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The body can be viewed from the next page.

Control System for Cargo Berth and Automated Warehouse*


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1 Introduction

This report relates to an operation control system for the product shipping berth capable of accommodating large vessels and for warehouses with a total storage capacity of 41 000 t built near the berth at the Chiba Works of Kawasaki Steel. Installed as part of a physical distribution efficiency improvement project at the Works, this system required an introduction of a computer system for controlling the storing and retrieving in the warehouses, loading ships with products, and operating automated machinery for ensuring a maximum equipment efficiency along with the automation of both the cargo berth and the warehouses built opposite to it. To carry out a well-planned, rapid and accurate export business, close information exchange and communication with the production control system for the upstream processes were established and, at the same time, an expert system was developed which supports the making of stowage plans hitherto based on the empirical know-how of specialists.

The development of the control system was carried out in parallel with the construction of the facilities and was brought into operation in April 1986. An outline of the facilities and control system is given below along with a description of the operating condition of the system.

2 Outline of Facilities

An outline of the cargo berth and product warehouses is given in **Fig. 1**. The berth is 300 m long with a water depth of 15.5 m and vessels of 80 000 DWT maximum can come alongside the berth. Two gantry cranes with a

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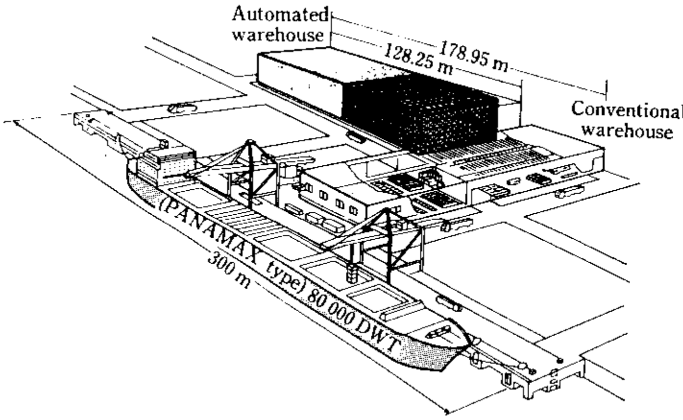

Fig. 1 Conceptual design of the new material handling facilities at Chiba Works

rated capacity of 50 t each are installed on the berth. the product warehouse buildings comprise one automated warehouse provided with stacker cranes and two conventional warehouses with a total storage capacity of 41 000 t maximum.[1] A rack storage is composed of 4 200 racks (12 rows × 10 tiers × 35 bays) and can store up to 12 t of products.

Tractor-trailers are used for the transportation of products to the warehouses and from there to the berth. All types of products produced at the Works–that is, hot-rolled and cold-rolled coils and sheets (including surface-treated steel sheets), plate, pipe, wire rods, iron powder–are handled.

All warehouse jobs are carried out by five persons, including two overhead traveling crane operators and one control room operator. On the berth, four to six persons make up one gang to conduct cargo handling.

3 Outline of System

3.1 Basic Concept

The following points were taken into consideration in developing this system:

(1) Achievement of Automation
The entire warehouse is operated by five persons. For this purpose, not only the automatic operation of stackercranes, carrier cars, and overhead traveling cranes, but the automation of processing of various kinds of information and easy grasping of the condition of all operations are aimed at.

(2) Rapid Cargo Handling
To attain rapid cargo handling, particularly in retrieving, improvement in overall operation efficiency including that for transporting machines is aimed at.

(3) Prevention of Misshipment
Unless products are stored at the specified place in the warehouse and are assuredly retrieved from the warehouse according to shipping instructions, great disturbances are caused during shipping, depriving the aim of the above-mentioned automation. Therefore, products carried into the warehouse are identified and each handling operation by overhead traveling cranes is checked.

(4) Continuation of Operation during Abnormal Conditions
It is necessary to continue operations without confusion when work cannot be conducted as planned due to the occurrence of equipment troubles and the like. For some products, special work is required. For this reason, various authorities are given to crane operators and control room personnel.

(5) Computerization of Stowage Plan Making
Techniques in the field of knowledge engineering, such as an automated loading simulator driven by loading rules, are adopted and a means of modifying stowage plans for various hold shapes is provided.

3.2 System Configuration

The system configuration is shown in **Fig. 2**. This system is hierarchically lower in position than the total shipping system that controls the shipping business of the entire Chiba Works. The role of this system is to efficiently conduct operations ranging from the receiving and storage of products from the manufacturing lines to the retrieving and ship-loading of these products. This system is composed of the following three subsystems:

(1) Operation Control System for Warehouses and Berth
Preparation of instructions for storing and retrieving; giving cargo handling instructions for each kind of product to crane operators and automated machines; elaborated yard control; etc.

(2) SPACE (Stowage Plan Assist CAD Expert System)
Making rational product-stowage plans using knowledge engineering techniques and CAD tech-

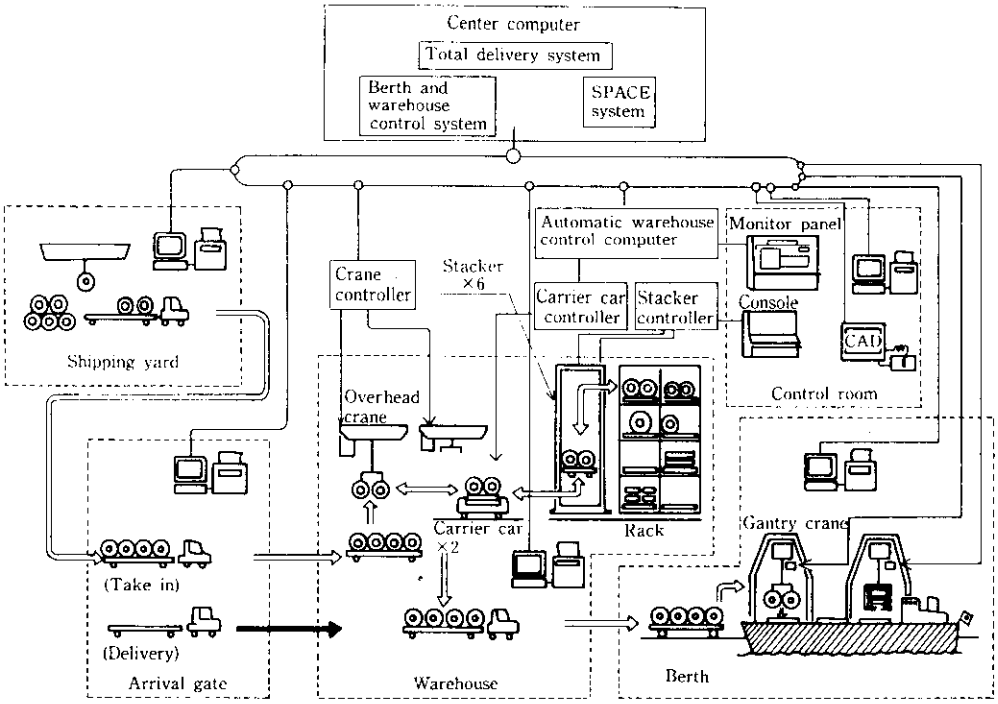

Fig. 2 System configuration

niques.

(3) Automated Warehouse Control System
Operation control for stacker-cranes and carrier cars.

4 Functions of Operation Control System for Warehouses and Berth

4.1 Control of Instructions for Storing and Retrieving

4.1.1 Acceptance inspection of products carried in

Loading positions on the trailer entered at the shipping yard of each plant or mill and specifications of cargoes are output at the arrival gate of the warehouse in question when the cargoes are carried in. Based on these data, the trailer operator checks the loading positions, number, and appearance of the products. Results of the acceptance inspection are used for preparing cargo handling work instructions, for example, for judging whether or not products should be stored into the automated warehouse and whether or not the crane operator can operate the crane at his own discretion.

4.1.2 Determining positions of products carried in

(1) Carrying into Automated Warehouse
Each rack can store up to two piles of products–2 coils maximum or 8 bundles of sheets (for two piles) maximum–within the size and weight limits. Therefore, products on the trailer capable of being stored on the same rack are grouped and the rack to be used is selected. In selecting the racks, the following points are taken into consideration:

(a) Products of the same content of orders are distributed to each lane to ensure that the burden on specific cargo handling machines is not excessive at the retrieving.

(b) To secure safety for the automated warehouse against earthquakes, the upper limit of tier level is set for each type of product and package. Racks are determined from lower to upper tiers and, in the same lane and tier, from outer to inner sides.

(2) Carrying into Conventional Warehouses
Storing places are determined in a manner that the same area number is given to products of the same type, the same type of packaging, and the same content of orders.

4.1.3 Determination of retriving order of the stock

The retrieving order of products from the warehouse is determined according to the order of ship-loading. The order of ship-loading is determined interactively by the stowage plan assist CAD expert system, which will be described later. The order of retrieving from the storehouse is finally determined based on this result by taking into consideration the progress of work, storing positions, discrimination between goods delivered from the warehouse and those transported from a plant or mill directly to the berth, etc.

4.1.4 Formation of lots for products to be loaded onto trailers

Based on requirements for products delivered from the warehouse put forth by the operator of an empty trailer at the arrival gate, products to be loaded onto the trailer are determined in the order of retrieving from the warehouse in consideration of the shape and weight of the products, the size and shape of the load-carrying platform, carrying capacity, etc. of the trailer.

4.2 Operation Control for Warehouses

4.2.1 Operation instructions to overhead traveling crane operators

In view of the operational characteristics of the overhead traveling cranes, the method and order of cargo handling are determined and instructions are given to overhead traveling crane operators.

Based on operational requirements by overhead traveling crane operators, operation instructions are issued per cargo work unit, and the next instructions for cargo handling are issued when the preceding work is finished. Results of cargo handling are reflected on information about loading places and goods in stock.

Instructions for cargo handling are shown on a plasma display on the overhead traveling crane via the ground station of inductive radio. Each overhead traveling crane has the function of position sensing by the inductive radio address cable method and can measure the present traveling and traversing positions to the nearest 100 mm. The appointed position of cargo is displayed based on instructions for cargo handling and is compared with the present position, and whether the cargo work was carried out properly is checked. In case of any abnormality, this fact is displayed and the entry of the completion of cargo work is not allowed.

4.2.2 Issue of operation instructions to computer for controlling cargo work in automated warehouse

Special attention was paid to the following points to carry out smooth cargo handling:

(1) The cargo handling capacity of an overhead traveling crane is three times that of a stacker crane. Therefore, instructions for cargo handling to multiple carrier cars are issued before the lifting operation by the overhead traveling crane to prevent the crane from waiting.

(2) The carrier cars can deliver products in each of the traveling yards of the two overhead traveling cranes. Therefore, an interference of carrier cars occurs when the two overhead traveling cranes perform cargo handling at the same time. To avoid this problem, carrier cars to be used are determined flexibly and instructions are issued while the progress condition of cargo handling in both yards are monitored. In this manner, concentration of work on a specific carrier car and a specific overhead traveling crane is avoided and a delay in the whole work due to the waiting of empty carrier cars is prevented.

4.3 Instructions for Ship-Loading Operation to Gantry Cranes

Information on trailers capable of performing ship-loading is displayed based on the hold number to be used for storing products given by the gantry crane operator. Operation instructions for each trailer are given to trailers selected by the gantry crane operator. The content of the operation instructions covers information on representative products on the trailers, instructions concerning lifting tackles and FROM-TO information.

4.4 Operation Control for Facilities

Results of operation and operating condition of each facility and machine are automatically gathered in the process of general storing and retrieving work and are utilized for planned yard control and for controlling the issue of instructions. Furthermore, results of operation are rearranged according to weights handled for each equipment division and each kind of product, cargo handling time, cargo handling interruption time, etc. and are outputted in the form of daily reports, thus lightening the burden of preparation of control materials.

5 Functions of Automated Warehouse Control System

From the standpoint of securing quick response and system reliability, a dedicated control computer was installed for the operation control of six cranes and twelve carrier cars. This computer has the following functions:

(1) Receiving instructions for cargo handling from the operation control system for warehouses and berth, which is the host system, and transmitting results of operation to the host system,

(2) Monitoring the operation condition of the stacker cranes and carrier cars,

(3) Decomposing received instructions for cargo handling into individual motions of cargo handling machines and outputting instructions for motions of these machines as required,

(4) Giving manual instructions for motions to cargo handling machines from terminals.

From the need to assure data, the information on the storing positions of each rack and product stored in the automated warehouse are collectively controlled by the host system. In case of a trouble, this computer clears data and starts again. In case of a trouble in a cargo handling machine, part of motions are performed in a manual mode and the cargo handling in question is continued in an automatic mode after restoration.

6 Functions of Stowage Plan Assist CAD Expert (SPACE) System

This SPACE system is aimed at two aspects, i.e., automation[2)] by a simulator and flexibility by CAD,[3)] and is composed of four subsystems, i.e., the rough plan input subsystem, hold-shape input CAD subsystem, loading simulator subsystem, and loading improvement CAD subsystem.

6.1 Receiving Rough Plans

The rough plan input subsystem reads various attributes–that is, name of vessel, package size, weight, contract number, port of discharge, trading company, type of product, etc.–from information on products and adds rough plan information indicated by the shipping company–that is, order of ports of discharge, hold number, method of unloading at ports of discharge, stowage specifications, stowage space, etc.–by interactive entry.

6.2 Entry of Hold Shape

The hold-shape input CAD subsystem selects a hold-shape pattern suited to the holds of the vessel which is to enter the port next time from among hold shape patterns already registered, and determines the size of the holds. In addition, the stowage space in holds, stowage space reserved for loading at other ports, and obstacle space are also inputted here.

6.3 Automatic Loading Simulator

The automatic loading simulator executes loading based on rough plan input and hold-shape input while referring to rule bases. Rule bases are written in the form of production rule.

Incidentally, conflict rules are selected according to the prescribed order of priority. Because the know-how on loading is separated from the logic section in the program, the subsystem can be improved by adding new rules or improving the existing rules, while the system is in operation.

6.4 Interactive Improvement of Loading

The loading improvement CAD subsystem interactively modifies results of automatic loading conducted by the above-mentioned loading simulator in accordance with rules by taking into consideration the condition in the field. Results of the improvement of loading are shown on a graphic display in the form of loading graph.

The loading information and order of delivery from the warehouse thus determined are supplied to the warehouse operation system.

7 Condition of Operation

This system has been operating smoothly since April 1986. In the warehouse, operation is carried out by five persons–about 1/3 of the number of workers before the adoption of this system. The desired purpose of labor-saving was achieved in this manner.

At the beginning of the development of this system, there was some fear of the product delivery capacity of the automated warehouse. As shown in **Fig. 3**, however, the average cycle of cargo handling by the overhead traveling cranes was about 2.9 min in a month after the start-up of the system. This value will possibly be decreased when the overhead crane operators become more skillful. This cycle time is short enough for handling cargoes to be loaded into ships. Incidentally, Fig. 3 shows cases where one cycle time is more than 6 min. The reason for this long cycle time is that waiting time occurred when the two overhead cranes in the yard took goods from one stacker crane at the same time. At the beginning of operation, three stacker cranes first move to the specified racks to take pallets. Therefore, the first operation requires about 5 min.

Figures 4 and **5** show an example of plan view and its front view, respectively, of the loading condition in a hold. In this case, automatic loading was first conducted by the simulator based on rules in the SPACE system and the result was partly modified by CAD.

The front view in Fig. 5 shows how sheets and coils in the bottommost line in Fig. 4 are loaded in the same line. Incidentally, the number in Fig. 4, i.e., 05–01–01 denotes a hold number and the numbers in Fig. 5 designate contract numbers.

The following advantages of the system have been ascertained from results of its application obtained to date:

(1) The simulator fully displays its performance in cases where the amount of products loaded is large and

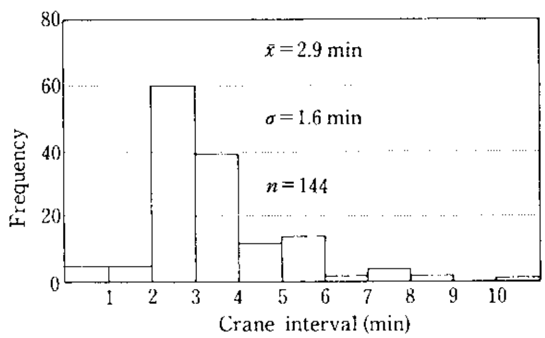

Fig. 3 Histogram of overhead-crane interval

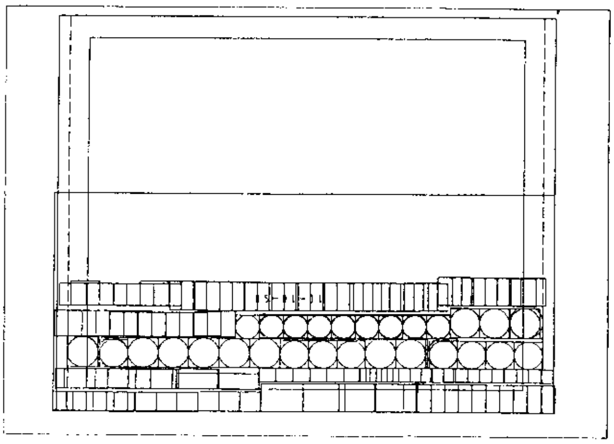

Fig. 4 A view from top of the loading in a hold

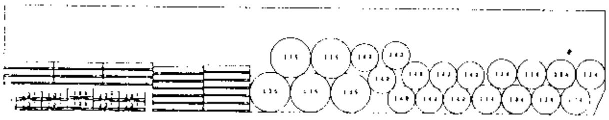

Fig. 5 A view from front of the loading at the first row

modifications by CAD are small.

(2) Variations due to individual differences of persons in charge of stowage planning decrease because automatic loading is conducted based on rules.

(3) Various cases of loading can be studied almost in the same time as before, thus enabling it possible to select better stowage plans.

(4) It has become possible to predict the condition in the holds after the completion of loading with high accuracy.

(5) Improvements in the efficiency of cargo handling and physical distribution can be expected because instructions for the order of retrieving from the warehouse are issued in consideration of ship-loading conditions.

The general view of the control room is shown in **Photo 1**. The condition of the warehouses and berth.can be grasped from the control room. In this control room, receiving and discharging plans for the warehouses are made, coordination of the whole work is carried out, and actions in case of an abnormality can be taken.

Photo 1 View of Control room

8 Conclusions

An operation control system for the product shipping berth and warehouses, particularly an automated warehouse, newly constructed at Kawasaki Steel's Chiba Works was outlined above. The features of this control system can be summarized as follows:

(1) Various attempts were made to conduct automatic warehouse operation. As a result, it has become possible to carry out all jobs by five persons.

(2) Ship-loading can be carried out smoothly by keeping the cycle time of cargo handling by the overhead traveling cranes at the level of 2 min in the retrieving of products from the automated warehouse.

(3) By making use of the SPACE system in forming stowage plans, the entire ship-loading work has been substantially mechanized which had relied greatly on the empirical knowledge of experts.

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