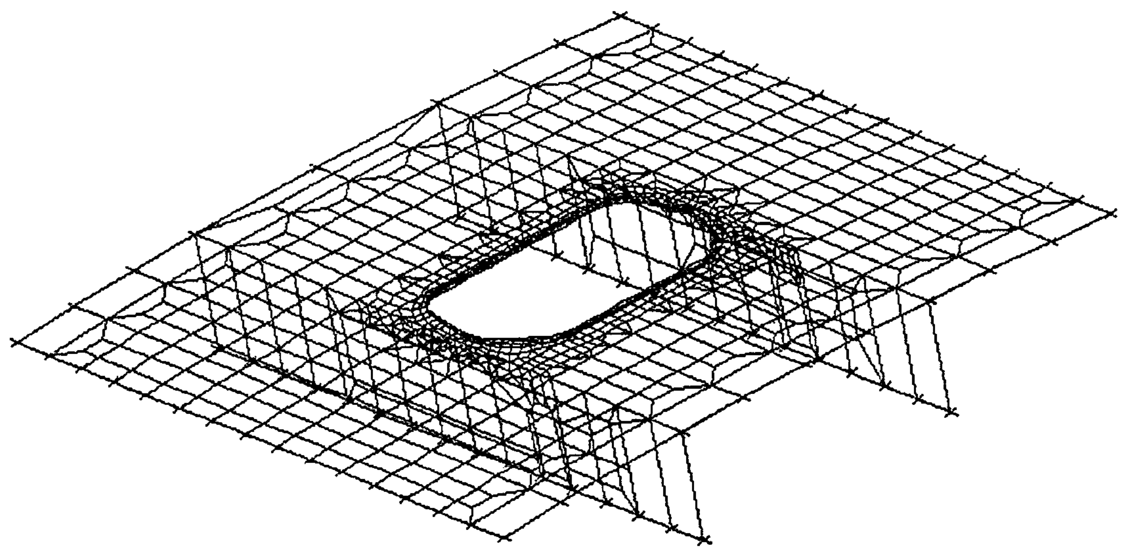

Figure 13: The Extended Deck Model Showing the Boundary Nodes

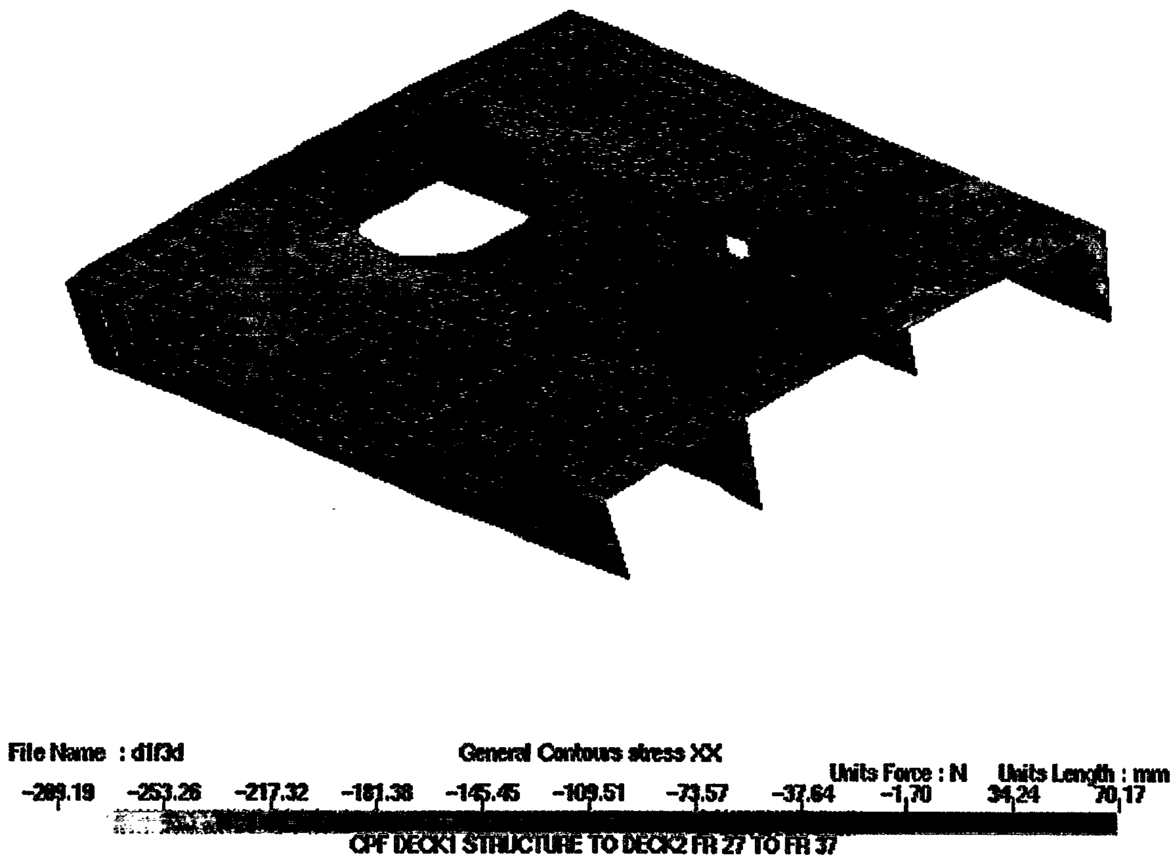

Figure 14: XX Stresses from the Top-down Analysis of the Deck Detail from Frames 27 to 32.5 with Superstructure

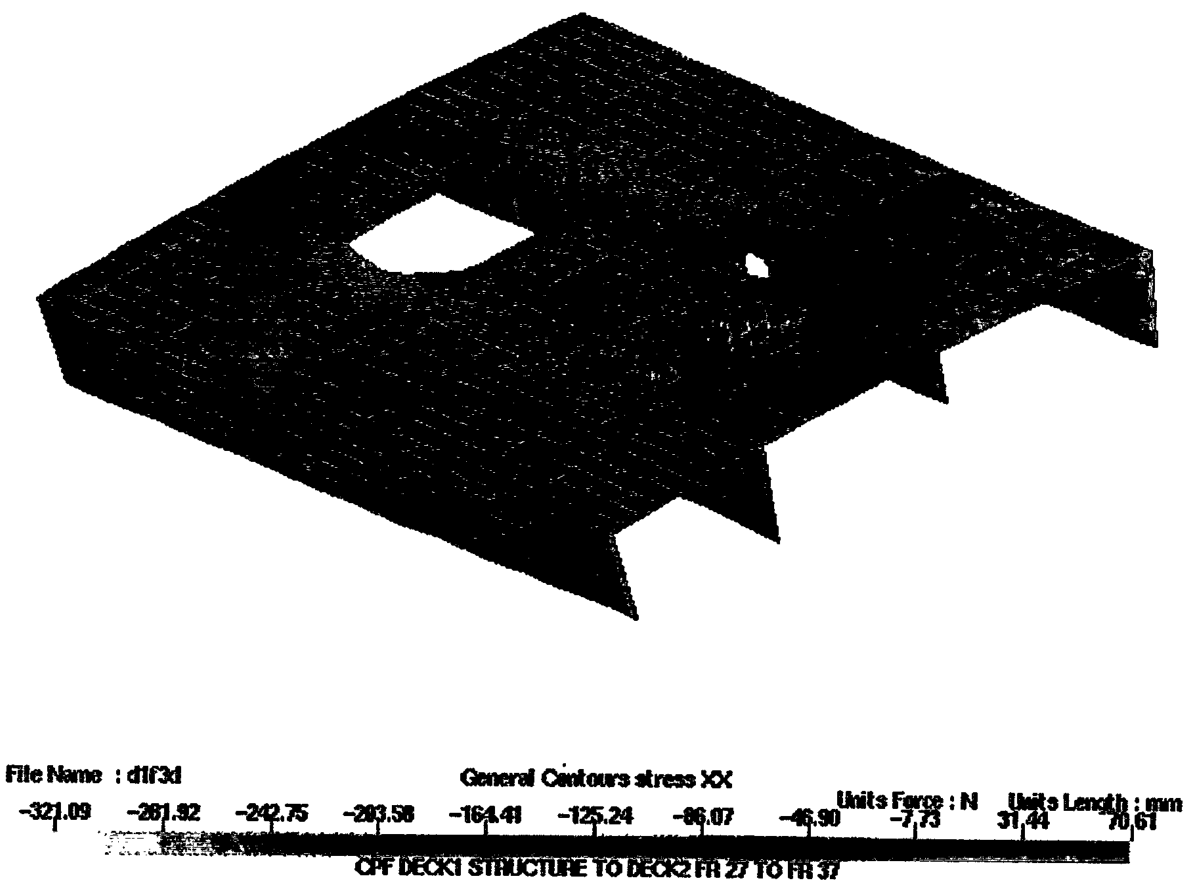

Figure 15: XX Stresses from the Top-down Analysis of the Deck Detail from Frames 27 to 32.5 without Superstructure

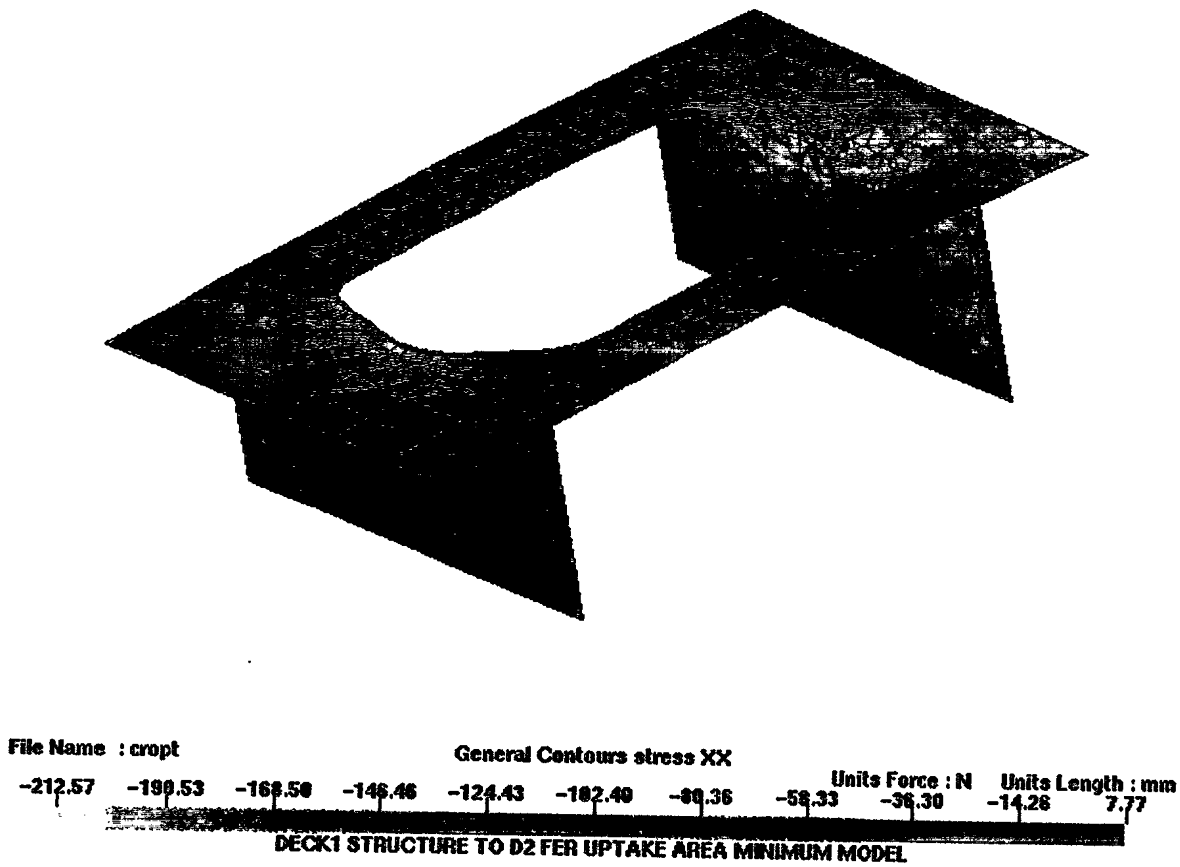

Figure 16: XX Stresses from the Top-down Analysis of the Minimum Model of the Large Opening in the Deck with Superstructure

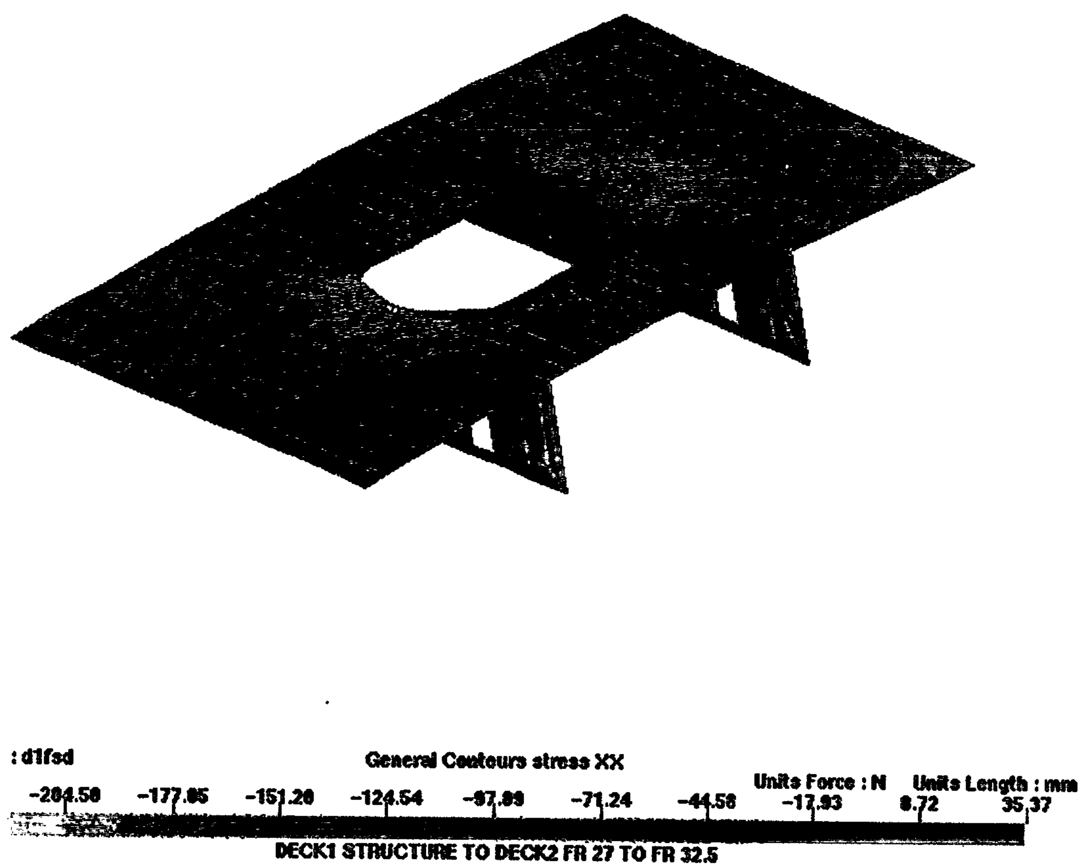

Figure 17: XX Stresses from the Top-down Analysis of the Intermediate Model of the Large Opening in the Deck with Superstructure

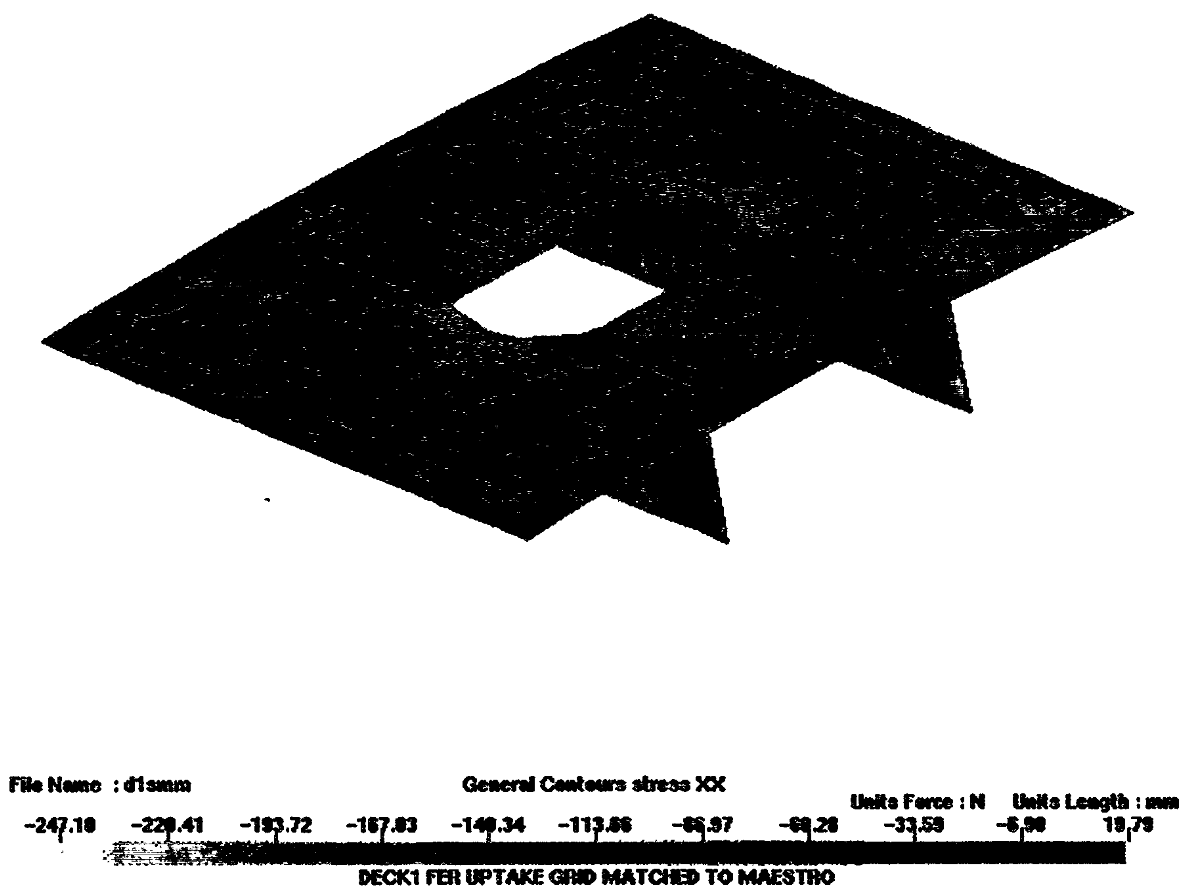

Figure 18: XX Stresses from the Top-down Analysis of the Extended Model of the Large Opening in the Deck with Superstructure

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