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A development of data structure and mesh generation algorithm for whole ship analysis modeling system

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Abstract

In the whole ship structure and vibration analysis, the FEA (finite element analysis) model of whole ship structure is required in the early design stage before the 3D CAD model is defined. Because ship structure has a complex curved surface, and many associated structural members, the whole ship analysis modeling job has become a time consuming job. For the effective support of the whole ship analysis modeling, a method to generate the analysis model using initial design information within the ship design process, hull form offset data and compartment data, is developed. To easily handle initial design information and FE model information, a flexible data structure is proposed. An automatic quadrilateral mesh generation algorithm using initial design information to satisfy the constraints imposed by the ship structure is also proposed. With the proposed data structure and mesh generation algorithm, whole ship analysis modeling job for various ship types can be effectively supported and these results are presented.

Keywords: Ship structure; Finite element; Whole ship analysis; Mesh generation; Data structure; Quadrilateral; Initial ship design information

1. Introduction

1.1. Background

Finite element analysis (FEA) is the application of the Finite element method (FEM) to the analysis of static or dynamic physical objects and systems. In it, the object or system is represented by a geometrically similar model consisting of multiple, linked, simplified representations of discrete regions—i.e. finite elements. Owing to the development of various analysis methods and rapid progress of computing power, FEA is widely used in the design process of almost all mechanical objects such as ships, automobiles, aeroplanes, etc. Nowadays, along the line of this trend, the whole ship structure analysis that analyzes ship structure as one finite element model is generally used for ship design. However, finite element model of whole ship structure analysis is manually created because of the starting point of whole ship structure analysis and the constraints to be satisfied (Fig 1).

Hence, it takes too much time to analyze whole ship structure. This becomes a major obstacle to get the result of analysis at proper design process. Because the analysis model generation process is a time-consuming job and takes much more time than the engineering work itself, the accuracy of analysis result becomes low. Therefore, it is necessary to reduce time for generating analysis model through automatic manner so as to reduce analysis time and acquire more accurate analysis result.

1.2. Characteristic of whole ship analysis

The present trend in shipbuilding is to build larger ships, and the demand for higher safety standards is also continuously growing. Furthermore, the emergence of large-scale ships has brought about the demand for new standards in ship structure design and safety assessment. In the conventional shipbuilding method, structural analysis is applied to only major parts of a ship. But in the modern method, most of the time, structural analysis is applied to the whole ship. Ship design process is composed of three major stages: basic design stage, detail design stage and

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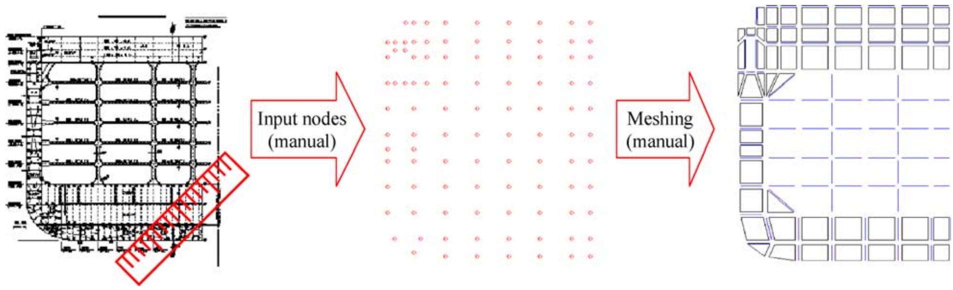

Fig. 1. Current modeling procedure by manual input.

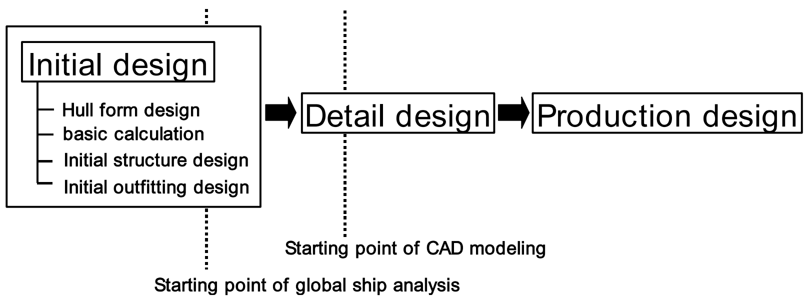

Fig. 2. The starting point of whole ship analysis in the general ship design process.

production design stage. In the basic design stage, hull form design for designation of outer shape of ship, basic calculation for evaluation of the cargo containment capacity and the stability of ship and initial structure design for designation of typical structural part of ship such as mid-ship section is performed without CAD model. Fig. 2 shows the starting point of whole ship analysis in the general ship design process.

As shown in Fig. 2, the whole ship structure analysis starts at the basic design stage. Because of the characteristic of the basic design stage, the whole ship analysis modeling is performed without CAD model. Therefore, whole ship analysis must be performed using not CAD model but computational data which is available on basic design stage.

The ship structure comprises external hull structure with sophisticated curved shape and internal hull structure with planar shape. The shape of mesh used for ship analysis differs from the shape of mesh used for other mechanical products such as airplane, automobile and general mechanical parts.

In the case of the ship analysis model, particular nodes have to be generated where user wants to place them and mesh has to be generated along these nodes, as shown in Fig. 3. Since the analysis results should be evaluated on the position of structure members such as girder, deck and stiffener, etc., the mesh must be generated with satisfying these structure constraints. The quadrilateral mesh generation algorithm with only geometry information requires a lot of numerical calculation. Therefore, the generation of quadrilateral mesh takes much time and is also unreliable. Especially, the generation of quadrilateral mesh on sophisticated curved surface with satisfying constraints as mentioned above is more complex. Under site operation, generating whole ship analysis model with existing quadrilateral mesh generation algorithm using only geometry information takes more time than hand operation. It takes much time to correct model by trial and error in order to make the adequate model to designer's concept. Therefore, a fast and robust mesh generation algorithm, which is suitable for generating whole ship analysis model is needed. Here, robust means that quadrilateral mesh is stably generated with no error in any case of ship analysis process.

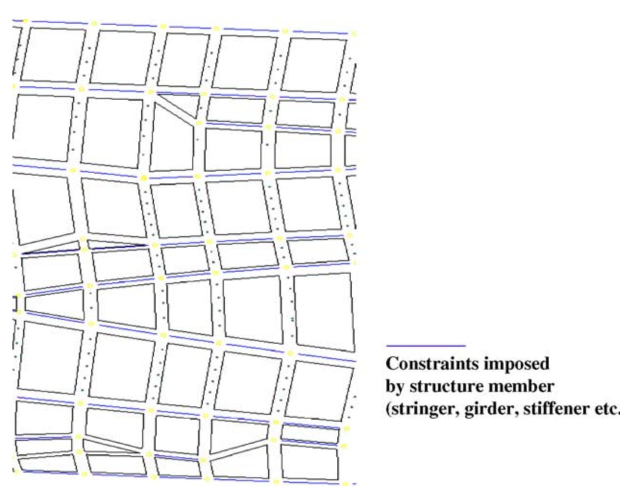

Fig. 3. Example of the shape of mesh to satisfy structure constraints.