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Development of panel generation system for seakeeping analysis

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ABSTRACT

In this paper, a panel generation system for analyzing seakeeping performance of a ship is developed. Given a set of offset data representing the ship hull, the system first creates a surface model of the ship. From the surface model, the wetted part of the ship is obtained by computing the intersection between the water surface and the hull, which is then processed to generate quadrilateral panels for the hull and the water surface. The system is designed to handle various kinds of ships such as ships with a mono-skeg, a twin-skeg and/or a bulbous bow in either an automatic or an interactive manner. Moreover, it can generate input panels for three different seakeeping analysis methods. Examples are provided to demonstrate the capabilities of the system.

1. Introduction

Computer-aided design (CAD) technology has been used in shipbuilding industry as an essential tool for shape representation, design data exchange, etc. Nonetheless it has been mainly considered as an assisting tool in the design process. As numerical analysis techniques are employed in the design step, however, accurate and efficient shape representation becomes important to produce acceptable analysis results and accordingly the significance of CAD technology which primarily deals with shape representation of a model is more and more appreciated.

Hull shape and the strength of the structure are two primary factors in the early stage of ship design. The hull shape is associated with speed, motion and cargo space, whereas the strength of the structure is critical for the safety of a ship in various loading and sea conditions. They are not, however, independent with each other. In particular, since the ship motion in waves is directly related with the forces acting on the ship structure, the shape of the hull should be designed with careful consideration of structural design aspects.

The primary purpose of seakeeping analysis is to estimate fluid forces acting on the ship hull for the analysis of the structure of the ship in various conditions. These forces not only include the direct forces from waves but also the indirect forces due to slamming, green water and sloshing resulting from various ship motions. Since such force estimation is very important in determining input parameters for the structural analysis, this seakeeping analysis becomes an essential step in order to accurately estimate the maximum loads on the ship structure in the design procedure.

Seakeeping analysis is performed either in the frequency or time domain. A typical example of the former analysis method is WAMIT [1] which requires panels of the ship hull only. For the latter analysis, SWAN [2] and LAMP [3] are the examples. This analysis needs either triangular or quadrilateral panels for the ship hull as well as the water surface. Here, throughout this paper the terms, 'panel' and 'mesh' are assumed to be identical. The time domain method can perform nonlinear analysis as well which requires that the panels of the ship hull and the water surface should be created by considering the motion of the ship and the incident wave profiles. Two pieces of software, SWAN and LAMP, contain the grid generation modules inside. However, they do not work satisfactorily for complicated hull shapes such as a twin-skeg hull.

Panel generation is one of the most popular topics in various engineering areas. Most research efforts have been given to the generation of triangular meshes from a point set or a shape, and there exist numerous commercial software packages which can create triangular meshes automatically. Moreover, quite an amount of work has been reported on the quadrilateral panel generation mostly used for electromagnetic analysis, structural analysis and general fluid analysis [4,5]. Also, for general mechanical parts, a lot of research on quadrilateral panel generation has been performed [6–9]. Such mesh generation is a huge topic which cannot be touched in this paper. So, we only pay attention to mesh generation used in the ship design process.

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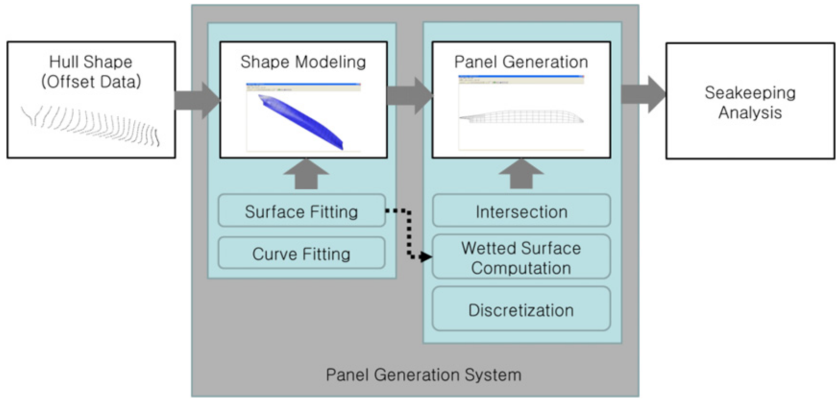

Fig. 1. The diagram of the proposed system. The arrows indicate the data flow between the modules.

Panel generation in the ship design area can be treated as a subset of mesh generation. Because of its narrow application scope much research work has not been reported so far. Although some techniques developed for mesh generation of mechanical parts or structural analysis such as [10] could be employed for the mesh generation for the seakeeping analysis purpose, they are computationally expensive and complex, so they are not suitable for the current work.

Panel generation for seakeeping is complicated because the analysis methods usually need quadrilateral panels and only the wetted part of the ship hull that is determined by the motion of the ship as well as the water surface condition should be considered. Therefore, most of the panel generation methods that have been developed in many application domains cannot be easily applied for the seakeeping analysis since those methods basically assume that the shape is fixed and the region for discretization does not change over time, whereas in the seakeeping analysis case, the region for discretization is dynamically determined, which increases the complexity of the discretization process. Kouh and Chau [11] proposed a method for panel generation using rational cubic Bezier curves. Their method only focuses on the panels for the entire hull shape. Bronsart and Knieling [12]discussed a panel-based representation of the entire ship hulls. They considered triangular and quadrilateral panel generation together, which are used for wave resistance calculation. Jensen [13] presented interface software which combines the ship hull design and seakeeping and wave resistance performance. He proposed a method to generate quadrilateral panels by combining triangular meshes. His panel generation routine, however, is hard to handle fully automatic instantaneous quadrilateral panel generation at each computation step given the motion of a ship as well as the wave shape. Currently, commercial software packages such as CATIA provide a capability of defining a ship hull and generating panels that may be used for seakeeping analysis. However, they are not intended for seakeeping analysis and no such commercial software is available which provides a function of generating panels for the wetted body surface considering the motion of the ship and the incident wave profiles in an interactive manner. Therefore, commercial software packages cannot be considered for seakeeping analysis.

In this paper, a set of software modules and an integrated system for defining a hull shape and generating panels for a seakeeping analysis software suite called WISH [14] which provides various seakeeping analysis methods are presented. The software modules are used for automatic panel generation in the computation loop, whereas the integrated system allows the user to create the shape model of a ship and panels for the analysis interactively. The system provides a function for modeling the shape of a ship hull from offset data, computes the wetted part and generates quadrilateral panels for seakeeping analysis modules. In particular, attention is paid to the efficient panel generation of a ship hull given a ship motion and waves which change dynamically over time.

The paper is structured as follows: in Section 2, the proposed panel generation system is presented. The system structure and each module for the structure are explained along with detailed algorithms used by the module. In Section 3, the analysis of the panel generation system is presented, followed by various examples demonstrating the system in Section 4. This paper concludes with future work in Section 5.

2. Panel generation system

2.1. System structure

The structure and data flow of the proposed system is given in Fig. 1. A ship hull is represented by a set of discrete points which are provided as input to the system. The system consists of two major components; one is for modeling a hull shape and the other is for generating panels from the hull shape. The modeling unit reads the offset point and allows a user to create a surface model of the hull shape using curve and surface fitting methods. The modeled hull shape is then given to the panel generation unit. The panel generation unit creates quadrilateral panels for seakeeping analysis. In this unit three modules for intersection computation, wetted surface computation and discretization are included. The generated panels are then given to the seakeeping analysis routines.

2.2. Offset data

In most cases, the shape of a ship hull is represented by a set of 3D curves only. They are orthographically projected onto three orthogonal planes, producing three drawings of body, half breadth, and sheer plans, all of which define a complete 3D shape of a ship as shown in Fig. 2. These drawings are called the *lines*, which is the standard way to define the hull shape in the shipbuilding industry. The intersection points of the curves at each section with the straight lines in each direction are taken to produce 3D points. These data points are called *the offset data* which are indicated as circular dots in the body plan as shown in Fig. 2.

2.3. Shape modeling unit

The shape modeling module allows the ship designer to model the hull shape using *B*-spline surfaces from offset data points either