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DESIGN OF PLANNING LEVEL SHIP PRODUCT MODEL FOR SHIP INITIAL DESIGN

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Key words: product model, STEP, UML, IDEF, ship initial design, application protocol, AP215, AP216, planning level ship product model.

ABSTRACT

This paper introduces a design of planning level ship product model (called SPPM hereinafter) based on ISO 10303 Standard for The Exchange of Product Model data (STEP). For the design of this model, the information modeling methodologies such as Integration Definition (IDEF) methods and Unified Modeling Language (UML) were reviewed, and a hybrid method was established. By using this method, ship initial design process was analyzed, and STEP-based information model and class libraries for SPPM were defined. For the data structure of this model, the shipbuilding Application Protocols (AP215, AP216 and Ship Common Model) of STEP were investigated and utilized to facilitate sharing of product model data with other CAD systems of subsequent stages. For the implementation and the verification of the model, a prototype system was developed using the ACIS geometric modeling kernel and object-oriented database management system.

I. INTRODUCTION

The ship initial design is an engineering activity to specify a ship during pre-contract stage, which is normally called as: preliminary ship design, basic ship design, integrated system design, or ship initial planning. The pre-contract activities are especially important for the design of new types of ships because more than 80 percent of the cost and the performance are determined in this stage.

During ship initial design stage, the specifications to meet owner's requirements are determined, and the modeling and performance analysis to support the design decisions are performed repeatedly. Accordingly, intensive collaboration is required among ship owner, classification society, design agencies, model basin, suppliers, and etc. Nevertheless, the process in this stage is not clearly defined yet and ambiguity or options to take may exist in many aspects. Skilled designers even cannot state their way of design in a concrete and unique manner at this initial design stage [2].

A product model is a set of objects and the relationships between the objects [9, 12, 13]. While the objects describe the assemblies and components of the products, the relationships describe the architecture of the product. As the basis for different activities, from idea to final product, the product model is the key to the successful realization of product. As a knowledge base, it contains not only the geometric and technical data but also general data such as company specific information, product background, history, synthesis and analysis results, reasons for decisions, and etc.

The STEP is an international standard for the computer-interpretable representation and exchange of product model data. The objective is to provide a neutral mechanism capable of describing product data throughout the life cycle of a product, independent from any particular system. The nature of this description makes it suitable not only for neutral file exchange, but also as a basis for implementing and sharing product databases and archiving. The application protocols formulate the requirements of the product data to be handled in the scope of a certain industrial area. These are documented in the Application Reference Model (ARM), which is part of each application protocol. To achieve this, the terminology of the industry is used [4-6, 9].

The SPPM (ShiP Product Model) is a planning level ship product model, which is a framework for the integration of various Computer-Aided Engineering (CAE) applications and functional simulations in the initial design stage. Fig. 1 shows the configuration of the ship initial design system based on product model. As shown at this figure, the system consists of various CAE applications such as hydrostatics calculations, hydrodynamics analysis, structural analysis, process modeling and simulations, cost estimation, and etc. The SPPM is the core of this system and provides input data for the client applications. The database must be managed and utilized from the related applications and subsequent detail design and

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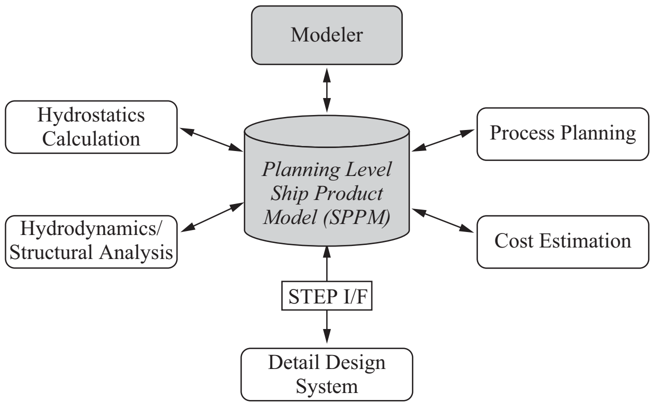


Fig. 1. Configuration of ship initial design system based on product model.

construction processes. To comply with these requirements, the application of STEP and the object-oriented technology are considered for the design of SPPM.

The SPPM compared to the existing system model provides the following advantages:

- It provides the qualified data structure for consistency, extensibility, and standardization in application.
- It makes it possible to change and extend the representation model without affecting client application.

II. DESIGN OF PLANNING LEVEL SHIP PRODUCT MODEL (SPPM)

1. Information Modeling Methodology

A model in the context of this study is a description form of a certain understanding of the real world. Modeling is the task to identify, abstract and formalize the universe of discourse towards an academic interpretation and an unambiguous representation. Developing a model for a software system prior to its construction or renovation is as essential as having a blueprint for a building [3, 8, 10]. As the complexity of systems increases, so does the importance of modeling techniques. A methodology is an organized, single-purpose discipline or practice. It may have a formal theoretical foundation, which may not be a requirement. Generally, methodologies evolve as a distillation of the best-practice experience in a particular domain of activity.

Many of modeling methodologies have been developed for the efficient analysis and design of information systems. Among these are Group de Recherche en Automatisation Integriel (GRAI) [1], Nijssen Information Analysis Method (NIAM) [1], Integration Definition (IDEF) [7], EXPRESS [14], Unified Modeling Language (UML) [11], and other object-oriented methodologies such as Shlaer & Mellor, Booch, Coad & Yourdon and so on.

Among these methodologies, with regard to the design of SPPM in this study, a series of IDEF methods are mainly reviewed because these methods are frequently used to analyze and design the Computer Integrated Manufacturing system. The UML model, as a standard modeling language of Object Modeling Group (OMG), is introduced for the detail object design and implementation. Also the EXPRESS, which is the object-flavored language designed for the description of product model by the ISO STEP committee, is studied with the STEP methodology for the design of SPPM data structure.

Based on the review of the modeling methodologies, an object-oriented hybrid methodology for the design of SPPM was established as shown in Fig. 2.

As shown in Fig. 2, the real-world, which is actually the ship initial design activity, is analyzed and modeled in a series of IDEF information models: the activity model with IDEF0, the process model with IDEF3, based on Structural Analysis and Design Technique (SADT) in the analysis stage. From the activity model and process model, a set of application objects as entities which have to be managed by the system, are identified and modeled in IDEF1 information model. These objects correspond to the entities defined in the application reference model (ARM) of STEP Application Protocol. Therefore the ARM of STEP AP215 (Ship Moulded Form) [5] and AP216 (Ship Arrangement) [6] are incorporated instead of IDEF1 model. From the analysis stage, the initial classes are identified based on the application objects from the information models. In the object design stage, the application objects are refined to the classes with the most specific features by the IDEF4 object design method with the series of UML models.

2. Information Modeling and Class Definition

The process of SPPM design is divided into two phases: the analysis phase for information model and the object design phase for class definition.

1) Information Modeling

Analysis phase was divided into three steps as shown in Fig. 3: 1) activity modeling, 2) process modeling, and 3) information modeling. According to this procedure, the initial ship design system is analyzed for the identification of entities and related behaviors and modeled into three types: activity model (or function model), process model and information model.

Usually the information modeling starts with the activity model (or function model) by functional decomposition of real-world system.

The activity modeling was done on IDEF0 method and supported by AI0win CASE tool. As the results of the activity modeling, a list of activities, a set of activity diagrams and activity-concept matrices were documented in digital form. And from this process, the Unit of Functionalities (UoF's) with related concept were identified and provided as a candidate of Unit of Behaviors (UoB) and attributes of the application objects. Through the process modeling, based on IDEF3 method and supported by ProCIM CASE tool, the work-flow and the dynamic features of objects of the system

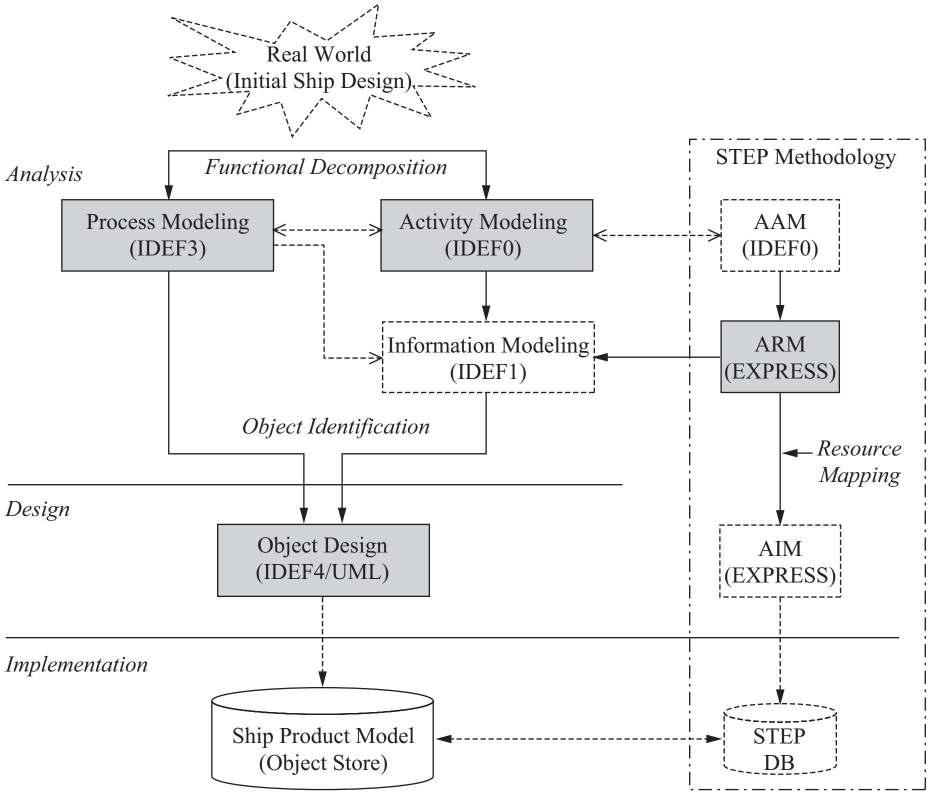


Fig. 2. Hybrid modeling methodology for design of SPPM.

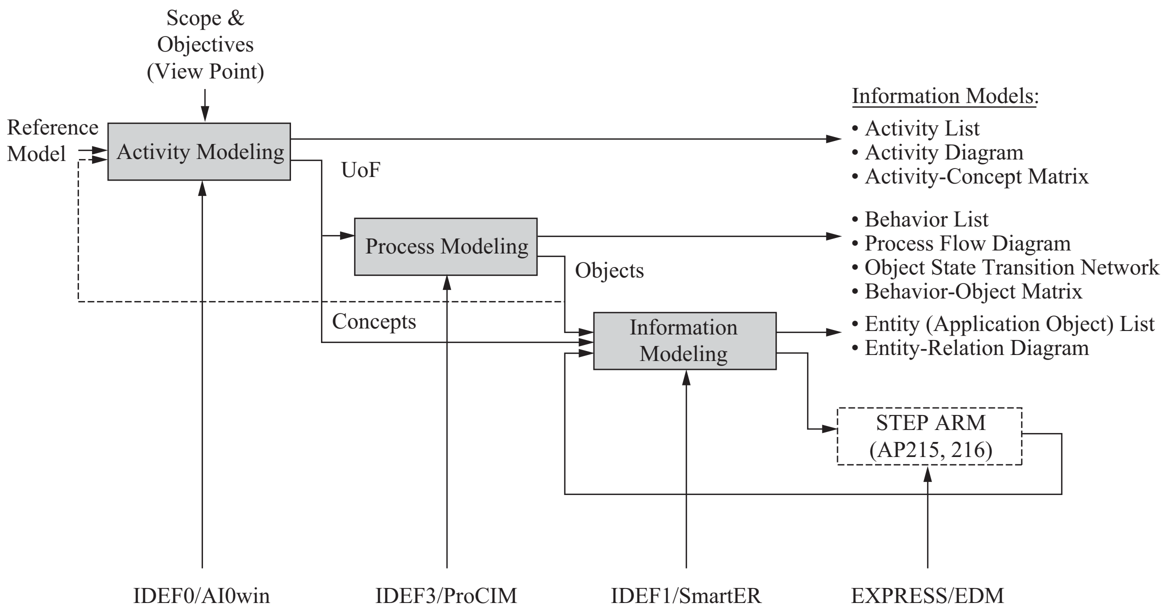


Fig. 3. Information modeling procedure in analysis phase.

were investigated and modeled in forms of Behavior List, Process Flow Diagrams, Object State Transition Network (OSTN), and Behavior-Object matrix. As results of this process, the behaviors of objects were identified.

From the activity model and the process model, the application objects were identified for the proposed system. The information modeling was used to represent the relationships and the attributes of the application objects have to be managed by the system. The application objects correspond to the entities in the ARM of STEP application protocols, and

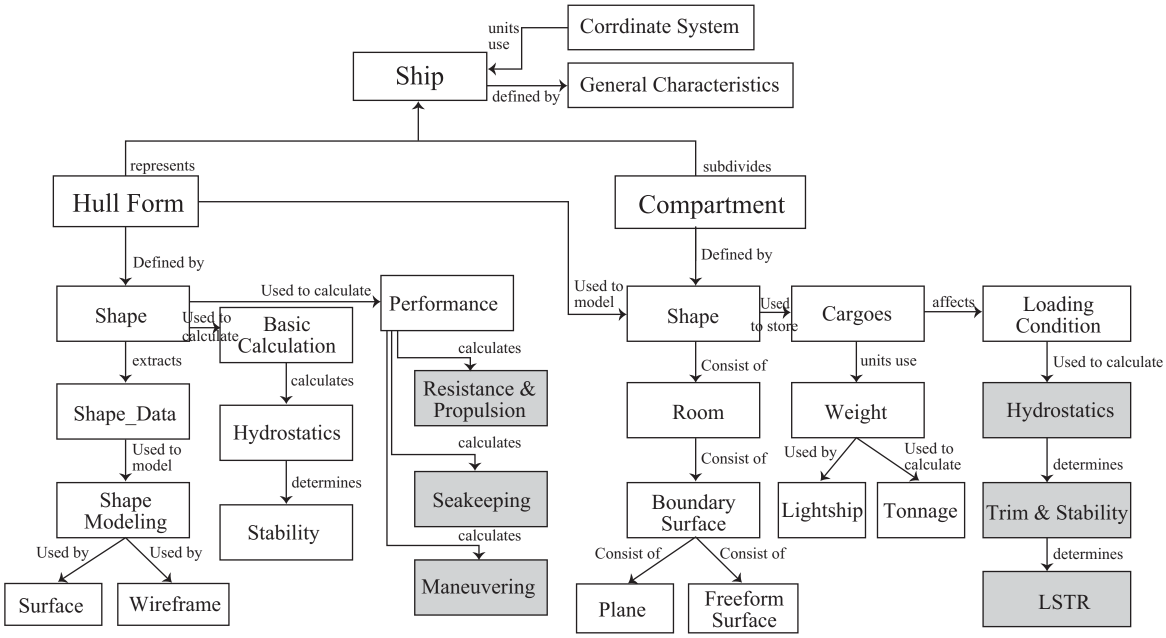


Fig. 4. Information model for SPPM based on STEP AP215 and AP216.

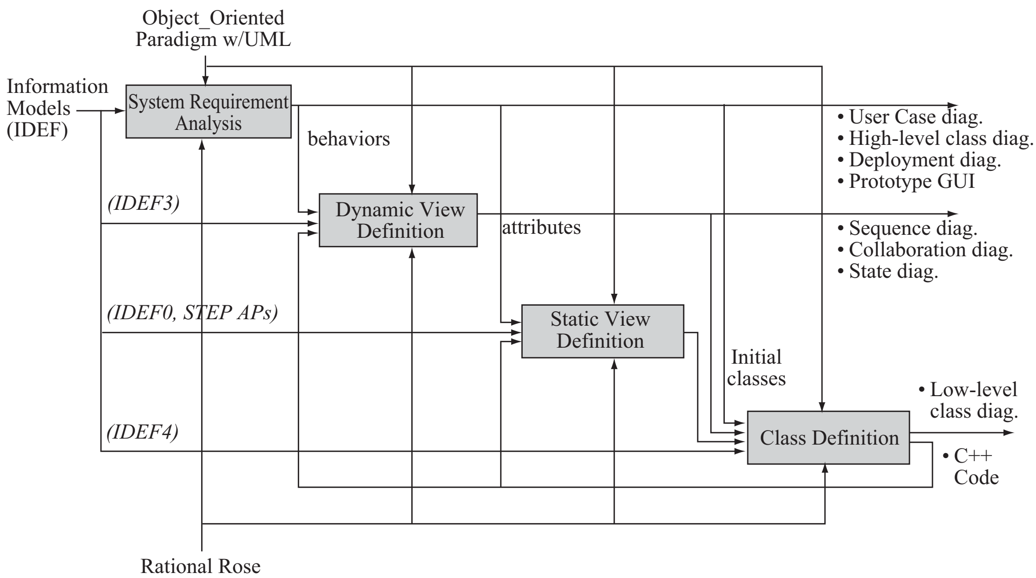


Fig. 5. Procedure of object design with UML.

accordingly the information modeling was replaced by STEP application protocols.

Fig. 4 shows the information model of SPPM based on ship STEP AP 215 and AP 216.

2) Definition of Class Libraries

The object design and the class definition phase was divided into three steps: 1) identification of initial (high-level) classes from the information models, 2) refining (low-level) classes through the iterative processes, and 3) generation of C++ code and full implementation of class libraries for applications.

For the design of SPPM, the object-oriented concept was fully addressed based on IDEF4 methodology. However the UML was used for visualization of the models instead of SmartClass-a CASE tool for IDEF4 because of poor functionality in the refining processes.

Fig. 5 shows the procedure of object-oriented design for SPPM with UML. As shown in Fig. 5, the IDEF information models are used for the identification of the initial classes, and the subsequent series of UML models are used for refining the classes.

From the UML model, corresponding C++ class libraries with default implementation of the basic model behaviors

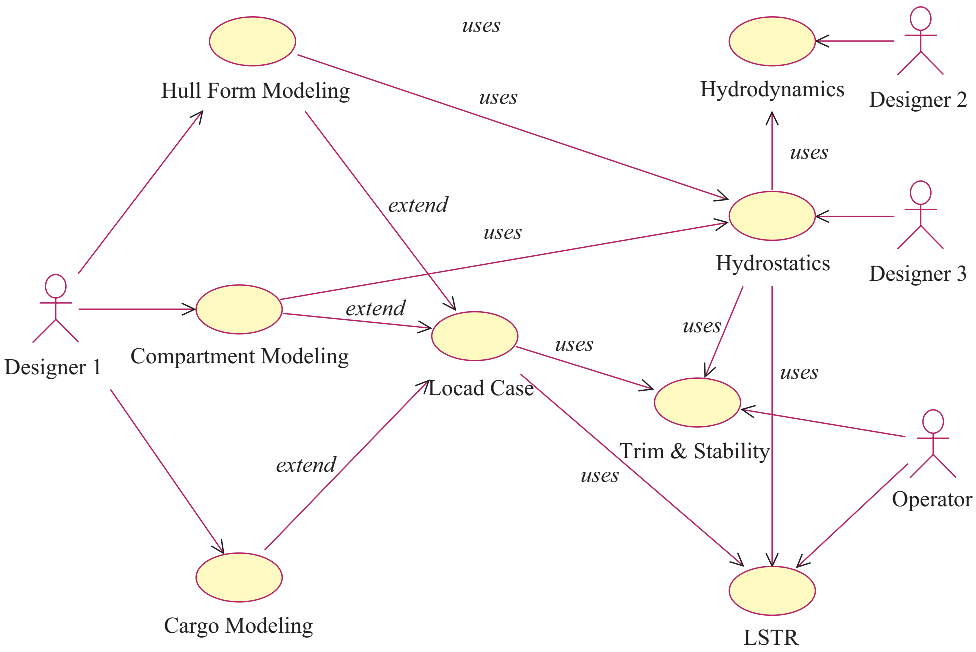


Fig. 6. Main use case diagram for SPPM.

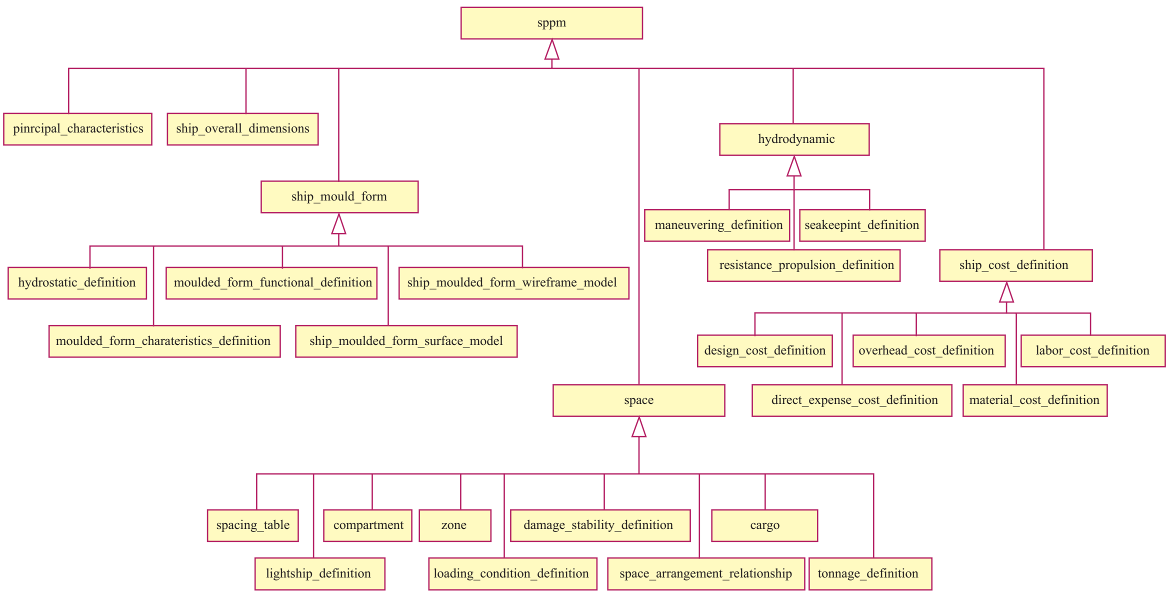


Fig. 7. High level class diagram of SPPM in UML.

were produced using the code generation facility of Rational Rose. These libraries are fully implemented with interfaces for the application use.

Fig. 6 is the main use case diagram of the initial ship design system. The users of this system are defined as the actors, and main functions or activities are defined as the use cases of the use case model. These information can be easily obtained from the activity model of IDEF0.

Fig. 7 shows the high-level class diagram of SPPM in UML model.

III. IMPLEMENTATION AND VERIFICATION OF SPPM

Resulting from the series of modeling works described in previous chapter, a set of fully implemented C++ classes, called the SPPM framework library, was obtained for the applications. In order to verify the applicability and the effectiveness of the SPPM as a framework for CAE integration and multi-disciplinary design optimization, a prototype system was developed, and a product model was implemented for

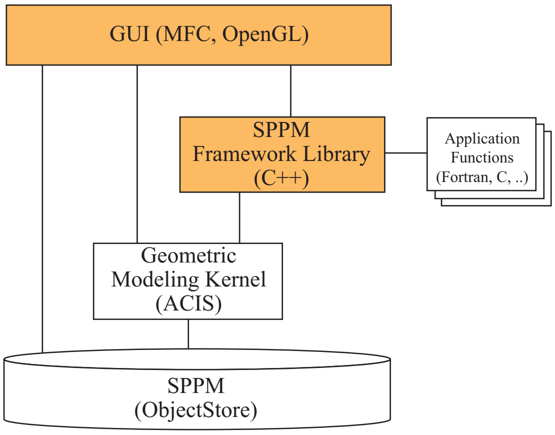


Fig. 8. Architecture of system prototype.

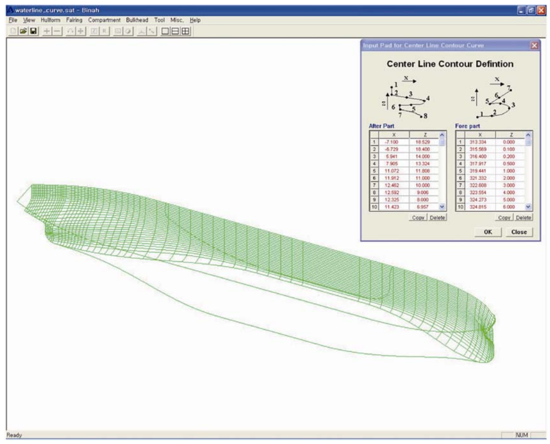


Fig. 9. Result of hull form modeling.

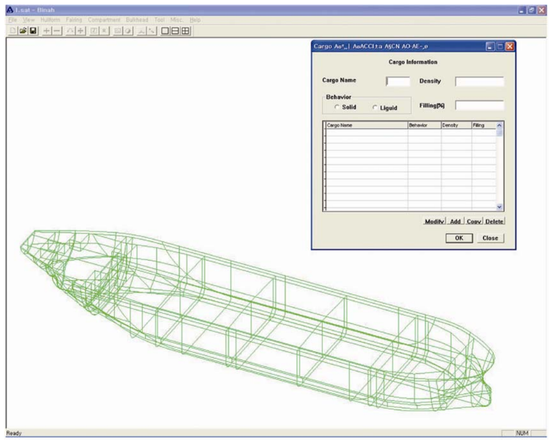


Fig. 10. Result of compartment and cargo modeling.

Computational Fluid Dynamics (CFD) analysis, the stability and longitudinal strength assessment, and STEP file generation.

1. Development of Product Modeling System

A product model is a structured set of objects which are the instances of classes. Modeling system or modeler is a software system, normally known as CAD system, to build a product model by instancing the classes.

The SPPM framework is a set of application level (ARM, Application Reference Model of STEP) C++ class libraries. This framework provides the STEP based standard structure of product model data and the common functionalities (behaviors) of the client applications in the initial ship design activities. Also the SPPM framework provides the interfaces to external application programs (written in Fortran and C language) and resources such as geometry kernel and database management systems.

To implement a product model based on the SPPM framework, a mean of Application Interpretation Model of STEP (AIM) level representation is needed.

Fig. 8 shows the architecture of the modeling system for SPPM. As shown in the figure, ACIS geometric modeling kernel was used for the geometric definition and representation. And for the persistent storage and management of the product model data, an object-oriented database management system - ObjectStore - was used. This database solution integrates the persistence mechanism between the application objects. The OpenGL graphic library was utilized for the visualization of the product model, and Visual C++ programming language for the implementation of Graphical User Interface (GUI).

In this modeling system the SPPM framework provides the interfaces to ACIS kernel and ObjectStore database.

2. Implementation and Verification of SPPM

1) Implementation of Product Model

The implementation of SPPM starts with the hull form modeling, and followed by the compartment modeling and cargo definition processes. For the hull form modeling, the basic curves (center line contour, bottom and side tangent lines, frame lines, water lines, etc.) are defined by using offset data. These curves are faired automatically or interactively, and used as the input data for the surface modeling in Non-Uniform Rational B-Spline (NURBS). The deck surface is also defined by the shear and camber information.

After completion of the hull form model, the compartment and cargo modeling continues for the SPPM. The compartment is a functional unit of space such as tanks, engine room, cabin, and so on. The compartment consists of one or more rooms. The room is a geometrical unit defined by the boundary surfaces. A special coordinate system, the frame system based on the frame number and space of the ship, is used for compartment definition. After the definition of an object geometrically, the properties of that object are also defined and checked automatically or interactively through GUI windows designed for each object. Also the cargo information is defined for each compartment and stored in SPPM.

Fig. 9 and Fig. 10 shows the results of hull form and compartment/cargo model respectively.

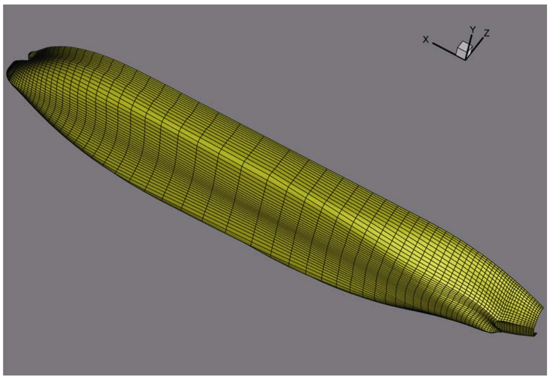


Fig. 11. Result of grid generation for CFD analysis.

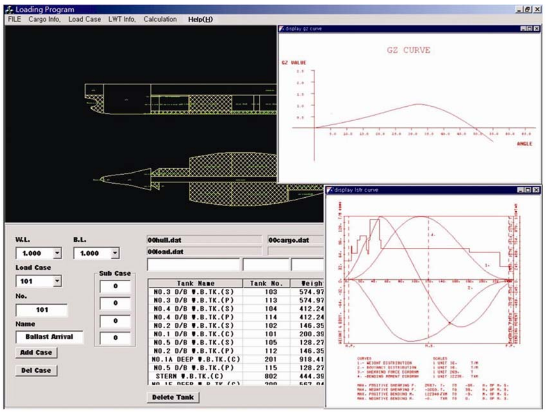


Fig. 12. Result of simulation results for the stability and LSTR assessment.

2) Verification of Product Model

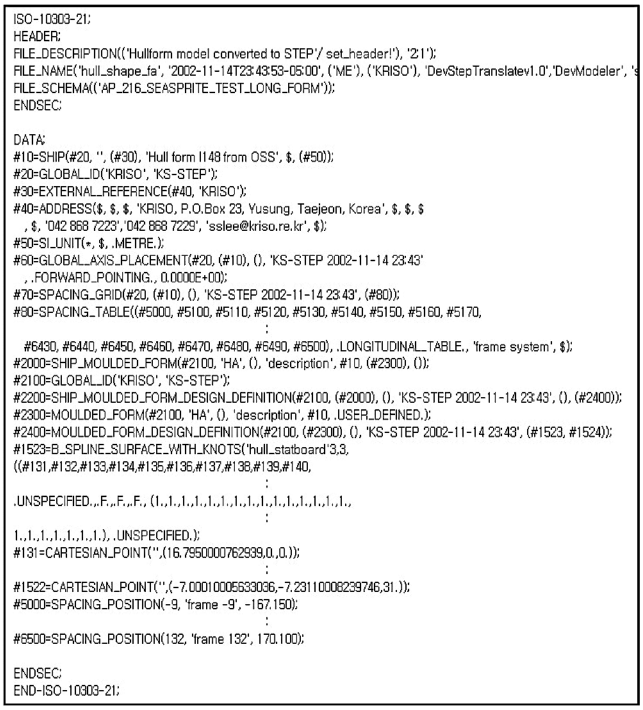
For the verification of the effectiveness and the applicability of SPPM, grid generation for CFD analysis, stability and Longitudinal STRength (LSTR) assessment were performed. Also generation of STEP data file for the exchange of design data to other system was tested.

For stability and LSTR assessment, the load cases must be defined based on the product model. The load case is a certain condition of ship, normally and intensionally defined for design purpose. The basic data required for the load cases are directly acquired from the product model. By changing conditions, we can simulate the changes of ship stability such as trim, rolling angle, GZ-curve and damage stability and so on. Simultaneously LSTR condition is checked through weight distribution, buoyancy distribution, shearing force distribution, longitudinal bending moment distribution and so on.

Fig. 11 shows an result of grid generation for CFD analysis from SPPM.

Fig. 12 is the result of the stability and LSTR assessment, which shows simultaneously display GZ curve, LSTR curves and related information in accordance with the change of load case based on SPPM.

Fig. 13 is an result of STEP AP216 physical file generated from the hull form model.



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ENDSEC;

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#30=EXTERNAL_REFERENCE(#40, 'KRISO');
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                                  :
1.,1.,1.,1.,1.,1.,1.), .UNSPECIFIED.);
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ENDSEC;
END-ISO-10303-21;
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Fig. 13. Result of STEP data generated from SPPM.

IV. CONCLUSION

For several years, the 3-D product model has been a standard in shipbuilding. However, 3-D design is still mainly used in the detail design phase. In some rare cases, the use of 3-D design extends to earlier design phases for hull form design and some naval architectural calculations.

In this paper, a STEP based ship product model (SPPM) was introduced and proposed as a framework for the integration of CAE applications and related design information in ship initial design stage. For the design of SPPM, an object-oriented hybrid methodology based on IDEF family of methods was defined and introduced as an information modeling tool for the development of shipbuilding information system.

For the verification of the SPPM, a prototype system has been designed and implemented using ACIS geometry modeling kernel and ObjectStore - an object oriented database management system - in Window XP environment. As a client application, the stability and the LSTR assessment for a damaged condition was selected, and the changes of stability and LSTR conditions was simulated according to the change of the load cases.

Additionally the authors assured that the STEP could be a baseline for the development of new shipbuilding CAD system because of their qualified data structure and well proven methodologies.

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