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Simulation Based Production Using 3-D CAD in Shipbuilding

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Abstract – The application of three-dimensional (3-D) CAD has been popularized for design and production and digital manufacturing has been spreading in many industrial fields. By simulation of the production process using 3-D digital models, which are the core of CIM (Computer Integrated Manufacturing) system, the efficiency and safety of production are improved at each stage of work, and optimization of manufacturing can be achieved. This paper firstly describes the concept of "simulation based production" in shipbuilding and also digital manufacturing; the 3-D CAD system is indispensable for effective simulation because ship structure is three dimensionally complex. By simulation, "computer optimized manufacturing" can be possible. The most effective fields of simulation in shipbuilding are in jobs where many parties have to cooperate, while existing two-dimensional drawings are hardly observed the whole structures due to interference between structures or equipment of complex shape. In this paper some examples of the successful application in IHIMU (IHI Marine United Inc.) are shown: assembly of a pipe unit, erection of a complex hull block, carriage of equipment, installation of a propeller, and access in an engine room.

Key Words **: Simulation Based Production, Digital Manufacturing, 3-D CAD, Shipbuilding, AJISAI**

1. Introduction

In manufacturing fields, "simulation based production" has been applied recently due to the popularization of simulation technologies, as shown in Table 1[1][3][4][7][9][10]. By simulating the production process before production, manufacturing efficiency and safety may be hoped for, and dynamic production by real-time management becomes possible using the information gained at each stage of work in the fields. This is most effective when using three-dimensional CAD model. This paper states that the 3-D CAD system is indispensable in order to apply the production simulation for ship production and that the three-dimensional viewer software is convenient to effect the simulation. The application is generally useful in fields where the cooperation between work parties is necessary, and where the work is very difficult due to dynamic interference, etc. As the application cases, the followings are introduced: assembly of a pipe unit, erection of a complex hull block, carriage of equipment, installa-tion of CRP(contra-rotating propeller), and "walk through" in an engine room.

2. Production Simulation

2.1 Simulation in shipbuilding

Computer simulation has been applied mainly in ship design stage up to now, especially in the initial planning and structural analysis at design stage, while it has not been widely implemented in production because ship production is very complicated and requires much experience. The aim to introduce the simulation is [4]:

1) Quality improvement: to predict and estimate performance such as vessel speed, dead weight, strength and so on, in accordance with design demand.
2) Shortening of lead times: to shorten the construction period and flow time from design to completion of a ship.
3) Reduction of production cost: to decrease the costs, both material costs and personnel expenses, and to reduce the waste time during the manufacturing process.

In ship production, simulations may be applied as follows:

(1) Analysis and evaluation of the production process
(2) Planning and assisting of production
(3) Simulator for training of skilled work such as line heating, welding, and straightening.
(4) To confirm work safety

Hereafter, only production simulation concerning points (1), (2) above is discussed.

2.2 Simulation in ship production

When CIM (Computer Integrated Manufacturing) is applied, design and production data are defined numerically in product models, and then production engineering becomes possible using these models. In order to raise productivity, quality, and safety, which are three major elements in production, it becomes important to study

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Table 1. Research concerning simulation based production

Referenc	First author	Application field	Contents	Nation
9	Thiel, M.	Semiconductor Industry	Order sequencing problems	Germany
3	Tones, A	Various production system	Production equipment & process	USA
1	Hertel, E.	Shipbuilding	Assembly simulation	Netherlands
10	Yoneda, T	Construction machinery	Evaluation of production efficiency	Japan
4, 7	Okumoto, Y	Shipbuilding	Production simulation using 3-D model	Japan

the production procedure in advance using various computer simulations. A ship is one of the large plants with complicated structures composed of a million of parts procured from all over the world, which are comprised of many kinds of materials. During ship construction many parts are collected at one place, a shipyard, hence it is necessary that the production method and timing should be planned by considering much information relating to the parts, as well as human resources and facilities in the shipyard. Current production planning has depended on the accumulated know-how of shipbuilding, which satisfies the efficiency and quality requirements among much combination of process in each job. However many skilled workers, who have supported the shipbuilding industry until now, have left the shipyards, in response to prolonged business stagnation. Simulation based production can substitute this decline.

In the meantime, it is said that three-dimensional CAD is effective in production simulation, and it may be successfully utilized in the automobile and aircraft industries. Though this idea itself has existed in shipbuilding from the past, it had not been successfully realized, because the cost to make 3-D models might be too much due to "job order production". However, the capability of computers has markedly improved, and the price has become cheaper in recent years fortunately, moreover, the application software has become more popular. Hence the computer simulation of ship production using these technologies has become easy. In addition, all ship structures and parts for both hull and fittings have been defined recently by three-dimensional CAD. IIHI MU (IHI Marine United Inc.) has developed "AJISAI" system for it (Fig. 1)[8], and all product models have been defined digitally.

Fig. 2 shows a display image on a computer for structures of VLCC in the building dock after two weeks from erection start. Using such product models, production simulation becomes possible for both hull structures and fittings, and further improvements in efficiency, safety, and quality are expected.

Though there are many applications for production simulation, the most effective applications are as follows:

1) To check the feasibility of the construction procedure and efficiency of the work (whether it is possible, easy, or not)

2) To confirm the interference both human and structures in the space

3) Optimization of the construction process

Regarding point (1) above, there are many examples using large three-dimensional models, and for (2) there is the possibility to check the production process in the complicated 3-D space using dynamic moving images. Even skilled workers have weak points and often make a mistake, hence the simulation will be a tool to compensate these errors and raise the integrity of the engineering. Regarding point (3) above, the following is noted.

2.3 Computer optimized manufacturing

In the production field of shipbuilding, most of the work depends on the cooperation of multiple workers. In accordance with scale and degree of difficulty of the work, the related field increases and the workers also

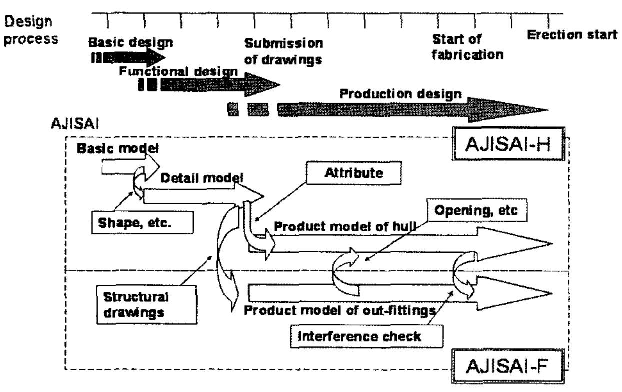

Fig. 1. IHI MU "AJISAI" system.

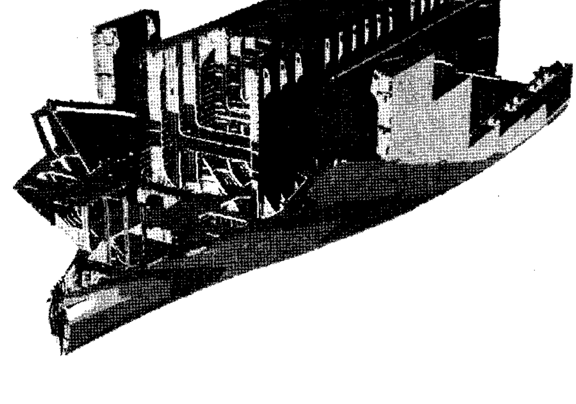

Fig. 2. Ship condition in building dock.

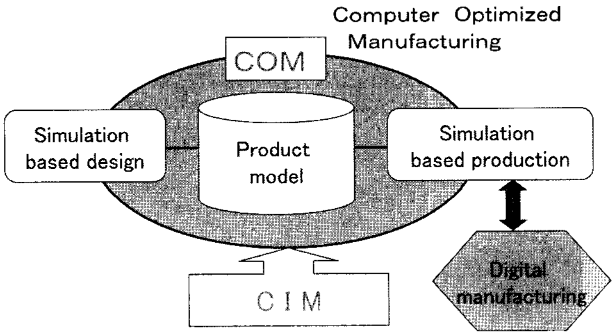

Fig. 3. Concept of COM in shipbuilding.

increase. In order to construct a ship efficiently and safely, it is necessary for all related workers to have a common acknowledge and to work in cooperation. Using the product model which is the core of the CIM, design and production planning of the simulation base can be carried out, and the global optimization is obtained as shown in Fig. 3 [7]. In the field, digital manufacturing based on this optimization plan can be done.

3. Assembly Simulation of Pipe Unit

Assembly work of fittings is a typical job in shipbuilding. As shipbuilding is a kind of "production to order", not "mass production", the design and production details are almost different every time. Hence, the work has to be carried out on the basis of personal experience by observing only the rough drawings which do not include detail instructions for work procedure generally. Therefore, the following problems of assembly of fittings exist:

1) Training and experience are necessary in order to imagine the completed condition and to plan the assembly procedure from the rough drawings.

2) Such operational procedure based on experience is not always optimal.

3) Design errors are not found until production.

4) Unpredictable problems sometimes occur, and the schedule is often interrupted.

5) Inexperienced people can not perform the work.

Firstly the pipe unit assembly was applied [7]. An

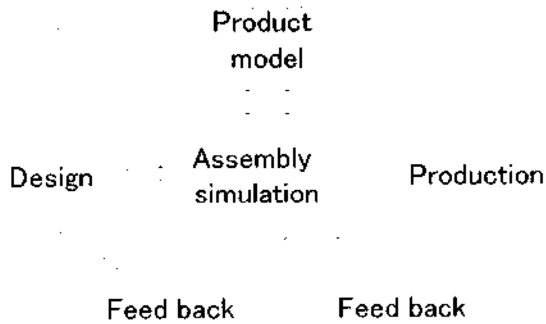

Fig. 4. Simulation based production.

Fig. 5. Computer in job site.

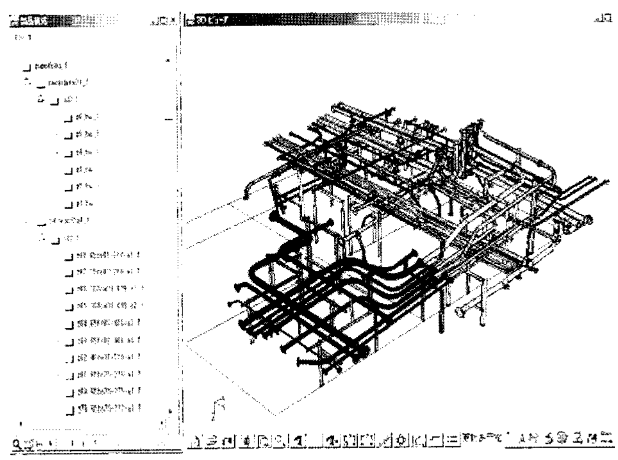

Fig. 6. 3-D image on a monitor.

assembly simulation system was recently developed (Fig. 4), so that even inexperienced workers can carry out the assembly of pipe units.

The results of the assembly simulation are displayed on a personal computer through wireless LAN in the yard (Fig. 5) and the worker operates it in the assembly site. On the display of the personal computer, the structural tree of components to be assembled is also shown as well as a birds-eye view of the pipe unit (Fig. 6).

Three-dimensional imaging of any desired area is possible on the display from any viewpoint, including a related parts list which contains the pallet name, kind of parts (support, pipe, valve, etc.), parts name, secondary parts (packing, volts & nuts, etc.), and the relation with each component. The display image is comprehensible even for inexperienced people.

In the assembly simulation program, the mounting order of pipes is automatically decided, sequentially from the bottom, so that these may not interfere between parts. Special consideration is given to the position of the top and bottom because the hull block may be upside down

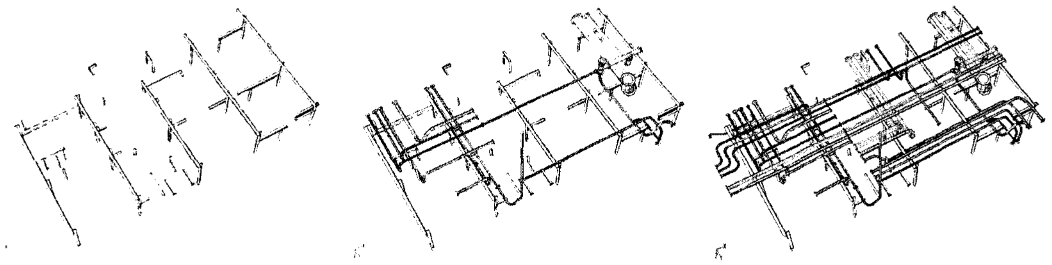
(a) (b) (c)

Fig. 7. Procedure of assembling

in the assembly. Also special attention is paid to branch pipes, short bend pipes, and diagonally arranged pipes. If this procedure is confirmed in advance from images on a computer display, the problems in the assembly work can be found beforehand, and the worker can understand the operational procedure beforehand. Fig. 7 shows the assembly procedure on a display screen: (a) the condition after the pipe supports are made, (b) the condition when 20% of pipes are installed, (c) the condition at 80%. For further development, especially for the parts management of pipes, a wearable computer system is being successfully developed [5] and also the RFID system is now being considered [6].

4. Other Examples

Four examples are introduced here [2]. By using three dimensional product models and viewers, verification of the production process and improvement in the quality were realized.

4.1 Block installation

Fig. 8 shows the simulation of a block installation on a building dock considering the 3-D data and design information of the surrounding structures. This case was the installation of an "inserted block" between the peripheral four blocks in the engine room. The relation between the inserted block and the adjacent structures installed in advance is very complicated, because blocks are finished on the ground where the work environment is good and equipment is mounted on the blocks as much as possible. Since various obstructions exist during the lifting down, the delicate and skillful operation of multiple large cranes of several hundred tons is required so that the block is set in the required position accurately.

However, it is very difficult to consider the dynamic relationship between the complicated three-dimensional structures in the mind. Much information of the three-dimensional CAD can comprehensibly express such transitional and complicated situation, and it is possible to construct smoothly by the prior understanding without discrepancies between the work parties.

4.2 Carriage of equipment

The example of carrying equipment in machinery space in FPSO (Floating Production Storage Offloading, one of the floating marine structures for oil storage) is shown in Fig. 9. Since continuous running is required throughout life span for such equipment, it is necessary to carry them to the outside of the hull without interfering with other equipment and structures, in the route beforehand planned for the purpose of repair and exchange.

This simulation was carried out for much equipment, and the effects have been confirmed. These simulations had been handed over to the ship owner for verification as an operational procedure book, as well as for the confirmation of the design.

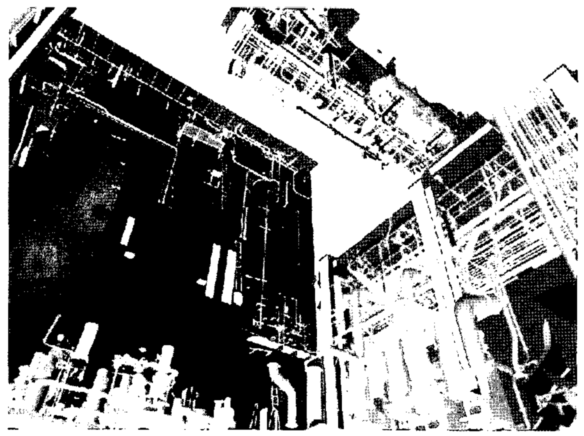
Fig. 8. Block installation.

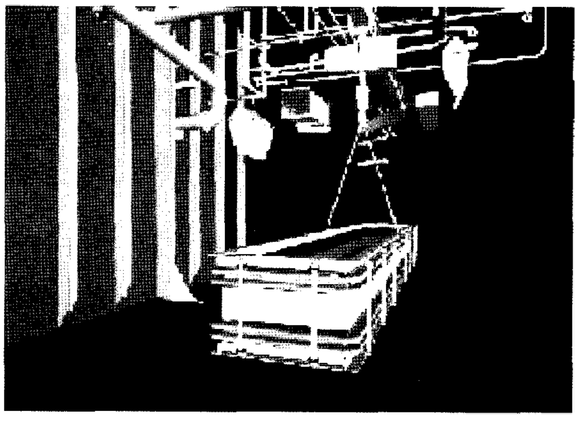
Fig. 9. Carriage of equipment.

4.3 Installation of CRP

The example of installation of a contra-rotating propeller (CRP) is shown in Fig. 10. Accurate setting for this is required in the narrow dock space, and also the cooperation of workers between ship inside and outside is indispensable in the insertion of the shaft. By confirming the procedure between workers involved beforehand, the good communication results, and the work was done smoothly.

4.4 "Walk through" in engine room

Fig. 11 shows an example of "walk through" in an engine room. This confirmation of human accessibility with a dummy board is often required by some classification societies and ship owners. If this confirmation is carried out at the design stage using the simulation by 3-D CAD, the interfering between equipment and structures can be avoided by design changes. Then, high-quality layout design without the retrogression was realized.

5. Conclusions

This paper stressed the importance of production simulation using three dimensional CAD as a part of a "digital factory and computer optimized manufacturing, and also introduced some examples of production simulation which have been applied successfully in actual production in IHI MU Kure shipyard, where a fully-fledged CIM system was developed and applied.

Through such a simulation approach it is expected to build ships rationally and safely. In the future, new IT tools such as a wearable computer and RFID system will be widely introduced, and it is expected that shipbuilding will become a modern industry.

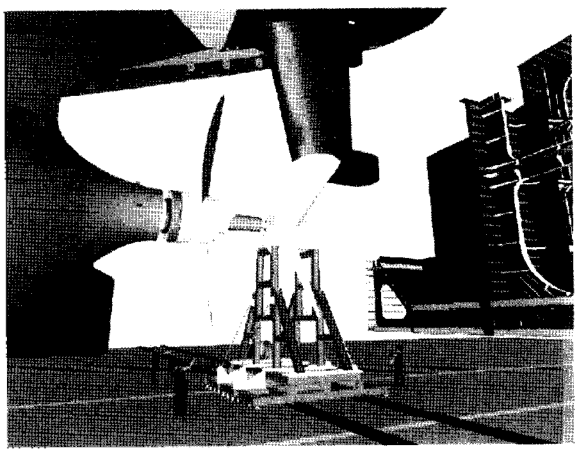

Fig. 10. Installation of CRP.

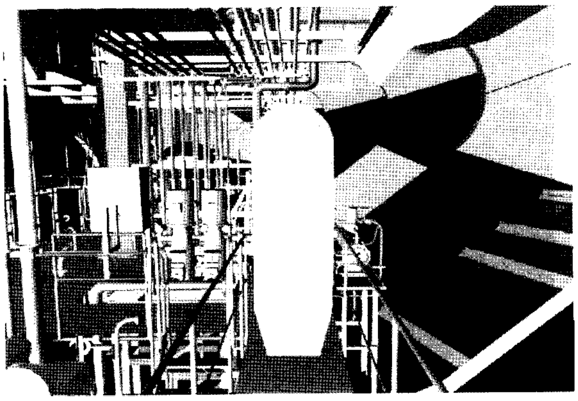

Fig. 11. "Walk through" in Engine room.

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