

Realization of CIM Based on Systematization of Production Department

Ken Ito*¹ Takashi Yoshimura*²
Akio Iida*² Masahiro Sonda*²

For more than 10 years, the Shipbuilding Division of Mitsubishi Heavy Industries, Ltd. (MHI) has been using its own design systems, MARINE and MATES, to improve design efficiency. Recently, a new production support system has been developed and put to practical use in the Production Department. The system uses the design data supplied by MATES, and has achieved efficient production management. Furthermore, new automated facilities have been introduced by the Nagasaki Shipyard & Machinery Works, for which the design data from MATES is in a prerequisite. This has led and leads to a remarkable improvement in productivity. The successful introduction of this production support system and the automated facilities was because information is integrated from design all the way to production, and in this sense, MHI's CIM has now been constructed. This paper gives an outline of MHI's CIM, focusing on the systematization of the Production Department.

1. Introduction

The increase in the rate of older employees and their wages in shipbuilding industry, as in the other industries, has accelerated the promotion of automation and computerized production system. In general, however, most of the works in shipbuilding fields are still resorted to manpower. It is, therefore, mandatory to build up a comprehensive production system taking due account of the works related to human system as well as the efficiency of each equipment.

The MHI Shipbuilding Division has developed and put into practical use, prior to the Production Department, the MARINE (Mitsubishi Advanced Realtime Initial design & Engineering system) and MATES (Mitsubishi Advanced Total Engineering system of Ships) design systems, taking into consideration the supply of information not only to the Design Department but also to the Production Department. Further, the Division has successfully developed and put into practice a production support system, aiming mainly at the improvement of control works in Production Department and the supply of accurate information to automated facilities.

With the adoption of the production support system as the foundation for field operation, and the introduction of automated facilities, the information from design to production has been integrated, thus realizing the MHI's shipbuilding CIM. This paper describes the outline of the Shipbuilding CIM, focusing on the systematization of the Production Department.

2. Overall view of CIM

The shipbuilding CIM configuration is given in Fig. 1. The shipbuilding CIM is composed of the initial design and engineering system MARINE used at the upstream, the total engineering system of ships, MATES, and the production support system to support the production works.

MARINE, an integrated CAE (Computer Aided Engineering) system to support the initial design, came under development project in 1984, and was put to practical use in 1986. The system was developed with a view to intensifying the capacity in ship dealings, improving the technical power, reducing the cost, and devising the reserve power of development.

MATES, a design CAD system covering a wide range from basic design and detail design to production design, works as a

nucleus of the shipbuilding CIM. Development on MATES started in 1983, and its application to actual ship started in 1986. Equipped with a high-degree design support function, the system greatly contributes to improving the design efficiency and shortening the design term.

The production support system, developed after an elapse of three years, has been put to full operation since 1996, supporting the Production Department in the fields of production control and parts control in different stages such as working, assembly, erection, outfitting and delivery. Further, the system is also used for supplying operation date to automated facilities such as robots, etc. and for collecting the operational records.

The shipbuilding CIM has been built up and put into practical use through a long-term development process based on aforesaid conceptions, with its application to actual ships widened, and its link with other systems enlarged to realize the commutation and integration of information.

3. Features of design systems

3.1 Features of MARINE

This system enables optimization of design under given conditions by creating the desired ship model on the basis of type ship, and promptly repeating various performance calculations, and has the features given below.

- Study of effective design due to powerful GUI (Graphic User Interface)
- Visual check and evaluation of input data and calculation results
- Groups of substantial programs to support the evaluation of lines/performance
- Smooth system operation due to various data base control functions

3.2 Features of MATES

A nucleus of CAD system to support basic design, detail design and production design, MATES is composed of hull system and outfitting system. The system particularly features in its rich functions to meet flexibly with diversified alterations due to trial and error in addition to the basic functions of an ordinary CAD.

The system also includes the distinctive functions given below.

*1 Ship & Ocean Engineering Department, Shipbuilding & Ocean Development Headquarters
*2 Nagasaki Shipyard & Machinery Works

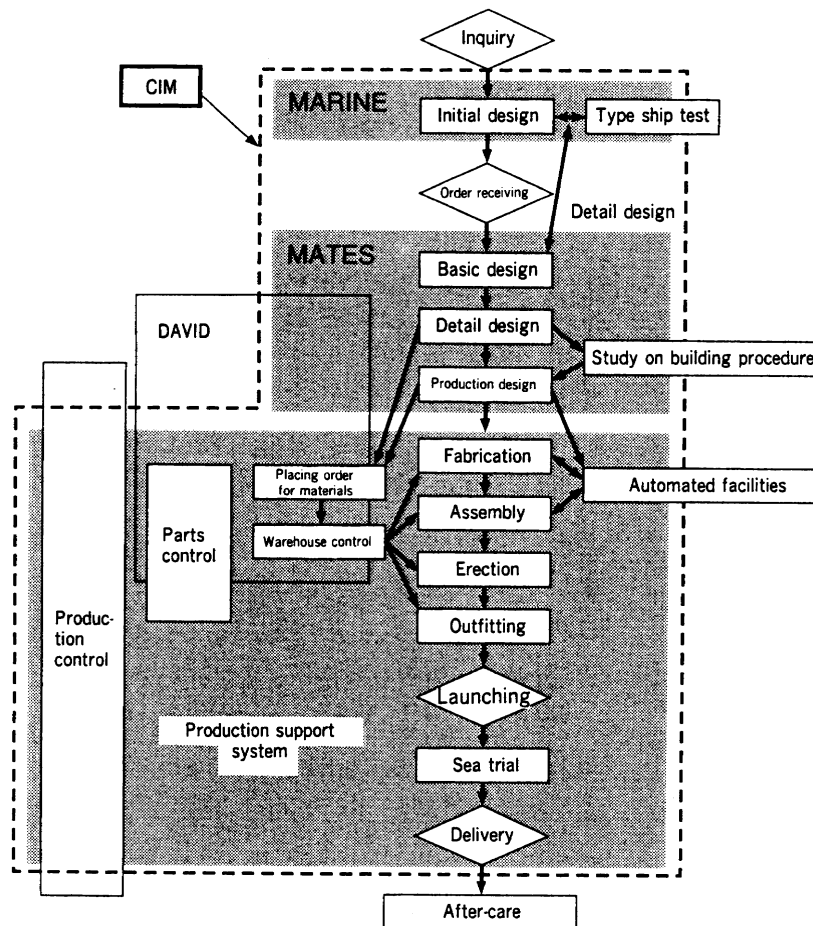


Fig. 1 Systems coverage of CIM
The systems and workflow in Design and Production Departments composing the shipbuilding CIM are shown.

- Various CAE functions to realize efficient design
- Substantial correcting function for diversion design
- Automatic processing function for parts making etc. in production design stage
- Data check and automatic set functions including design know-how

Furthermore, the design systems supply the material amount for production control like welding length, weight, etc., the three-dimensional structural data required for operating the automated facilities in production site, and working data to the production support system at the downstream.

4. Functions and features of production support system

The unique production support system, newly developed by making use of the design data of MATES, has actually been put into practical use in Production Department, contributing drastically to the improvement in the efficiency of production management. The newly developed system extends a wide support ranging from initial production planning to detailed production control tasks: mainly the precise tasks per work type and per facility controlled by a foreman, promotes integration of production information, and is equipped with various automated functions to support the optimization of production planning. The system is developed particularly with a view to implementation of target control for task group or individual.

The design data such as welding length is fed into this system to get processed into material amounts required for production control before being used for calculating the

number of man-hour or leveling the process. Detailed design data is essential to improve precision target control. Further, the design data is also used for preparing the action data and processing data to operate the NC cutting machine, automated pipe assembly factory, high-precision assembly system, and automated facilities such as sub-assembly and welding robots, etc.

In production control, the production schedule mesh gets successively fragmented from manager or managing staff to foremen and workers, whereas the production record is subjected inversely to proceeding control as the whole factory by integrating the data obtained by the foremen.

Described below are the representative systems to support the aforesaid tasks.

- (1) Long-term scheduling system
- (2) Mid-term scheduling system
- (3) Detail scheduling/Production control system

4.1 Functions and features of long-term scheduling system

This system has been developed for the manager or the staff in Production Planning Department.

The long-term scheduling calls for making plans several years ahead when the design is not yet completed. This system sum up the long-stored records regarding work types and machines, and is equipped with the following functions required for effective scheduling on the basis of parameters obtained through regression analysis.

- Scheduling function
- Personnel planning function

- Register function of sum

Fig. 2 shows an example of scheduling screen.

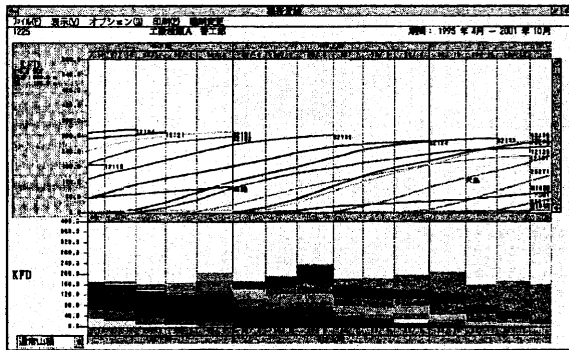


Fig. 2 Long-term scheduling system

The scheduling screen of the long-term scheduling system is shown.

4.2 Functions and features of mid-term scheduling system

This system, developed for the manager or the staff in Production Planning Department, is a support system for production control work involving adjustment of concrete production process some 3 to 6 months ahead based on the basic schedules made during long-term scheduling.

The system makes use of the design information such as welding length, obtained through MATES in making process adjustment, and carries out schedule adjustment by evaluating the work load, and is equipped with various functions befitting with the different scheduling methods such as optimization through simulation, etc. regarding the process adjustment and conveyor tact scheduling while making schedules for disposition places.

The mid-term scheduling system carries out various functions given below in accordance with the production control workflow, contributing to effective execution of work in each process.

4.2.1 Erection schedule planning function

This is a function to support the erection schedule planning for the erection block of ship in dock. The erection sequence differs according to the ship, but there exists a standard schedule depending on the type of the ship, ship model, size, etc. Systematization of these items has enabled automation and contributed to improving the efficiency of each work.

4.2.2 Scheduling and layout planning function

This is a function of carrying out simultaneous planning for schedule adjustment and block layout in grand assembly area around the building dock, with the adaptability between schedule and place constantly maintained through interference check function in order to prevent block overlap. (Fig. 3)

4.2.3 General schedule adjusting function

This function allows automatic formation of standard schedules for the preceding assembly and working processes on the basis of the building block erection day. The standard schedules are prepared, taking into consideration the block shape and assembly method, to ensure adaptability of all processes needed for one unit of block. The schedule adjustment is carried out while evaluating the workload, and the schedule thus fixed is used for determining the design drawing

submitting day or material purchase day.

The material amount, indispensable to schedule adjustment, is automatically supplied from MATES in required units to respective processes. Precisely, the applicable material amounts are: individual welding length, number of pipes, quantity of hull and outfitting parts, painting area, weight, etc.

Since it is possible to refer to the work records and proceeding information, stored in the detail schedule/production control system at the downstream, the adjustment can be made while observing the records.

4.2.4 Mid-term scheduling function

This function supports in making schedule adjustment for several ships per building or per equipment in the building for several months, allowing load adjustment of the concerned process while referring to the sum of the concerned building or equipment.

4.2.5 Assembly area layout scheduling function

This function supports simultaneous schedule making for block assembly area layout inside a building and process adjustment, allowing to make a draft of optimum layout while referring to the assembly area and total occupied area.

4.2.6 Conveyer tact scheduling function

It is necessary to draft optimum tact schedules for several stages such as material distribution, fitting works, welding, etc. in a conveyer type assembly area. The conveyer tact scheduling function allows to carry out simulations, with block charging sequence, personnel allotment, overtime working hours, etc. as parameters for optimization.

4.3 Features and functions of detail schedule/production control system

The production plan laid out in mid-term production planning is subjected to detailed monthly or weekly execution scheduling. This execution scheduling is carried out per work group or per equipment, and involves diversified fields, so that building up and operation of a support system for production control of this level is normally difficult. However, it is an essential function for supporting implementation of individual target control and improving the productivity, one of the important objects of the production support system.

This is a support system for job-wise, equipment-wise or

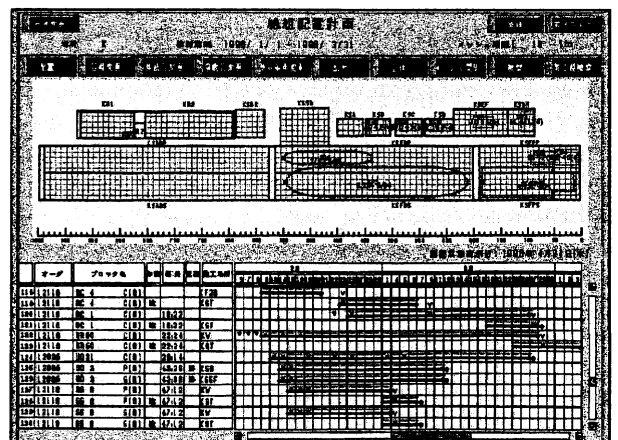


Fig. 3 Scheduling & layout planning for ground assembly blocks

The overall scheduling and layout planning for building blocks around the dock are shown.

group-wise control, one of the most important features of production support system. The main features of the system are given below.

This system is operated by means of personal computers in each control room in production field, enabling dynamic production planning and collecting daily records. Further, the personal computers are linked to the server machine through LAN, so that the input record data can be monitored at real time using any of the EWS or personal computer on the network. Further, special attention is paid to the GUI (Graphical User Interface) for foremen not accustomed to using a personal computer.

4.3.1 Staff and foreman support system

The main support functions are as follows.

(1) Schedule adjustment

Referring to the execution schedules of the before/after processes, the state of work proceeding, and workload sum of material amount and number of man-hour can make schedule adjustment. Fig. 4 shows an example of the screen for schedule adjustment.

(2) Work schedule time layout

The allocation of the amount of daily work and the target time is carried out for each job and each equipment, which is used for target control of individual or group.

(3) Input of daily report

The foreman makes daily input of the material amount produced and the record of number of man-hour. The work records are fed into the production control server machine through the in-company LAN, and are stored there to be used for data analysis etc.

(4) Output of weekly report

The schedules drafted in the preceding week, and the records of the week are compared and automatically transmitted.

4.3.2 Optimization simulation function

The automatic and optimized scheduling function of the 2 units of 600-t Goliath crane in the building dock is a representative simulation function for optimization. The function enables automatic drafting of crane schedule by using optimization method to minimize the crane traveling distance and block erection time, taking due account of the constraint conditions such as interference and hanging object with two cranes. The example is shown in Fig. 5.

4.3.3 Individual/group target control function

The target control of individual/group is essential to realize real improvement in productivity through production control, and for this it is necessary to provide detailed information according to the object. In shipbuilding CIM, various functions have been developed for target control by using design information. Two of them are described below.

(1) Pipe line installation control

Each individual worker is provided with a work procedure sheet for the installation of pipes or outfitting parts for one day and the target working hours, calculated by using the three-dimensional model information of design. This enables the workers to do their jobs effectively without having to consult the complicated drawings.

Further, using the bar code put on the pipe carries out the work proceeding control.

(2) Painting work instruction sheet

Work instruction sheet is issued indicating the three-dimensional model diagram of the hull block drawn from design data, painting area, target number of man-hour, work procedures, etc. in order to give clear image of work, contributing to drastic improvement in the work efficiency and to preventing the error. The example is shown in Fig. 6.

4.3.4 Function of solidarity with outside makers regarding production control information

The information regarding any alterations in process proceedings in the shipbuilding yard is transmitted smoothly at real time to the production control system of the maker, preventing the delay in delivery of products from the maker and promoting the just-in-time delivery of products and materials.

5. Operational support for automated facilities

The latest automated facilities such as high-precision assembly device, sub-assembly, installation and welding robots, etc. have been introduced mainly in Koyagi Plant of MHI Nagasaki Shipyard & Machinery Works in order to make drastic improvement in productivity. These facilities are all based on the premise of design information from MATES, and the production support system supports the operation of

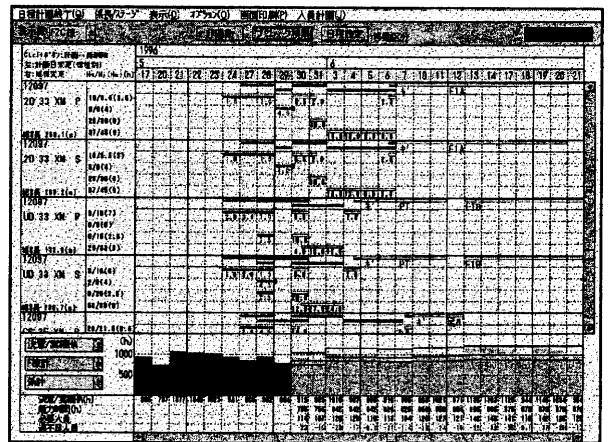


Fig. 4 Staff & foreman support system
The schedule adjustment screen for staff and foreman support system is shown.

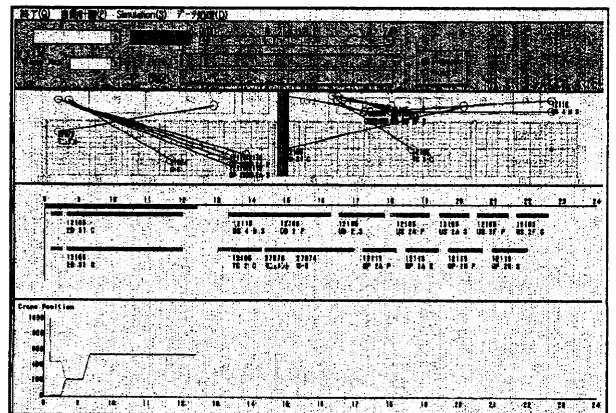


Fig. 5 Simulation system for optimization of crane scheduling
The simulation screen for automatic and optimized scheduling of two units of crane is shown.

Work name	3D31P				Process		Work start	March 24,1997
Paint name	Area	Number of cans	Film thickness	Interval	HC	HA	Fitting day	May 9, 1997
Tar epoxy	171	6.7	175	20-5				
Vinytar	171	2.5	50					
ZINC	909	13						

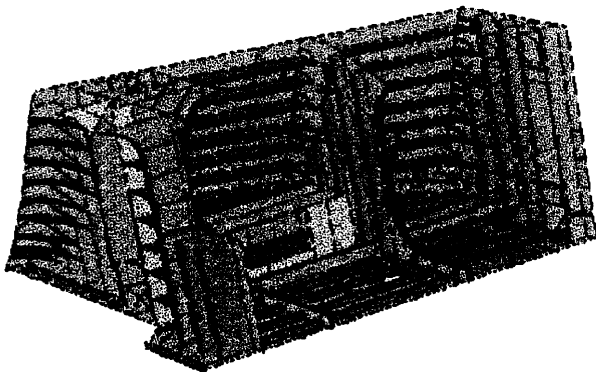


Fig.6 Work instruction sheet at painting stage

The work instruction sheet using the three-dimensional model of the hull block is shown.

Work procedure sheet	① Standard time (h)	② Target time (h)	①-② Difference (h)	③ This time (h)	③-② Difference (h)	Measure
Initial setup before surface treatment (Vehicle, rust removal machine)	1.0	0.9	0.1			Initial setup of bilge collect car
Surface treatment (Rust removal machine, disc sander)	31.0	25.5	5.5			S/P of outside plank at P/E
Cleaning (Air blow, oil removal)	6.0	5.5	0.5			Cleaning by using bilge collect car
Inspection witness	1.0	1.5	-0.5			Repair or corrections at witness
Initial setup before painting	3.5	2.8	0.7			Material distribution of painting site
Spray painting	12.0	10.0	2.0			Spraying on outside plank at P/E
Cleaning up	3.5	2.9	0.6			
Total	58.0	49.1	8.9			

these facilities. Described below are two examples of these facilities.

5.1 High-precision block assembly system

The block built in Koyagi Plant of MHI Nagasaki Shipyard & Machinery Works is one of the largest size blocks in the world with width 23 m, and since the block is built by connecting several pieces of steel planks, it has been a big hurdle how to overcome the problem of the work accuracy error caused by the complicated shrinkage and deformation attributed to welding. In order to realize the high-precision assembly, the data regarding the shape and position of steel plank or longitudinal frame is used as the design data.

Further, the accuracy standards of the concerned facilities are all reviewed to improve the accuracy of supplied parts, and high-precision working and assembly are carried out on the basis of design data in preceding stage facilities for marking on steel plank and die steel, NC cutting, longitudinal assembly, etc. The improvement in block accuracy greatly contributes to the high efficiency of work in after processes.

5.2 Sub-assembly, installation and welding robots

Shipbuilding is an order-made production, and the parts are all produced after receiving the order, so that the robot teaching method adopted in the production field is offline teaching method.

The sub-assembly robot holds the hull members such as stiffener to be installed to the sub-assembly base plank by the centered position, carries the members to the installation place, and corrects the position by recognizing the marking line on the steel plank before carrying out temporary installation. The

working data is prepared by using the design information such as shape of hull members.

The sub-assembly and welding robot operates by preparing the robot operating data based on offline teaching method by using design information such as welding length, leg length, and shape of the concerned member, etc. The operating data is automatically prepared on the basis of the member shape so as not to cause interference between robot and member.

6. Conclusion

Ten years after the development started on MATES, the development of production system has at last been commenced in compliance with the original objective, and the objective has recently been achieved, bringing about the realization of shipbuilding CIM.

It has become increasingly necessary for the Design Department to make study on a flexible product model capable of representing the whole shipbuilding industry including the uncertain information, and for the Production Department to develop the aforesaid model into a CIM capable of making simulation of engineering method and shipbuilding.

On the other hand, the "LINKS project" under the sponsorship of Ship & Ocean Foundation and other main Shipbuilding Companies and the "NCALS" under the guidance of the Ministry of International Trade and Industry are briskly operating. The objects of these projects are similar to those mentioned above, so that we are determined to make close cooperation and promote harmony to make further improvement in shipbuilding CIM.