Factory simulation based on shipbuilding CIM

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Abstract

This paper considers factory simulation based on shipbuilding CIM in which a computer integrated design and manufacturing system is considered. The author proposes the product model and several alterative functions for designing ship's structure, and develop a ship definition system for computer integrated design and manufacturing. This implemented system is called SODAS (System Of Design and Assembly for Shipbuilding). Object oriented concept is used to develop this system. As well as the product model, the design function, cutting function, and virtual assembling function are introduced. By using the design function, any type of ship's structure can be designed. And also factory simulation can be carried out by using the cutting function and virtual assembling function.

1 Introduction

Since the early 1960s, many computer systems have been developed to support the design and manufacture in shipbuilding industries. However, the environment of design and manufacture is constantly changing, and manufacturing industries have to adapt to these changes. So in the sense of software technology, new systems which can be applied design and manufacturing activities must be developed.
A relatively new concept in design and manufacturing systems is proposed here. This is a kind of Computer Integrated Manufacturing system (CIM) in shipbuilding industries.
Various manufacturing industries have made efforts to develop CIM. In the shipbuilding industry, which is called to be a mature industry, various possibilities have already been tried out in several companies.
In this paper, the author pays particular attention to research into the development of CIM in shipbuilding in two main areas.

1) Modeling design and manufacturing activities in shipbuilding. Various activities and targets are analyzed and organized in an attempt to clarify which information should be generated, transmitted, and processed by a computer.
2) Developing a prototype system for CIM in shipbuilding. A prototype system is developed in order to carry factory simulation based on shipbuilding CIM.

2 Design and manufacturing systems in Shipbuilding

2.1 Problems in developing CIM

In order to develop CIM, it is necessary that information on design and manufacturing activities should be integrated. However, there are several problems in the current system.

They are
1) Information used in each system is isolated.
2) The administration and transmission of essential information is inadequate.
3) The generation of information is more important than its transmission.

2.2 Modeling for design and manufacturing systems

At the various design and manufacturing stages, information is generated, transmitted, and processed. Such information from the stand point of design manufacturing systems is summarized as below.

1) Information on design and manufacturing target (design requirements, design specifications, engineering drawings, product performance, production process, etc.)
2) Information on design and manufacturing processes (design procedures, production preparation procedures, etc.)
3) Information on manufacturing control (production planning, production results, stock, orders, shipments, etc.)
4) Information on manufacturing resources and environment (technological data, production equipment, etc.)

It is thought that integration of the generation of necessary information for production activities and the transmission and administration of such information is vital in the development of CIM. Therefore, products and manufacturing activities have been modeled along the following lines.

1) Modeling the product. Expression of product on a computer
2) Modeling manufacturing processes. Expression of manufacturing activities on a computer.
3) Modeling the manufacturing environment. Expression of the manufacturing environment, such as the factory, the production equipment, and the workers, on a computer.

2.3 Characteristics of the design process

The design stages in manufacturing can be classified as follows:
Concept Design→ Elementary design
→ Detailed design → Production design
The information on a product is generated at each design stage, and the information generated at each stage is different. Therefore, it is thought that the design activities can be examined in the following way.

1) The designer configures a product from the requirements specified at each design stage.
2) The designer then generates enough information on a product for manufacture to take place.
The design process itself should be modeled on a computer as a design process model.

3 Product model in Shipbuilding

Many models are needed to support the various design activities in which computer systems are used. If these models are entirely independent from each other, handling them becomes difficult. So the concept of the integrated model is very important. However, the integrated model is not clearly defined, so this aspect is now considered here.
The final shape of a product is not an adequate description of the product for computer system. It is necessary to input a lot of information which does not appear in the overall shape of the product. That information must be considered in the design process, and the model which describes all this information is [1] product model. If the product model in shipbuilding is defined and the product can be expressed on a computer, then all the product information can be used at the various design stages.
This paper reports on a development of CIM system for shipbuilding. This system is called SODAS (System Of Design and Assembling for Shipbuilding). It was developed using Smalltalk, which is an object oriented language. In SODAS, several objects are defined for the product model in shipbuilding: These are a parts object, a connection object, a room object, a unit object, a module object, and so on.

3.1 Parts object

A parts object is defined as information on a parts member, the shape of a parts member is expressed by a surface model, and the thickness and material are described as attribute data. The parts object is stores in the unit object.

Plate parts: The shape of a plate parts member is expressed by a surface model in three-dimensional space, and plate thickness is disregarded. This shape is described by several vertices and several edges.

3.2 Connective relation between parts members

A connective relation between parts members is defined as a connection object. Information on the location of a connection relation is described by a wire frame model, and the two parts objects which are joined to each other are described in this object. Moreover, this connection object is described in the corresponding two parts objects as information of the connective relation.

Connection object: Information on a connection between two parts members is defined as a connection object. This information is later converted into weld line information.

3.3 Room Object

A room object is defined as information or a compartments and various tanks. The shape of a room object is expressed as a solid model which encloses several parts members. This object is generated (designed) by the design function for spaces.

3.4 Unit Object

A unit object is defined as information on primary and secondary internal structures. This object has some parts objects and is generated (designed) by the design function for internal structures. In this paper, two types of unit objects are defined. They are a plate unit and section unit.

3.5 A Module Object

A module object is defined as a set of parts to express an intermediate product which is the construction unit at each production stage. A data structure of the module is expressed as a

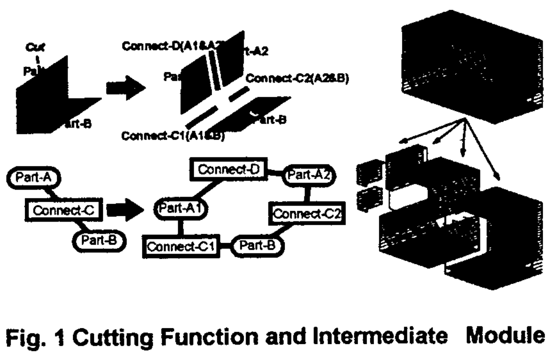

Fig. 1 Cutting Function and Intermediate Module

hierarchical structure. The module of the lowest layer is composed of parts member. The module relates to the module construction method of the shipbuilding industry.

4 Functions for structural design

In order to generate and store information on a product as the product model at the structural design stage, the design function is defined in SODAS. There are two design functions, they are "design function for spaces" and "design function for internal structures."

4.1 Design function for spaces (rooms)

One closed space (room) is divided into several spaces (rooms) by the design function for spaces. Compartments and tanks in a ship can be designed by using this function. It is thought that this function corresponds to the elementary design of a ship.

4.2 Design function for internal structures

The design function for internal structures is used to design longitudinal structural members and transverse structural members to reinforce plate members. The concept of a parametric design is introduced for this function. Because parametric design makes it easy to design those members. Using this function, the plane unit object and the section unit object are generated as the internal structures in a ship.

5 Functions for production design

It is important to generate more detailed information for the production stage from those information which are generated in the structural design stage.
In SODAS, cutting function virtual assembling function are introduced to define detailed information for the production design.

5.1 Cutting Function

The designed structure must be decomposed into erection modules, middle modules (i.e. middle intermediate products) or small modules (i.e. small intermediate products).
In order to realize the above mentioned function, cutting function is introduced in this system. This function can be used not only for the division of a parts member but also for the division of a module and a whole ship structure.

5.2 Virtual assembling function

The structure divided by using cutting function is a partial structure which is designed by a designer, and information about its parts is not enough for the production stage. Therefore, SODAS supports another function which is called virtual assembling function.
The virtual assembling function is a function that enables the designer and the scheduler to define the assembly order by picking out each part from the structure which has been generated by the cutting function. In order words, this function can be used for process planning in shipbuilding. The designer can input information on production using this function. For example, the selection of welding process, welding condition, a detail shape of an edge preparations, or the value of extending certain parts can be determined.
Moreover, if the virtual assembling function has high level definition, it is possible that a system itself can check interference between a fillet weld which has already been welded and the corner of the floor plate member which is being inserted. This system supports the production design.

6 Simulation system applicable to CAD/CAE (Integrated CAE system)

When a designer wants to evaluate a designed product on all the design conditions through calculations by using a computer, a elaborating work must be done by a designer. In order to execute

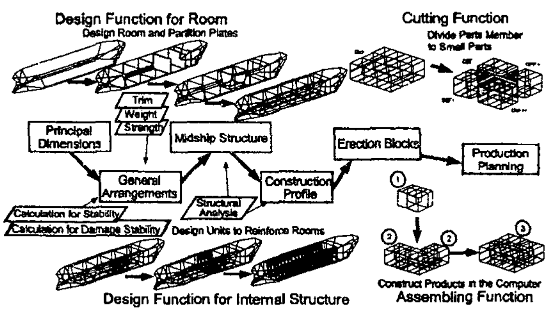

Fig. 2 Design Process and Product Model

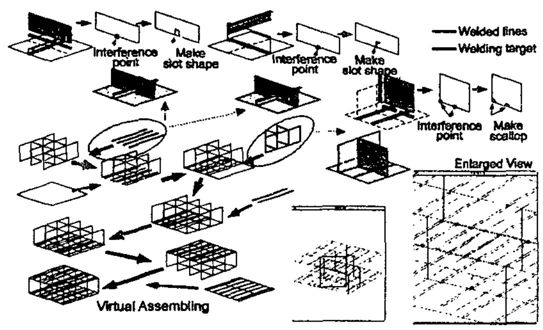

Fig. 3 Virtual Assembling Process

these elaborative works systematically in SODAS, several CAE systems which are integrated to product model system are developed.

6.1 Supporting system for initial ship design

In the supporting system for initial ship design, such information on a performance, a stability, a structural strength and so on of the ship are obtained. In order to get these information from the product model, information on a cargo such as cargo types, and quantity are introduced in addition to information on a ship such as three-dimensional shape, weight of ship and the center of gravity of a ship.

6.2 Integration with a calculation system of ship motions by strip method

In shipbuilding technology, an external wave induced force which is applied to a hull structure should be calculated by a calculation system of ship motions. And it is impossible to estimate those wave induced force determinately. Therefore, in order to estimate probabilistic wave induced force, great many

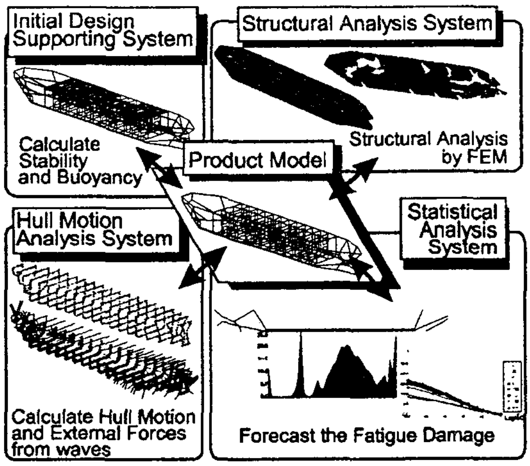

Fig. 4 Integrated CAE System

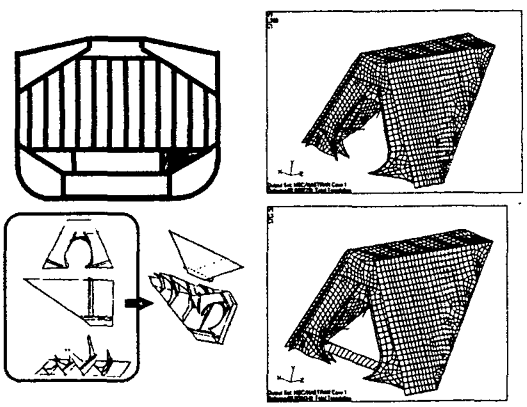

Fig. 5 Estimation of Weld Deformation

calculations should be carried. In the SODAS, the necessary data for these calculations are systematically generated from the product model easily, and it is possible to store many data of an external force in the product model.

6.3 Integration system with FEA

The finite element method analysis is often carried in shipbuild industries. It is often said that an amount of input data for FEM calculation is so large that a work for a generation of data is very hard. The product model system is also used to generate the data for FEM calculation in which mesh generation function is developed in the SODAS.
The structure which should be analysed can be taken out from the product model by using the cutting function. When a designer inputs a standard size of the finite element mesh, nodes for FEM calculation can automatically be generated for the analysis target. Generated nodes and meshes are stored in the product model and it is possible to generate input data for NASTRAN and for MARC.

6.4 Integration with the structural optimization design system

GENESIS which is developed in NASA is a structural optimization design system. GENESIS itself can search for optimized design variables under a defined constraint. Some structural designers willing to use such system like structural optimization. In order to integrate the GENESIS with the SODAS, the control system of GENESIS is developed. This control system can set problems of the structure. And the product model can automatically be modified by the optimization results of GENESIS.

7 Simulation system applicable to manufacture

7.1 Supporting system for production planning

We can generate information on process planning by the virtual assembling function. When an intermediate product is generated by the cutting function, we can get information on connective relation between intermediate products. And we can get a list of operations, a PERT (Program Evaluation and Review Technique) diagram and scheduling table when a designer or scheduler define assembly order by picking out each part from the structure.

7.2 Designing the detail shapes of parts

In order to generate detailed information on parts, the designer has to select a lot of detailed information such as detail shapes of groove. In the structural design in SODAS, the shapes of parts members are expressed as a surface model. However, it is more advantageous to express the shapes of these parts as a solid model in the production design. For instance, it is convenient to express the shapes of parts as solid model so that

we can use this information to generate data of the NC cutting machine.
Since plate thickness is described as attribute data in SODAS, this thickness has to be processed. It is therefore necessary to develop a function which will change a surface model to a solid model. In order to determine the detail geometric data of any part, it is necessary to consider the influence from all the other adjacent parts.
When all these preparations have been made. The only one thing the designer have to do is to make use of the virtual assembling function prepared in SODAS.

7.3 Simulation system for block transportation

The system which supports to hoist block and to transport block is developed in SODAS. When we add models such as the hoisting points, the wires and the cranes in the system, we can simulate how to control the operation of the wire and where we have to set the hoisting piece.

7.4 Controlling system for accuracy of products

The controlling for an accuracy of a product is the most important problem in the production of the welded large scale structure. So, the controlling system for an accuracy of a products which considers the welding deformation is considered from the following two viewpoints in the SODAS.

1) The comparison the intermediate product stored on a computer with a real product (which assembled at shipyard.)
2) The comparison with two real products by using data which is stored on a computer. By this comparison, it can be confirmed whether it is possible to joint real products on a computer.

7.5 Integration with a robot simulation system

Recently, the welding root comes to be used. In SODAS, we have already a lots of work data on a computer, it is not so difficult to generate weld teaching information by using SODAS.

8 Simulation based design and manufacturing

8.1 The product definition spiral and application systems

In this paper, what is the product model for shipbuilding and what is the function to generate the product model are discussed. The growing process for implementing the product model in shipbuilding through a concept design, an initial design is expressed in the product definition spiral. This spiral shows the design function, the cutting function and the virtual assembling function which is necessary to grow the product model clearly.
We can easily understand that the relation between the product definition spiral and the application

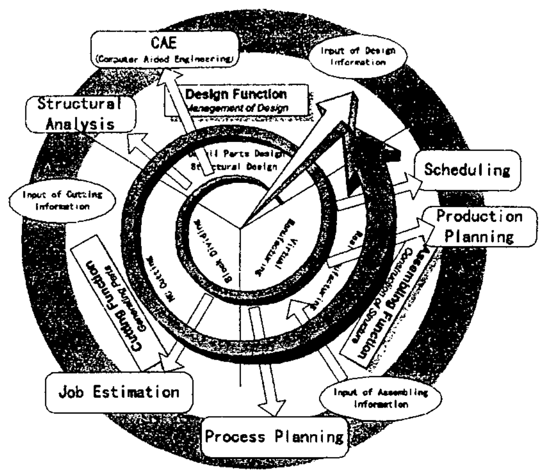

Fig. 6 Product Definition Spiral

systems.

8.2 Simulation in design stage

In the SODAS, we can design general arrangement by the space design function. And we can design ship structure by the internal structural design function. The transverse ring members, the longitudinal members and the small structural members are generated by this function. The system can quickly respond to a designer's demand. We can calculate the capacity of tanks and weight and the center of gravity of the structure easily. And it is thought that the information on connection relation is automatically generated. The information on position and the length of the weld line is easily taken out by using connection information.

8.3 Simulation in engineering judgement (Evaluation of design result)

After the design simulation is carried, a result of design should be evaluated. In this step, an excellent design engineer works through whole his experience. The engineering simulation by CAE system in the SODAS offers proper information for an excellent design engineer to make judgement.
In shipbuilding industry, each CAE system should be integrated with CAD. People are usually more interested in an individual element technology than an integration technology discussed in this paper. We should recognize that it is very important not only the individual technology but also the technology which integrates the several individual technologies.

8.4 Simulation of manufacturing

The simulation of manufacturing becomes a next problem, after the simulation of design. The simulation of manufacturing includes the simulation for production planning, for welding robot and for NC

cutting machine. Those simulation systems are shown in this paper. But these systems are often thought far from the practical use, because the Product Model is not clarified yet. However, it is impossible to discuss the simulation of manufacturing in the near future in the sense of high productivity. We can get any kind of information for production planning from the Product Model. And a detail shape of parts and a control data for a robot can be also generated from the Product Model.
At present, there is little practical idea on the *simulation of manufacturing. Therefore, the industrial* engineers should discuss what they can do if there exist the simulation of manufacturing by using the Product Model.

9 Conclusion

When it is possible to simulate whole activities of a design and production in the shipbuilding, the shipbuilding industry will have a bright future.
For instance, a designer will be able to select the best ship from several ships which a designer designs with evaluating merits and demerits.
Moreover, after design information is obtained, a production planner will be able to simulate the production planning and decide the best plan for production planner which uses the factory equipment enough in the shipyard. Especially, if the design of ship with considering high productivity in shipyards must be realized. If such a dream could come true, it might approve the shipbuilding industry without a shipyard. In order to realize the simulation for the shipbuilding , in a short time.

10 References

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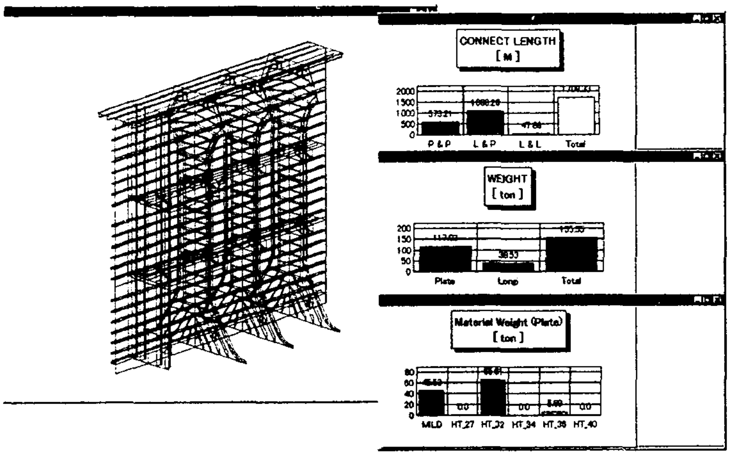

Fig. 7 Block Division and it estimated Values

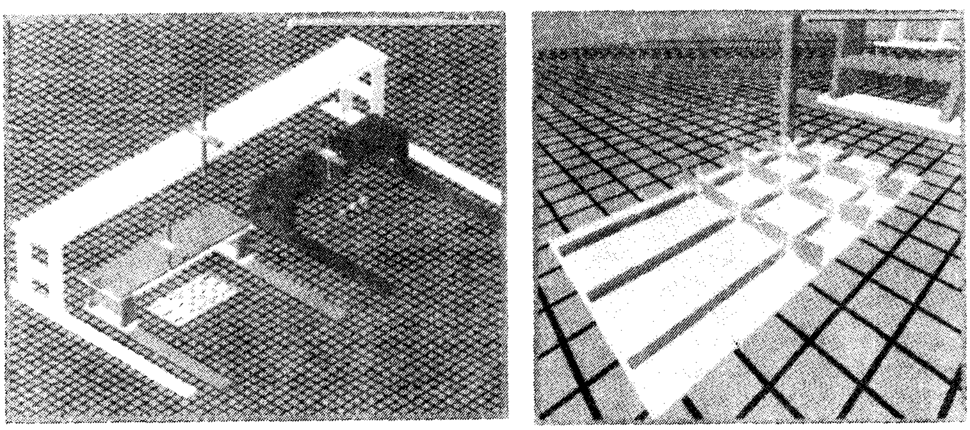

Fig. 8 Robot Simulation by CimStation