Journal of
Ship&Ocean
Technology
©DECEMBER 2006

SOTECH Vol. 10, No. 4, pp. 24 ~33, 2006

An Algorithm for Generating the Hull Structural Analysis Model Using the Seam Information of the Hull Structure at the Initial Design Stage

Myung-Il Roh[1] , Kyu-Yeul Lee[2] and Seong-Jin Yoo[3]

[1] Lecturer, School of Naval Architecture and Ocean Engineering, University of Ulsan, Ulsan, Korea
[2] Professor, Department of the Naval Architecture and Ocean Engineering and Research Institute of Marine Systems Engineering, Seoul National University, Seoul, Korea
[3] Researcher, Information Technology R&D Team, Daewoo Shipbuilding and Marine Engineering, Geoje, Korea;
Corresponding Author : miroh@ulsan.ac.kr

Abstract

So far, the generation of a hull structural analysis model, that is, a finite element model of a hull structure, has been manually performed by a designer using design experience, and thus has required lots of time because of many constraints, the complexity, and the huge size of the hull structure. To make this task automatic, an algorithm for generating the hull structural analysis model is developed using the seam information of the hull structure. A generating system of the hull structural analysis model is implemented based on the developed algorithm. The applicability of the developed algorithm is demonstrated by applying it to the generation of the global and hold structural analysis models of a deadweight 300,000 ton VLCC (Very Large Crude oil Carrier). The results show that the developed algorithm can quickly generate these models at the initial design stage.
Keywords: hull structural analysis model, hull structural model, seam, initial design stage, VLCC

1 Introduction

A designer performs a hull structural analysis to meet the increasing request of ship owners and ship classification societies for finite element analysis at the initial design stage. This task is generally comprised of three sub tasks: pre-processing, solving, and pros-processing tasks. In the pre-processing task, a designer manually generates a hull structural analysis model using 2D drawings and design experiences. In the past, the solving task required the most time in the hull structural analysis. However, advanced computers have reduced the time required for the solving task. Thus, the pre-processing task requires more time than the solving task now. The existing procedure of manually generating the hull structural analysis model at the initial design stage is as follows. First, a designer finds the necessary information (e.g., the position of nodes to be generated) in 2D drawings. Then, the designer manually generates a number of nodes and elements (or meshes) which constructs a hull structural analysis model, by inputting such information in the commercial structural analysis program such as the PATRAN/NASTRAN, ANSYS, etc. Thus, it takes the designer several days or weeks to perform this process according to the type of a ship and the application purpose of the hull structural analysis model (e.g., global, hold, local, and fatigue structural analysis models). Moreover, some errors may be caused by incorrect input since this process is manually performed by the designer. However, if a hull structural model, that is, a 3D CAD model of the hull structure, can be given at the initial design stage, the hull structural analysis model can be rapidly generated by applying an automatic mesh generation algorithm to the hull structural model. For this, we developed recently a hull structural modeling system which can generate the hull structural model at the initial design stage (Roh and Lee 2006). In this study, an algorithm for generating the hull structural analysis model is developed using the seam information of the hull structural model.

The generation of the hull structural analysis model at the initial design stage has been the focus of studies in practical engineering fields as well as academic fields. Most academic researches (Park and Shin 1992, Lee 1993, Lee 1995, Yum 1995, Kim et al. 2001 and Lee et al. 2005) at universities and institutes have been performed about only the single-type ship such as the VLCC, bulk carrier, etc. In these researches, a simplified hull structural model of not a whole hull structure but the midship region was generated for hull structural analysis first. Then, the hull structural model was transformed into the hull structural analysis model. However, these researches could be applied to only the single-type ship. The hull structural model was not used for any or all design stages and it should be temporarily generated only for hull structural analysis. Thus, overlapped work was caused by generating the hull structural model. Moreover, an automatic mesh generation algorithm in the commercial structural analysis program was used to generate the hull structural analysis model from the hull structural model. Lee et al. (2005) developed an algorithm of generating the hull structural analysis model. Their research showed that this algorithm could be applied to various types of ships. However, a designer must generate roughly the hull structural model before applying the developed algorithm.

As practical engineering researches at shipbuilding companies, Kim et al. (2005) generated the hull structural analysis model, using simple information about a ship such as the hull form and ship compartment information. Their research has a simple but robust algorithm. However, the algorithm can generate the structural analysis model of a hull structure having only longitudinal hull structural parts because of the limitation of the information. Jang et al. (2004) generated the hull structural analysis model, using 2D drawings in IGES format. They developed an automatic mesh generation algorithm which reflects on design practice and is based on the commercial pre-processing program (PATRAN). However, a designer must carry out a tedious pre-task before executing the algorithm. For example, the designer must delete all symbols and texts except geometric information in the 2D drawings beforehand.

Many of the researches that have been performed have some limitations, as mentioned above. To overcome these limitations, we developed a new algorithm for generating the hull structural analysis model in this study.

2 Overview of the hull structural model

As stated earlier, we developed recently a hull structural modeling system which can generate a hull structural model at the initial design stage. The hull structural model contains information on the hull structure and we call such information the hull structural information. Figure 1 gives an example of the hull structural information in the hull structural model of a panel ('Panel 1').

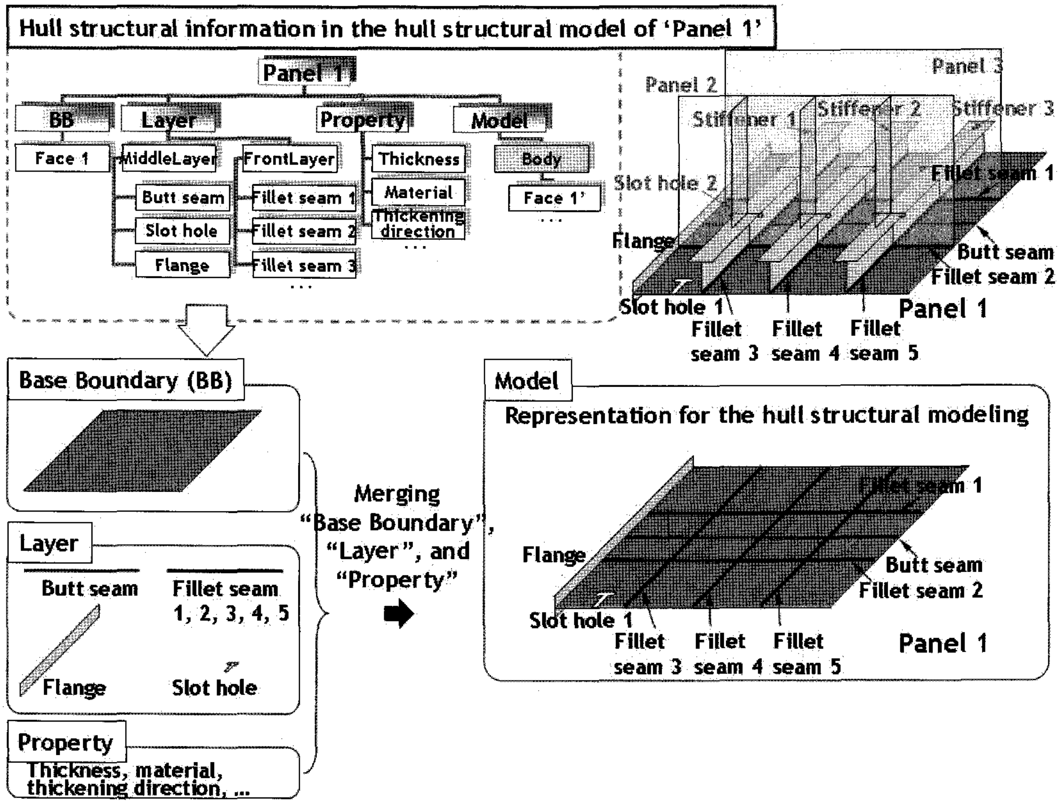

Figure 1: Example of the hull structural information in the hull structural model of the panel

As shown in this figure, the hull structural information representing the panel consists of four elements: 'BB (Base Boundary)', 'Layer', 'Property', and 'Model'. 'BB' represents an outer boundary of the panel without considering the shapes of elementary hull structural parts such as butt and fillet seams, hole, slot hole, and flange. 'Layer' represents a list of the elementary hull structural parts which are placed on the panel. 'Property' represents properties of the panel such as the thickness, material, thickening direction, etc. Lastly, 'Model' represents the final shape of the panel considering the shapes of the elementary hull structural parts.

A seam can be used to represent the relationship between the hull structural parts. The seam can be regarded as a joint line or welding line between the hull structural parts. There are two types of seams: the fillet seam and the butt seam. The fillet seam represents the joint line between a horizontal and vertical part. The butt seam represents the joint line between two horizontal parts. In the hull structural model of this study, the seam has information on the hull structural parts that are welded by the seam and the geometric information of the seam as its properties. For example, 'Seam 1' has 'Panel' and 'Stiffener 1' which are welded by 'Seam 1' and a joint line ('Curve 1') as the properties, as shown in

Figure 2. Thus, the hull structural parts, which are welded to each other by the seam, can be obtained from the corresponding seam in the hull structural model.

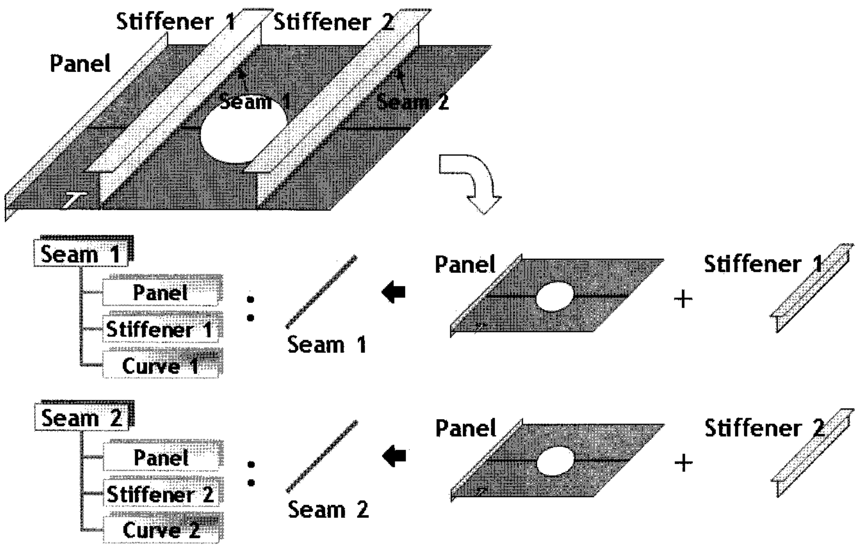

Figure 2: Representation method of the relationship between hull structural parts in the hull structural model of this study

3 Algorithm for generating the hull structural analysis model

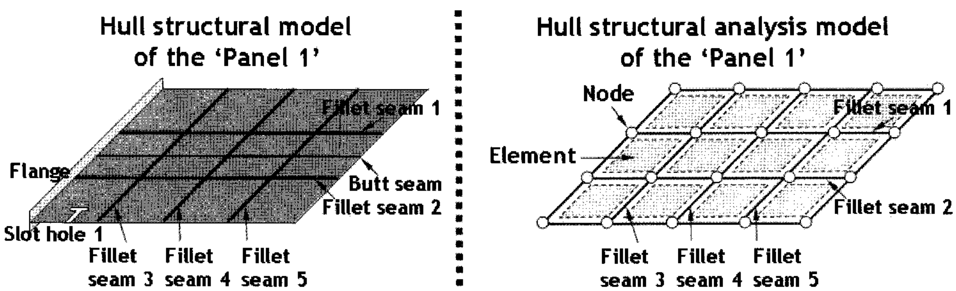

Figure 3: Example of the hull structural model and the corresponding hull structural analysis model of the panel

As shown in Figure 3, the hull structural model of the panel contains various elementary hull structural parts such as 'Butt seam', 'Fillet seam 1', 'Fillet seam 2', …, 'Fillet seam 5', 'Slot hole', and 'Flange', which are placed on the panel. On the other hand, the hull structural analysis model of the panel consists of nodes and elements (or meshes). In the hull structural analysis model, a boundary of each element is determined by the outer boundary of the panel and fillet seams. Each node exists on the outer boundary of the panel or the fillet seams. Thus, elementary hull structural parts except for the fillet seams are generally not considered when generating the hull structural analysis model at the initial design stage. That is, the fillet seams are important information in generating the hull structural analysis model.

Like this, the hull structural analysis model is different from the hull structural model. However, all information (e.g., geometric information of nodes, geometric information and properties of elements) required to generate the hull structural analysis model exists in the hull structural information of the hull structural model. That is, the hull structural analysis model can be generated using the hull structural information of the hull structural model.

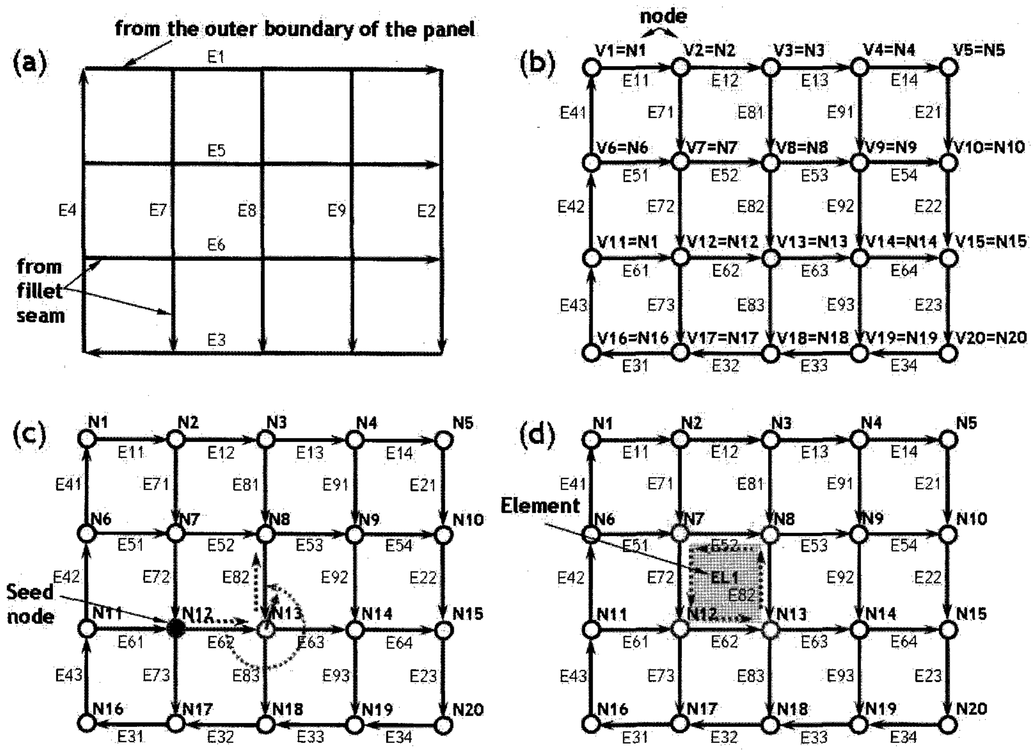

Figure 4: Overall process of generating one element for the panel

Now, let us see in detail how to generate the hull structural analysis model. There are two types of an element: the shell element and the 1D element. In addition, there are two types of the 1D element: the truss element and the beam element. The shell element is used for representing the panel and the 1D element is used for representing the stiffener. Figure 4 shows the overall process of generating one element, that is, shell element, for the panel ('Panel 1') using the developed algorithm in this study. Of course, the 1D elements are generated for the stiffener, we present only the process of generating the shell elements in below.

In the first step (Figure 4(a)), edges on the outer boundary of the panel are extracted from 'BB' in the hull structural information (Refer to Figure 1). Edges on the fillet seams placed on the panel are also extracted from 'Layer'. Moreover, 'Property' is extracted as it is. The thickening direction of the panel among 'Property' is used at the third step, and the thickness and the material of the panel will become the properties of the elements to be generated later. For readers' convenience, we suppose that the outer boundary of the panel consists of four edges ('E1', 'E2', 'E3', and 'E4') and each fillet seam consists of one edge ('E5' for 'Fillet seam 1', 'E6' for 'Fillet seam 2', 'E7' for 'Fillet seam 3', 'E8' for 'Fillet seam 4', and 'E9' for 'Fillet seam 5'), as shown in Figure 4(a).

In the second step (Figure 4(b)), all extracted edges are merged into one using a Boolean operation such as 'UNION' in the geometric modeling kernel (Lee and Lee 2001). As a result, a non-manifold model, that is, a base model for generating the hull structural analysis model is generated. In the base model, a vertex, which is shared by two and more edges, becomes a node of the hull structural analysis model. More details about this step are as follows. (2-1) Intersection points are generated by performing the intersection calculation between the edges, such as 'E1', 'E2', 'E3', and 'E4'. (2-2) Then, each intersection point is inserted into the corresponding edge using an Euler operator such as 'SEMV (Split Edge and Make Vertex) in the geometric modeling kernel. For example, through this step, 'E1' is changed into four edges ('E11', 'E12', 'E13', and 'E14) through the intersection calculation with other edges ('E2', 'E4', 'E7', 'E8', and 'E9'), as shown in Figure 4(b). As mentioned earlier, a vertex generated from the intersection point corresponds to a node of the hull structural analysis model.

In the third step (Figure 4(c)), a list of the nodes constructing each element is generated using an outer normal vector at each node. Here, the outer normal vector at each node can be obtained from the thickening direction of the panel, which is one of properties of the panel. The list of the nodes can be generated by tracking the edge that is most left to the search direction at each node. More details about this step are as follows. (3-1) One vertex is randomly selected as a seed node. Suppose that 'N12' is selected as the seed node in this example, as shown in Figure 4(c). In addition, 'N12' is marked as a start node. (3-2) One edge is randomly selected among edges sharing the node 'N12'. If 'E62' is selected, 'N13' becomes the other node of 'E62'. In this case, the search direction for generating the list of the nodes is set to the direction from 'N12' to 'N13'. (3-3) At 'N13', three edges sharing this node exist except for 'E62': 'E82', 'E63', and 'E83'. Using the outer normal vector at 'N13' and the Fleming's right hand rule, the edge (in this case, 'E82'), which is most left to the current search direction ('N12' to 'N13') at 'N13', can be found. (3-4) The current seed node 'N12' is added to the list of the nodes. Now, the next seed node is set to 'N13', and the next search direction is set to the direction from 'N13' to 'N8'. Here, 'N8' is the other node of 'E82'. The above process (3-3) and (3-4) are repeated with the next seed node and the next search direction until the next seed node becomes the start node 'N12' which was marked in the process (3-1).

In the last step (Figure 4(d)), each element is generated from the list of the nodes constructing the corresponding element, which was generated at the third step. At this time, the element is generated only when the number of nodes in the list is three or four. For example, the element 'EL1' can be generated since four nodes 'N12', 'N13', 'N8', and 'N7' exist in the list. This constraint is given by designers who perform hull structural analysis at shipbuilding companies. The designers did not want a fully automatic algorithm which automatically generates the hull structural analysis model without any interaction of the designers since the resultant model is very different from the model which is manually generated by them. This is one reason why many automatic mesh generation algorithms were of no practical use for hull structural analysis. According to this constraint, the developed algorithm does not generate all elements for the hull structure and remains some region, where the number of nodes in the list is not three or four, as it is without the generation of elements. Thus, the post touch-up task can be necessary using the commercial structural analysis program after performing the developed algorithm in this study. Next, properties of the panel extracted at the first step such as the thickness and the material are used as properties of the generated element. By repeating the third and last steps for all nodes, which are generated at the second step, the hull structural analysis model can be generated.

4 Application example of the developed algorithm

The developed algorithm was successfully applied to the generation of the global and hold structural analysis models of various ships. Here, an application example for a deadweight 300,000 ton VLCC (simply, '300K VLCC') are presented. Figure 5 presents the result of hull structural modeling of the 300K VLCC by application of a developed system in our previous study. It took one designer about 2~3 days to generate this result using our previously developed system.

Figure 6 and 7 present the result of the generation of the global and hold structural analysis models of the 300K VLCC by application of the developed algorithm, respectively. It took the designer about 20 minutes and 40 minutes to generate the global and hold structural analysis models using the developed algorithm, respectively. To make the best use of the hull structural analysis model generated in this study, it is necessary to interface the model with the commercial structural analysis program. Thus, the function which exports the hull structural analysis model into input files of the PATRAN/NASTRAN and ANSYS programs was developed in this study. Figure 8 presents the result of the display of the global structural analysis model of the 300K VLCC in the PATRAN and ANSYS programs.

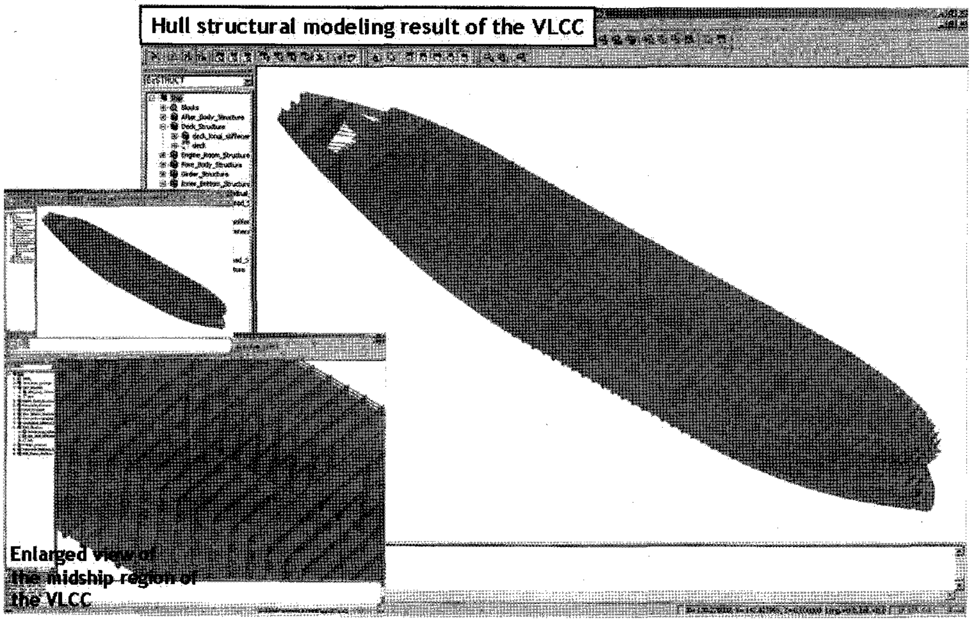

Figure 5: Result of hull structural modeling of the 300K VLCC by using the developed system in our previous study

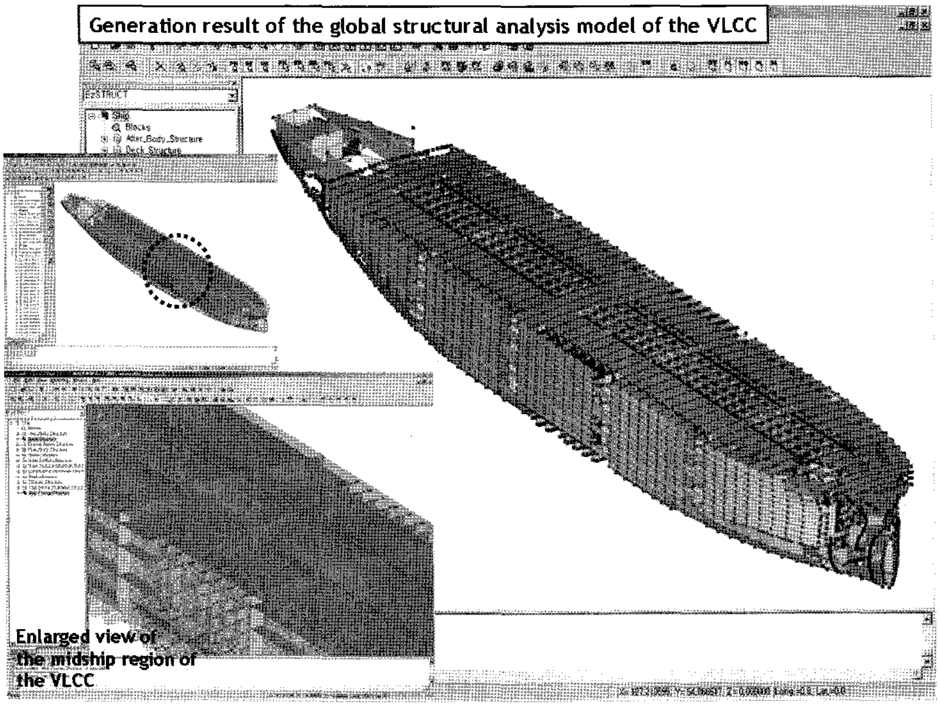

Figure 6: Result of the generation of the global structural analysis model of the 300K VLCC by using the developed algorithm in this study

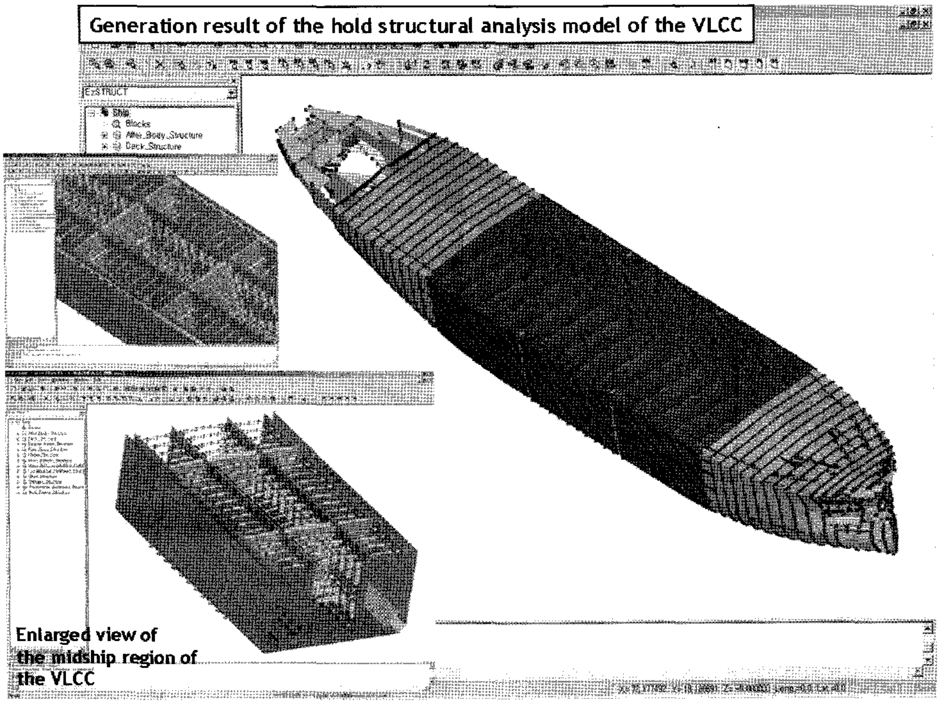

Figure 7: Result of the generation of the hold structural analysis model of the 300K VLCC by using the developed algorithm in this study

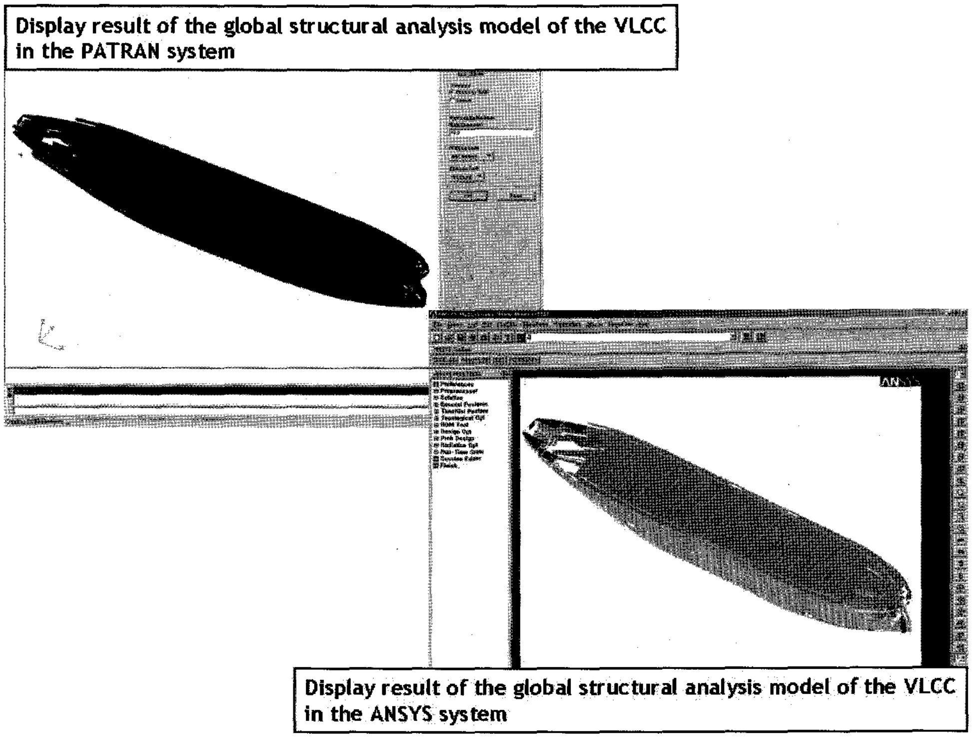

Figure 8: Result of the display of the global structural analysis model of the 300K VLCC in the PATRAN and ANSYS programs

5 Conclusions

In the most of shipbuilding companies, without the hull structural model, a designer has manually generated the hull structural analysis model at the initial design stage. For solving this issue of manual generation of the model, we developed an initial hull structural modeling system in the previous study. In this study, we developed an algorithm for generating the hull structural analysis model using the seam information of the hull structure. The developed algorithm was applied to a deadweight 300,000 ton VLCC. The result shows that the developed algorithm quickly generated the corresponding model at the initial design stage. That is, the global and hold structural analysis models were rapidly generated by applying an automatic mesh generation algorithm of this study to the given hull structural model. As future works, it is required to develop the function which automatically generates the boundary and loading conditions for hull structural analysis.

Acknowledgements

This work was supported partially by the Research Institute of Marine System Engineering of Seoul National University and University of Ulsan, Korea.

References

Jang, B.-S., Y.-S. Suh, E.-K. Kim, T.-H. Lee, K.-B. Jang, Y.-S. Song and M.-S. Chun. 2004. Development of Integrated Structural Analysis System Including Automatic Modeler for Cargo Hold and Whole Ship Model, Proceedings of The Annual Autumn Meeting of The Society of Naval Architects of Korea, Sanchoeng, Korea, 20-22.

Kim, I.-I., J.-H. Choi, H.-J. Jo and H.-W. Suh. 2005. A Development of Data structure and Mesh Generation Algorithm for Global Ship Analysis Modeling System, Advances in Engineering Software, **37, 2,** 85-96.

Kim, J.-H., J.-Y. Lee, C.-W. Yum and H.-C. Son. 2001. Development of Hold Structural Analysis System, Proceedings of The Ship Design Conference of The Society of Naval Architects of Korea, Daejeon, Korea, 199-210.

Lee, J.-Y., H.-C. Son and J.-H. Kim. 2005. Development of Technique of Finite Element Modeling for Ship Structural Analysis, Proceedings of The Annual Autumn Meeting of The Society of Naval Architects of Korea, Yongin, Korea, 398-404.

Lee, M.-K. 1995. Development of Automated Finite Element Model Generation Program for VLCC Structural Analysis, M.Sc. Thesis, Seoul National University in Korea.

Lee, S.-H. and K. Lee. 2001. Partial Entity Structure: A Compact Boundary Representation for Non-Manifold Geometric Modeling, ASME Journal of Computing & Information Science in Engineering, **1, 4,** 356-365.

Lee, S.-T. 1993. Development of the Automated Geometric Modeling Pre-Processor for Finite Element Analysis - Specially Emphasized on Bulk Carriers, M.Sc. Thesis, Seoul National University in Korea.

Park, S.-H. and J.-G. Shin. 1992. Development of Automatic Data Generation Program for Finite Element Structural Analysis of Oil Tankers, Transactions of the Society of Naval Architects of Korea, **29, 3,** 149-156.

Roh, M.-I. and K.-Y. Lee. 2006. An Initial Hull Structural Modeling System for Computer-Aided Process Planning in Shipbuilding, Advances in Engineering Software, **37, 7,** 457-476.

Yum, J.-S. 1995. A Study on the Object-Oriented Structural Modeling of Double Hull Tankers and the Automatic Generation of Structural Analysis Model, Ph.D. Thesis, Seoul National University in Korea.