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Automatic Coil Transportation System in the Packing-Storage-Ship Route

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1 Introduction

Material-flow rationalization in and out of the steel mill has been executed in the order of (1) improvement in the hoisting accessories of the crane, (2) rationalization of operation inside the warehouse including information processing, (3) increased efficiency of transportation in the steel mill yard by the carrier pallet and (4) substantial improvement in efficiency of transportation between the steel mill and distribution center, and together with the expansion of objects in the rationalization scope, more advanced automation and unmanned operation have been carried out.

Recently, in the cold-rolled strip coil material-flow at Mizushima Works, we have been able to realize the world-first continuous automatic transportation system from coil package line (CPL) to inside-of-ship, which has included the rationalization of warehouse operation and the rationalization of transportation inside the steel-mill yard and which has contained a new automatic coil transporter.

This report introduces the design concept of the system and the features of its facilities.

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2 Problems of Existing Facilities

Between the cold-rolling mill and the cold-coil warehouse of Mizushima Works, which started working in 1970, it was possible to carry out continuous transportation of coil products by a vehicle as shown in **Fig. 1**. However, since there was only a single vehicle, and the receiving capacity of the warehouse was low, the transportation capacity of the vehicle dropped, and as shown

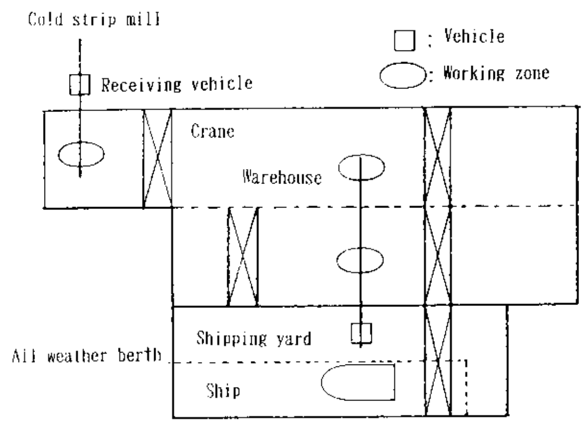

Fig. 1 Layout of warehouse before improvement

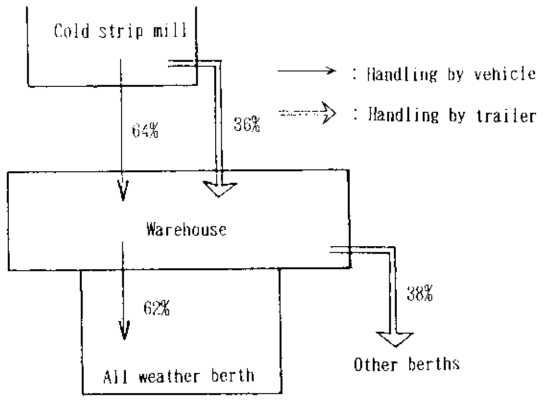

Fig. 2 Material flow before improvement

in **Fig. 2**, the average vehicle transportation ratio was 64%, and the remaining 36% depended on trailer transportation, thereby constituting one of the reasons for raising the physical distribution cost.

Further, between the cold-coil warehouse and the all weather berth, continuous transportation of the product coils was possible by a vehicle. However, owing to the low capacity of receiving and delivery of the warehouse, and the capacity imbalance between the warehouse and the berth due to such low capacity of the warehouse, the transportation capacity of the vehicle dropped, and the transportation ratio by the vehicle accounted for only 62%.

In order to solve these problems of the existing facilities, it is important to improve the receiving and delivery capacities of the cold-coil warehouse and to improve the shipping ability of the all weather berth.

3 Examination of Function Composition

3.1 Measures for Improving Capacity of Warehouse Crane

In order to improve the receiving and delivery capacities of the warehouse crane, the following three are considered, namely, (1) an increase in the number of coils hoisted by the crane per one time of hoisting, (2) shortening of crane cycle time and (3) improvement in the operability rate of the crane.

However, the increase in the number of coils hoisted by the crane of item (1) will obstruct the operability of CPL, and the shortening of the crane cycle of item (2) also is not to be adopted, owing to the limit of motor ability and the accuracy of the stopping position. Therefore, we have examined how to improve the operation rate of the crane.

The causes which are lowering the operation rate of the crane are ① the waiting time due to mutual interference between the plural number of cranes and ② the waiting time due to the imbalance between operation loads of the plural number of cranes.

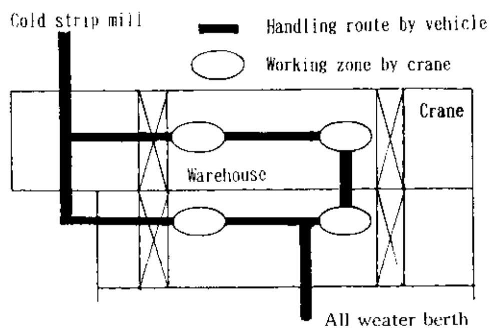

Fig. 3 Anti-interference plan of crane

3.1.1 Measures for avoiding mutual interference[1] among plural cranes

As shown in Fig. 1, the conventional cold-coil warehouse had a layout of generating mutual interference among cranes, because the number of working cranes was larger than the number of locations where cranes could load or unload coils to and from the vehicle (number of operable places). As shown in **Fig. 3**, therefore, the number of workable locations was increased to four, which corresponded to four cranes, thereby making the number of operable locations larger than that of operable cranes. As a result, the division of operation scope of each crane has become possible, thereby avoiding mutual interference. Further, for the layout of vehicle transportation of coils, it was decided to connect respective operable locations by a railway vehicle.

3.1.2 Measures for avoiding imbalance of loads among plural cranes

As a feature of warehouse operation, it sometimes occurs that the locations where coils to be delivered are concentrated due to uncontrollable reasons of the factory or the warehouse, such as,

(1) Changes in the order of delivery and in the quantity of delivery due to the customer's demand,
(2) Fluctuation of the delivery quantity due to the customer's holidays such as the New Year and Golden Week,
(3) Fluctuation in the delivered quantity by typhoon and rough weather so on.

In these cases operation loads among cranes become imbalanced, thereby lowering the entire receiving and delivery abilities.

In order to cope with this situation, we have decided to adopt the method of adjusting the load balances of overall cranes. Namely, as shown in **Fig. 4**, we have adopted the method of avoiding the crane (or zone), at which delivering operation is concentrated, and of transporting the received coils to the crane whose load is smaller.

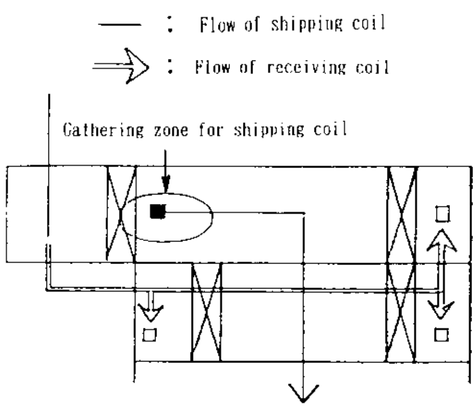

Fig. 4 The measure to avoid unbalance of crane load

3.2 Improvement of Shipping Crane Capability

In order to improve the ability of the shipping crane, as in the ability improvement of the warehouse crane, the following three points are considered, namely, (1) an increase in the number of coils hoisted by the crane at one time, (2) improvement in the operation rate of cranes and (3) shortening of the crane cycle time. However, the increase in the number of coils to be hoisted by the crane exceedingly obstructed the operability of the warehouse, in the same way as the aforementioned case of receiving coils from the mill; therefore, we examined items (2) and (3) only mentioned above.

3.2.1 Improvement in crane operation rate

The maximum cause obstructing the improvement in the crane operation rate is waiting for product delivery from the warehouse. As a measure for coping with this situation, we utilized the exchanging time of ships at the all weather berth, and also we decided to have 40 buffer skids[1)] in order to transport products and to prepare for shipping from the warehouse, thereby completely solving the cargo-waiting at the all weather berth. As shown in **Fig. 5**, during the changing time of the ship after its completion of ship-loading operation, the products for the next ship were transported from the warehouse to the buffer skid, and by this method, it was possible to avoid the waiting for product delivery from the warehouse.

3.2.2 Shortening of crane cycle time by parallel operation with automatic coil transportation (ACT)

To shorten the cycle time, three methods are considered, namely, (1) improvement in crane velocity, (2) shortening of the motion distance and (3) execution of parallel operations by division of the loading function. However, the improvement in the crane speed and shortening of the motion distance cannot be expected to provide the great effect in the same way as in the case of the aforementioned warehouse operations; hence only the execution of the parallel operation was examined.

Major functions of the shipping crane are traversing, travelling, hoisting and stowage. Here, when the required time classified by function was analyzed, and the results, taking "traversing" as "1," were that the time ratios were 1 for travelling, 4.4 for hoisting, and 1.8 for stowage. Therefore, facilities, having the hoisting function requiring the most time, were newly installed, but the remainder would be taken care of by the conventional crane; namely, a function division method was applied.

This new facility is so called ACT. In order to give a hoisting function, the ACT proper was able to put to the inside of the ship, and further a delivering skid was provided to have a buffer between the skid and the crane, so that a system was formed in which each of them will not be governed by the ability of the other, and both of them can carry out parallel operations.

As shown in **Fig. 6**, the operation from the berth to stowage was carried out by the loading crane in the past; hence, this operation required 8.2 in total in the abovementioned time expression. After the introduction of ACT, the operation from the berth to delivery was carried out by the loading crane at 5.4, and the operation from the delivery skid to stowage was carried out by the crane at 2.8. Since these operations are carried out in parallel, it became possible to shorten the loading operation to total 5.4 which is the required time by ACT.

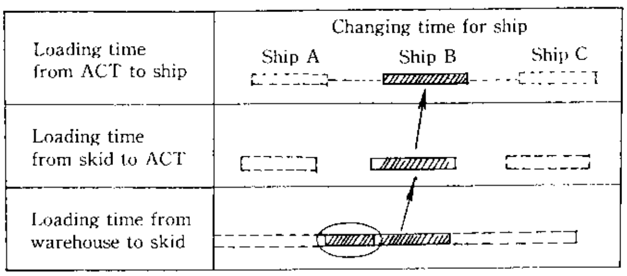

Fig. 5 The concept of working time from warehouse to shipping

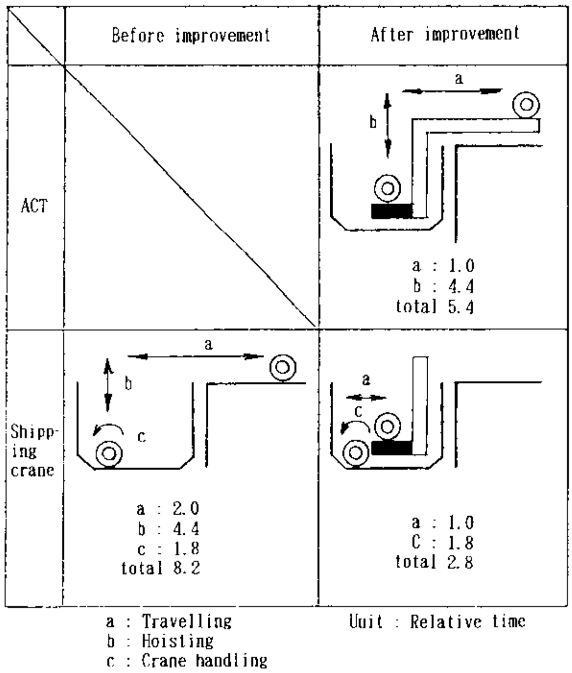

Fig. 6 Division and simultaneous work of shipping

3.3 Crane Operator Guidance System

As for the measures related to information processing, the crane operator guidance system was introduced to realize the following:

(1) Manual-input load was relieved by an automatic position detector; computer tracking was carried out and its accuracy was guaranteed.

(2) A terminal was installed in the crane operation room and at every operation unit, the operator inputs operation results for each operation unit.

Through the above-mentioned preventive operations, ability improvements were achieved as 1.5 times in the loading ability and as 2.0 times in warehousing ability, compared with the pre-operation time of the new system. **Figure 7** shows the abilities before and after the improvement, and **Fig. 8** shows the material flow after improvement.

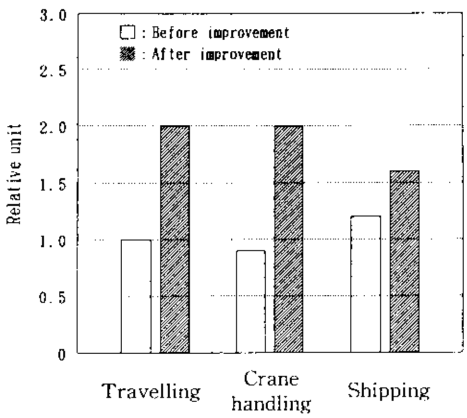

Fig. 7 Comparison of handling capacities

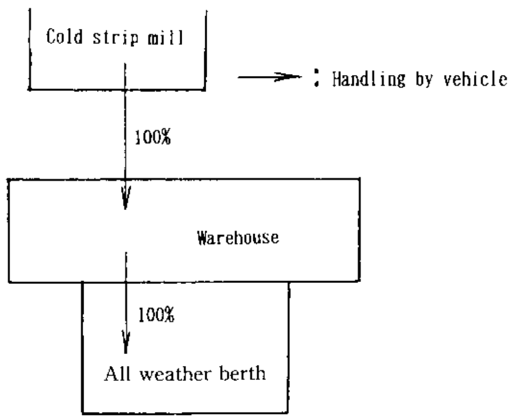

Fig. 8 Material flow after improvement

4 Facility Specifications

Figure 9 shows the layout of the main facilities, and **Table 1** shows the ability particulars of main facilities.

4.1 Transportation from Mill to Warehouse

The rail base of the existing overhead vehicle (4.8 m above the ground) was extended to the all weather berth, and receiving at two warehouses was made possible. Further, since this line was made into double-tracking,

Table 1 Specifications of main equipment

		Single vehicle	Lifter	Combination vehicle		Rail turner	ACT lifter
				Traversing	Travelling		
Coil	Max. weight (t)	20	20	26	26	26	26
	Width (mm)	500～2 000	500～2 000	500～2 000	500～2 000	500～2 000	500～2 000
	Outer diameter (mm)	500～2 000	500～2 000	500～2 000	500～2 000	500～2 000	500～2 000
Travelling	Speed (m/min)	200	—	200	40	1 rpm	90
	Control	Inverter	—	Inverter	Inverter	Inverter	Inverter
Hoisting	Speed (m/min)	—	12	—	2.4	—	15
	Control	—	Inverter	—	Hydraulic cylinder	—	Inverter
Electric supply		Cable	Cable	Trolley	Trolley	Trolley	Cable
Numbers of device		2	2	6		2	1

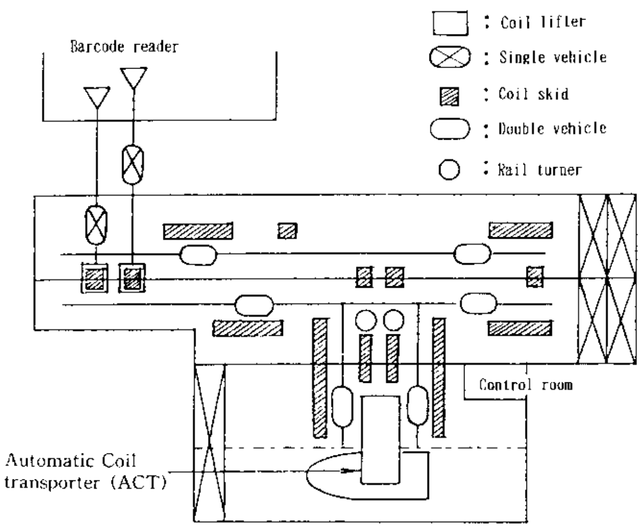

Fig. 9 Layout of main equipment

the transportation ability was doubled compared with the past. This vehicle is mounted with a coil at its center part, and is assigned to transportation between two points. Since coil loading and unloading are carried out by the coil-moving lifter installed at the delivery location, the vehicle control logic is simple; hence, there are merits of shortening the software developing period, a decrease in anomaly accidents, etc.

4.2 In-warehouse Transportation and Shifting between Buildings

This system consists of parts called the "traversing vehicle" and "travelling vehicle," and the coil skid on the ground, as shown in **Fig. 10**.

(1) Traversing Vehicle

The traversing vehicle incorporates a V-shaped hoisting-type coil pedestal, and after it self-travels to the skid and enters it, it carries out loading and unloading of the coil to and from the skid.

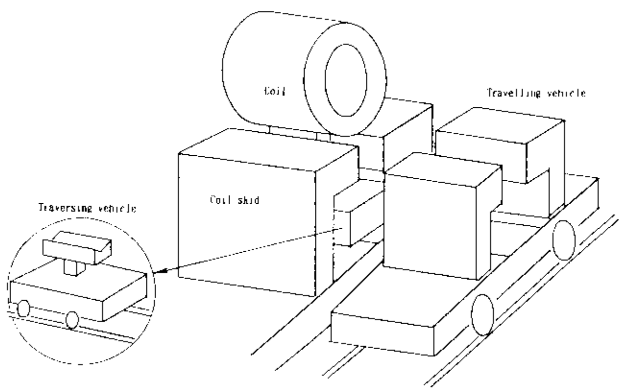

Fig. 10 Sketch of combination of vehicle and coil skid

(2) Travelling Vehicle

The travelling vehicle temporarily places a coil on the skid of itself, and is a vehicle to travel between skids, while housing the traversing vehicle in itself. Since it mainly travels a long distance of several tens of meters or above, it has a speed of max. 200 m/min.

Further, since two vehicles run face-to-face on a single lane, attention was paid to safety securement such as collision prevention, and the block control system[1] was used.

4.3 Transportation from Berth to Inside of Ship with ACT

ACT is composed of the receiving skid, lifter, delivering skid, and the frame part containing these parts, as shown in **Fig. 11**.

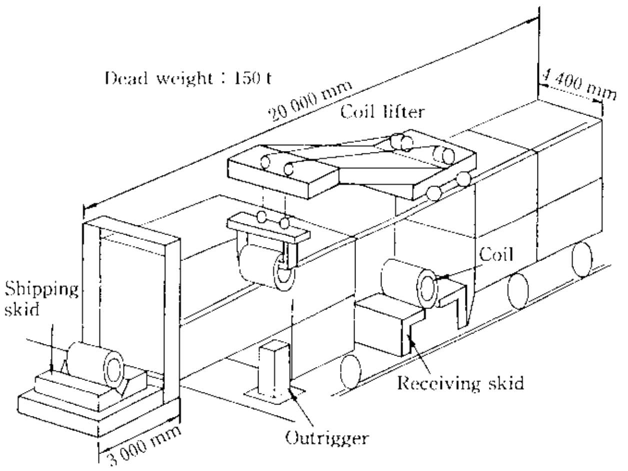

Fig. 11 Sketch of ACT (automatic coil transportation)

4.3.1 Receiving skid

The receiving skid was installed at the center part of ACT to enable the ride-in by the double vehicle. Through this set-up, it has become possible to carry out the parallel operation between the vehicle and ACT by the skid buffer and the continuous operation by automatic operation between the factory and the inside of the ship.

4.3.2 Lifter[2,3)]

The lifter is a facility for hoisting the coil placed on the receiving skid, and after travelling to the inside of the ship, it temporarily stocks the coil on the delivering skid in the ship.

The features of the lifter are as follows:

(1) At the time of descending to the delivering skid, the lifter is made to carry out soft landing control of 0.05 m/s following the variations in the skid height and the outside diameter of the coil.

(2) In order to avoid the interfference by the ship-loading crane and double vehicle, a standby point has been provided in the middle.

4.3.3 Delivering skid

The delivering skid is a relaying facility of coil transportation between the lifter and ship-loading crane. It can adjust the height in 5 stages according to the tidal level in full automation by the lifter.

4.3.4 Frame part[2,3)]

The above-mentioned parts are supported by the frame part. The frame part is also capable of 3 stage position adjustments of the original in-the-ship position, the outside of the ship position during the high tide, and the sheltering position during the typhoon.

5 System Configuration

5.1 Hardware Configuration

The present automatic transportation system is controlled, as shown in **Fig. 12**, by three layers of business computers (B/C), process computer (P/C), and direct digital controller (DDC). Further, the part between the crane terminal and B/C is connected by radio control, which carries out sending and receiving of information, crane position detection, etc.

ACT is controlled by the sequencer of ACT itself, and in order to prevent collision and to guarantee tracking,

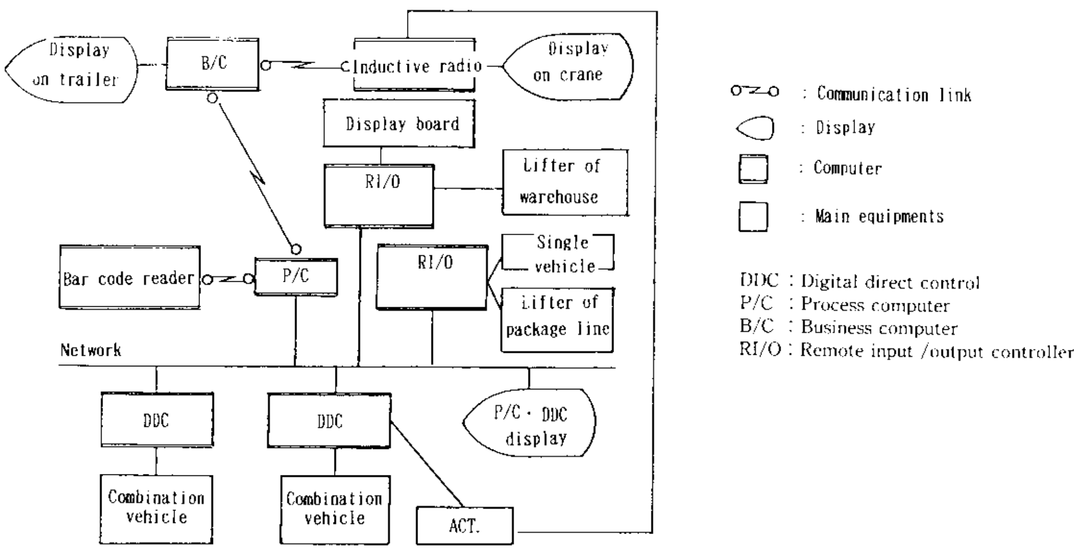

Fig. 12 Configuration of the automatic coil transportation system

an interface is formed between DDC and B/C.

5.2 Control Room

In order to monitor constantly the working condition of the above-mentioned transportation system from the viewpoints of operation, facilities, and software, a control room was installed at a location which can command the entire views of the warehouse and the berth. The control room members carry out mainly the following duties:

(1) Facility condition monitoring by P/C and DDC picture screens,
(2) Monitoring of the facility condition and operation condition by 6 units of television camera monitors,
(3) Instant coping with action (primary step) at the time of anomaly occurrence,
(4) Simplified daily inspection of facilities,
(5) Intervention into automatic operation by P/C picture screen, etc.

6 Conclusions

A cold-rolled strip coil automatic transportation system has been constructed at the product warehouse of Mizushima Works. The features are as shown below.

(1) By introducing the automatic vehicle and ACT, a continuous coil automatic transportation between the mill and the inside of the ship has been made possible. Among them, ACT has made possible three-stage position adjustments according to the tidal heights such as the inside of the ship, outside of the ship and sheltering.
(2) A high-speed, face-to-face-type linear travelling route, taking into consideration the characteristics of the product warehouse, has been adopted.
(3) A buffer each has been installed between plural automatic transportation facilities and between the facility and the crane, thereby completing systems which can achieve maximum ability of each facility.
(4) Through the introduction of the crane operator guidance system, the automatic location detection has become possible, thereby guaranteeing the tracking accuracy.
(5) Simultaneous and parallel operations of crane handling and product transportation at the warehouse and ship-loading have been made possible, and the ship-loading ability and the receiving and delivery ability of the warehouse have improved to 1.5 to 2.0 times compared with those before the working of the new system.

The present system officially started its operation in August 1992 and is continuing satisfactory operation at present.

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