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Stainless Steel Cold Rolling Plant at Chiba Works

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The body can be viewed from the next page.

Stainless Steel Cold Rolling Plant at Chiba Works*


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1 Introduction

Kawasaki Steel Corporation completed an initial phase of mass production setup at Hanshin Works in 1962 for stainless steel cold-rolled products by installing a wide strip Sendzimir mill and an annealing and pickling (AP) line. A subsequent installation of vacuum oxygen degassing (VOD) steelmaking facilities in 1971, accompanied by a development of SS (strong stirring)-VOD method enabled Hanshin Works to produce various new types of steel sheets in the ensuing years. Along with an increase in demand, the steelmaking unit was moved to Chiba Works, and in 1982 a hot-rolled strip continuous annealing and pickling (HAP) line was commissioned, thereby establishing an integrated manufacturing setup for stainless steel hot-rolled products.

In order to meet a growing rigidity of customer demand in quality and lead time, a new cold rolling plant was built at Chiba Works in March 1991, to form an integrated manufacturing setup for stainless steel cold-rolled products, thereby completing a two-base production system in Japan, one at Chiba in the East, the other at Nishinomiya in the West. This report outlines the Chiba Works' Stainless Steel Cold Rolling Plant.

2 Outline of the Overall Facilities

The stainless steel manufacturing flowchart at Kawasaki Steel is shown in **Fig. 1**, while the layout of the new Cold Rolling Plant at Chiba Works and its external view in **Fig. 2** and **Photo 1**, respectively. In March 1991, this plant commissioned a cold rolling complex consisting of a stainless steel cold rolling mill (SCM), cold-rolled strip continuous annealing and pickling (CAP) line and recoiling (RC) line. The cold rolling plant further started up a slitting (SL) line and a levelling and shearing (LS) line in March 1992, followed by a three-dimensional coil warehouse in September 1992. A series of these installations provided a two-base (east and west) production setup for cold-rolled stainless steel manuffacture covering both Chiba and Nishinomiya; with "2B-finished" strip from 0.5 mm and over thick and up to 1 600 mm wide to be made mainly at Chiba, and "BA" and "2B-finished" under 0.5 mm thick at Nishinomiya.

All these production facilities combined have significantly improved the company's capability for cold-rolled stainless steel, while simultaneously strengthening competitiveness in non-price aspects such as quality and lead time, thereby reducing labor requirement and improving working environment. The new plant with a premise of 120 000 m^2 is located adjacent to the Chiba No. 2 Cold Rolling Plant for carbon steel where the HAP line is in operation. Cold-rolled coil is transported from the No. 2 Cold Rolling Plant by carrier pallet. All the subsequent material flow in the new stainless steel plant

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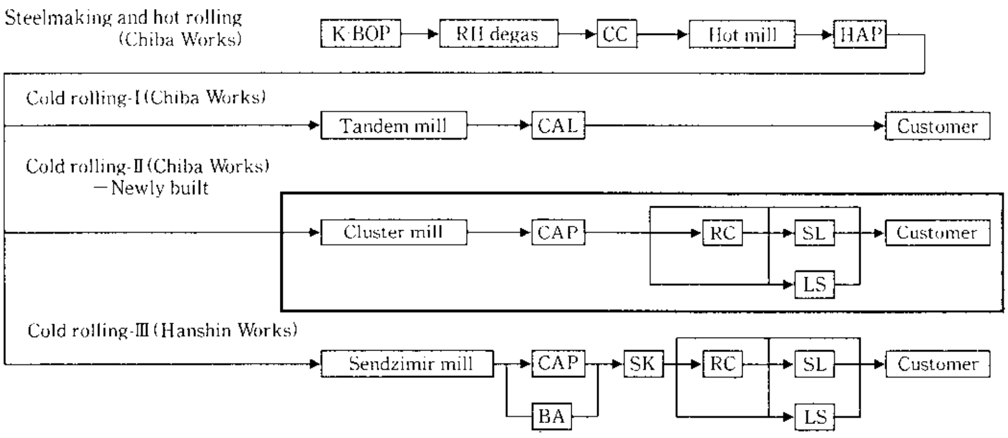

Fig. 1 Manufacturing process of stainless steels at Kawasaki Steel

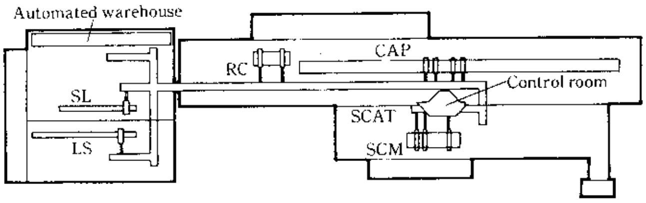

Fig. 2 Layout of the cold mill and finishing plant for stainless steel

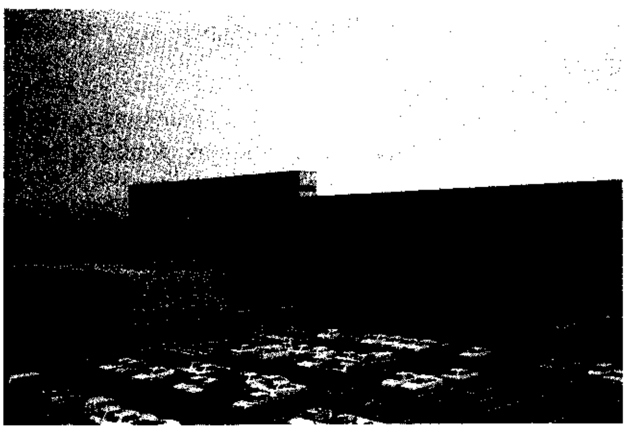

Photo 1 External view of Stainless Steel Cold Rolling Plant

is fully automated to a finishing plant, using overhead crane, coil transport system and three-dimensional warehouse, thus requiring no manual operation. The cold rolling plant has a common-control room between SCM and CAP to monitor entry and delivery operations for both lines. This common control for SCM and CAP has unified quality and production control phases.

3 Cold Rolling Plant

3.1 Cold Rolling Mill (SCM)

The design objectives for SCM are (1) to achieve high quality in gauge accuracy, flatness and brightness, (2) to implement high-speed rolling, and (3) to apply automation as much as possible.

3.1.1 Outline of the facilities

Table 1 shows the main SCM specifications. The mill, a 12-high cluster type, reverse-rolls wide-strip up to 1 600 mm width at a maximum tension of 60 t. The maximum rolling speed is 800 mpm and 600 mpm average, which is markedly high among stainless steel rolling mills.[1)]

Figure 3 shows the line layout. A pay-off reel is provided at the entry side to permit top and bottom paying-off. The tension reels are 660 mm dia. drums for optimum durability, and are of the controlled collapsible type both right and left so that they will not restrict the number of passes. On the both sides of the mill, a coolant wiper, X-ray thickness gauge, shape meter and deflector roll are arranged in this order, and a tension meter is installed at the bottom of the chock for the

Table 1 Main specifications of stainless steel cold mill

Items		Specification
Mill type		12Hi-cluster type
Coil width	(mm)	650~1 600
Coil thickness	(mm)	1.0~8.0 (entry)
		0.2~5.5 (delivery)
Coil weight	(t)	max. 30
Line speed	(m/min)	max. 800
Line tension	(t)	max. 60
Rolling force	(t)	max. 1 000

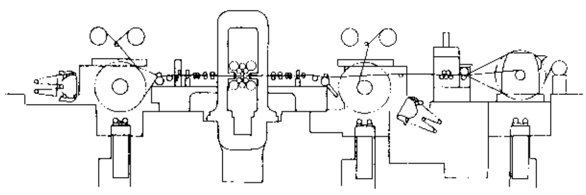

Fig. 3 Layout of stainless steel cold mill

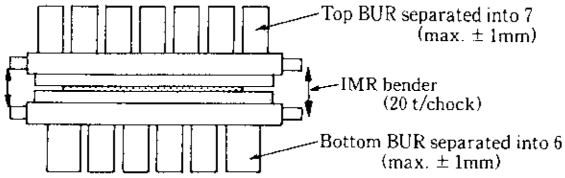

Fig. 4 Schematic drawing of shape control actuater

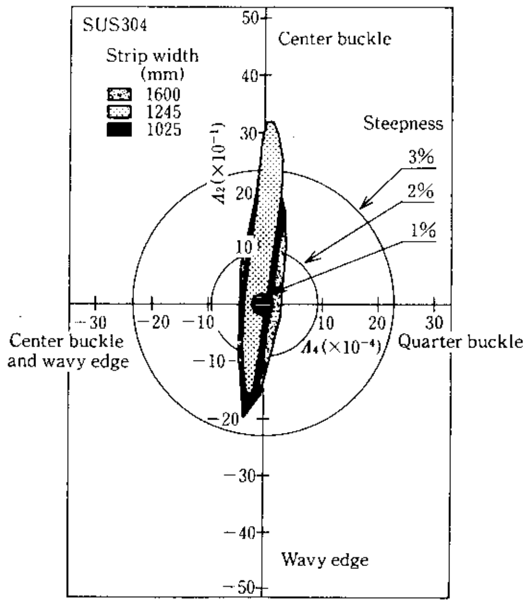

Fig. 5 Controllability of strip shape by shape control system

shape meter.

The mill provides a maximum rolling force of 1 000 t for normal use, and the work roll diameter, which is an important factor for creating stainless steel brightness, has been designed within the range of 79 to 120 mm.

3.1.2 Features of the facilities

(1) Quality

The automatic gauge control (AGC) system combines the feed-forward, monitoring, BISRA, and massflow methods to ensure high accuracy.

Low-viscosity mill oil is used with a Schneider filter in the filtering system. As a result, a stable level of brightness has been obtained, and the cleanliness of the mill oil is maintained in the range of NAS 5 to 7 class to minimize the generation of defects.

Shape is controlled, as shown in **Fig. 4**, by employing divided back-up rolls (BURs), with 6 segments for the bottom and 7 for the top, together with intermediate roll (IMR) bending. This provides good control for a wide range of controllable strip-shape plans as shown in **Fig. 5**. Here the term "controllable strip-shape plane" means a plot, which has a y-axis representing the degree of center buckle/wavy edge (Λ_2), and an x-axis for the degree of quarter backle (Λ_4), expressing the controllable range of shape when respective actuators have been operated. The wider this plotting range is, the larger the shape correction ability; i.e., steepness can be controlled to a high degree for all steel types and all widths.[2)]

(2) Productivity

The maximum rolling speed of 800 mpm necessitated an improvement to the strip coolant system. The coolant specification is shown in **Table 2**, and the layout of the coolant components is in **Fig. 6**. An improvement to oil wiping from the strip edge required an installation of a small-diameter 3-roll type wiper, together with a tube wiper for handling thin-gauge materials.

(3) Automation

A fully automatic operating system has been installed for (1) coil handling, (2) roll changing, (3) pre-setting the flatness and pass schedule, and (4)

Table 2 Coolant specifications (*l*/min)

Device	Coolant flow rate
Rightside strip coolant	0~3 000 (auto flow controll)
Roll coolant	max. 9 000
Leftside strip coolant	0~3 000 (auto flow controll)
Total	15 000

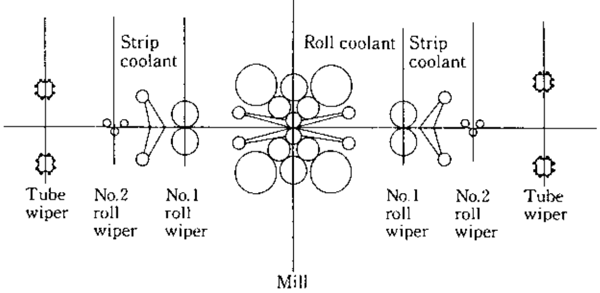

Fig. 6 Layout of coolant header and wiper

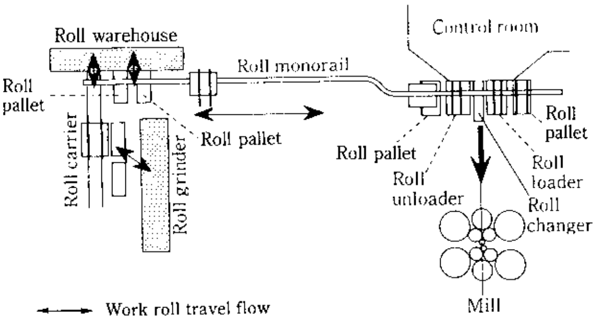

Fig. 7 Schematic diagram of automatic roll transportation

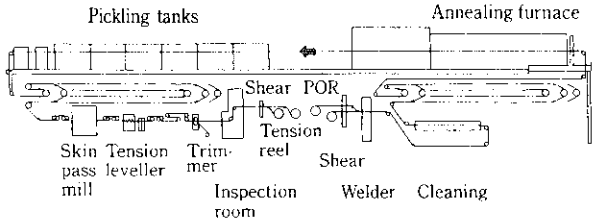

Fig. 8 Layout of the cold-rolled strip annealing and pickling line system

Table 3 Specifications of the cold-rolled strip annealing and pickling line

	Material type	SUS300, 400 series
Coil	Thickness (mm)	0.5~5.5
	Width (mm)	650~1 600
	Inner diameter (mm)	Ent. : ϕ508, 610, 660 Del. : ϕ508, 528, 610, 660
	Outer diameter (mm)	Ent. : ϕ990~2 500 Del. : ϕ780~2 400
	Weight[a] (t)	Ent. : max. 33 Del. : max. 30
Speed	Entry section (m/min)	8~120
	Center section (m/min)	8~80
	Delivery section (m/min)	8~150
	Sledding speed (m/min)	20~30

[a] Including sleeve

slowing down to stop the mill. In particular, the work rolls have a high changing frequency, an automatic roll warehouse being provided between the roll shop and the mill, with automatic delivery by using a roll monorail on the mill side and a roll carrier on the roll shop side, as shown in **Fig. 7**.

3.2 Continuous Annealing and Pickling Line for Cold-Rolled Strip

A high level of quality and productivity has been achieved on this line by directly coupling such facilities as cleaning, annealing, pickling, skin-passing, side-trimming and inspection, resulting in a monthly capacity of 15 000 t.[3)] The line layout and main specifications are shown in **Fig. 8** and **Table 3**, respectively.

3.2.1 Entry-side facilities

Cold-rolled stainless steel coils are charged into the entry-side pay-off reels by automatic coil-handling equipment. In addition, coil band cutting, coil leading end setting, off-gauge processing are all automated. A laser beam welder with 5 kW output is used for coil welding in order to obtain sufficient weld strength for stainless steel coils which are difficult to weld.

3.2.2 Cleaning facility

Mill oil and iron powder are deposited on the strip after rolling, and it is known that, if the strip is annealed as it is, stains will be generated or inferior brightness will result. Electrolytic cleaning equipment is therefore installed on the entry side of CAP to ensure the manufacture of high-quality products.

3.2.3 Annealing furnace

A stable annealing atmosphere is maintained by using a unit type of annealing furnace. High efficiency of the gas usage has been achieved by installing such facilities as a strip preheating section, waste-gas heat recovery boiler and recuperator for preheating the burning air.

On the control side, a strip temperature control system has been installed for high speed control of strip temperatures by calculating line speed and furnace temperature, while taking into consideration limiting factors such as strip welding conditions and others. An outline of the furnace control system is shown in **Fig. 9**.

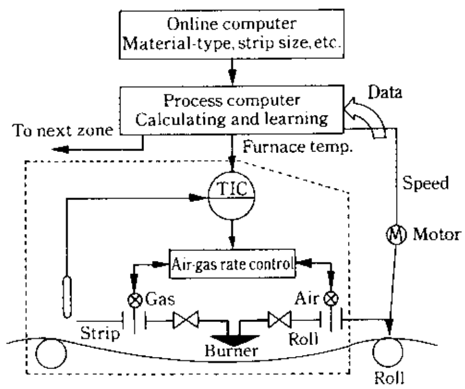

Fig. 9 Outline of the furnace control system

3.2.4 Pickling line

The layout of the pickling line is shown in **Fig. 10**.

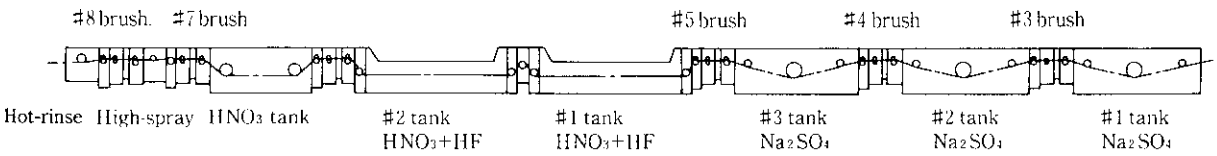

Fig. 10 Layout of the pickling line

The Ruthner method has been adopted for final pickling, which excels in respect of surface quality, cost, pickling speed and environment. This method has been improved by Kawasaki Steel in the layout of electrodes and brushes installed between the neutral salt tanks. The descaling reaction is promoted by providing all the tanks with reserve capacity and by circulating the acid solution. An automatic analyzer for the pickling solution has been installed, which automatically samples and analyzes the acid solution in these reserve tanks, thereby achieving high-accuracy concentration control of the acid solution and saving labor.

3.2.5 Delivery-side facilities

The skinpass mill, tension leveller and trimmer, which have been installed as separate units in the past, have been directly coupled in order to improve quality and productivity. Further, the delivery-side shear has been given functions for tracking (1) elongation abnormalities at the skin pass mill and tension leveller, and (2) defect information at the coil ends based on automatic surface defect inspection to be mentioned later, thereby eliminating such portions automatically.

3.2.6 Quality assurance equipment

A surface defect inspection system, whiteness and brightness meter, γ-ray thickness gauge and width gauge are provided to monitor strip quality.

The surface defect inspection system utilizes the surface diffraction of a laser beam that is projected on to the strip to detect the defect type and degree to high accuracy. This defect information is fed forward to the delivery-side shear and subsequent processes and used for analytical purposes, and the defect information is also used to provide the surface quality inspection results for the coil.

3.2.7 Recoiling line

This line has been installed in order to carry out accurate inspection whenever necessary after completing the CAP process. Its main specifications and layout are shown in **Table 4** and **Fig. 11**, respectively.

3.3 Finishing Lines

For finishing, both a slitting line and leveller/shearing line are used for the integrated manufacture of 2B products with widths of up to 1 600 mm, high demensional accuracy, high surface quality, and high line operating efficiency.

Table 4 Specifications of the recoiling line

Thickness (mm)	0.5~5.0
Width (mm)	650~1 600
Inner diameter (mm)	Ent. : ϕ508, 610, 660 : ϕ508, 610, 660
Outer diameter (mm)	Ent. : ϕ603~2 400 Del. : max. ϕ2 400
Weight (t)	max. 30
Speed (m/min)	max. 190

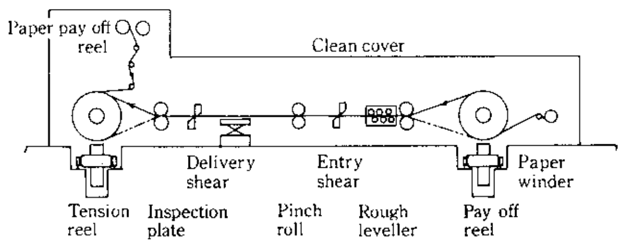

Fig. 11 Layout of the recoiling line

3.3.1 Slitting line

The layout and specifications of the slitting line are shown in **Fig. 12** and **Table 5**, respectively.

(1) Enhanced Quality
The slitter design enables knife setting in a short time to high accuracy by the use of a hydraulically clamped knife holder. Small edge-waviness at the time of slitting is prevented by controlling the tension of the winder. Reel-tip support prevents any telescoping of the products at the tension reel, and EPC prevents any telescoping at the time of trimming. Keeping the line length as short as possible and covering the work area with an air-conditioned, dust-proof tent prevents defect generation and improves the operating environment.

(2) High Operational Rate
The operational rate of SL (the actual slitting time) has been improved by using a two-position shifting skid on the entry side in order to smoothly set and draw-out coils from the pay-off reel. This facilitates coil handling between the coil car and automatic

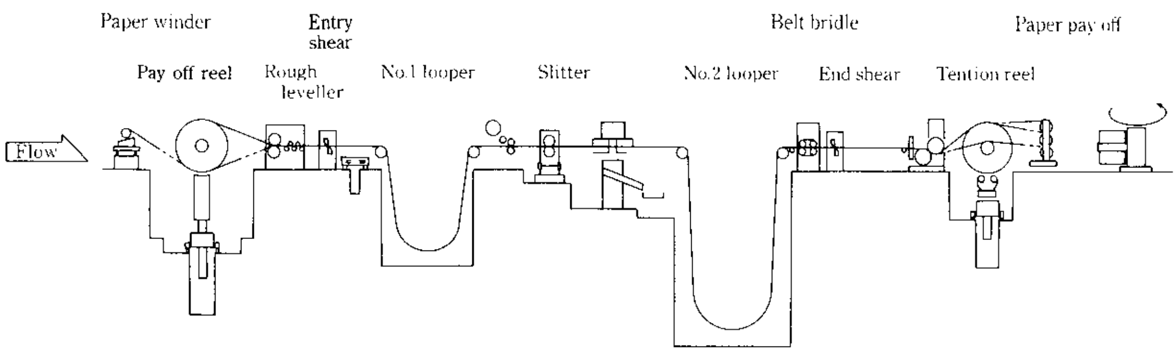

Fig. 12 Layout of slitting line

Table 5 Specifications of the slitting line

Coil thickness (mm) Coil width (mm) Coil weight (t)	0.5~4.0 600~1 300 max. 20
Slitter coil width (mm)	100~1 300
Line speed (m/min)	max. 200 (trimming) max. 100 (slitting)

Table 6 Specifications of the leveller/shearing line

Coil thickness (mm) Coil width (mm) Coil weight (t)	0.7~4.0 600~1 600 max. 20
Sheet length (mm) Sheet weight (t)	600~4 500~9 000 max. 3
Line speed (m/min)	max. 60

coil transportation vehicle. Two cutter stands of the change-over type are fitted, and a turning arbor is used to expedite cutter changing. Similarly, a shift changer with a quick-change arm is installed on the line drive side to facilitate separator changing. In order to process the coil wound by the tension reel in a short time, a snubber is incorporated into the coil car so that coil banding can be carried out with the coil still on the unloading arm. This unloading arm rotates, loads the coil directly on to the shifting changer, transports the coil to the packing area and, during transportation, weighs the coil. The processing time has been further minimized by providing automatic threading and side-guide setting.

3.3.2 Levelling and shearing line

The layout and basic specifications of the LS line are shown in **Fig. 13** and **Table 6**, respectively.

(1) Enhanced Quality

A 6-high, 17-roll leveller with a work roll diameter of 85 mm has been installed, using the wet method to prevent defects, together with a cleaning unit and dryer on the delivery side. The shear is an up-cut flying type driven by a crankshaft. One reject piler and two prime pilers (4 500 mm + 4 500 mm) are provided, and the high-speed suction method is used for high-reliability piling. Defects are prevented by paper interleaving and coating with a protective film as required. As with the slitting line, the leveller and shearing line has been made as short as possible and covered with a dust-proof tent.

(2) High Operational Rate

A shifting skid is installed on the entry side of the pay-off reel in a way similar to that used on the slitting line. This minimized the coil-changing time and prevents the generation of coil defects caused by an overhead crane. Automatic threading and side guide setting also minimize processing time as in the case of the slitting line.

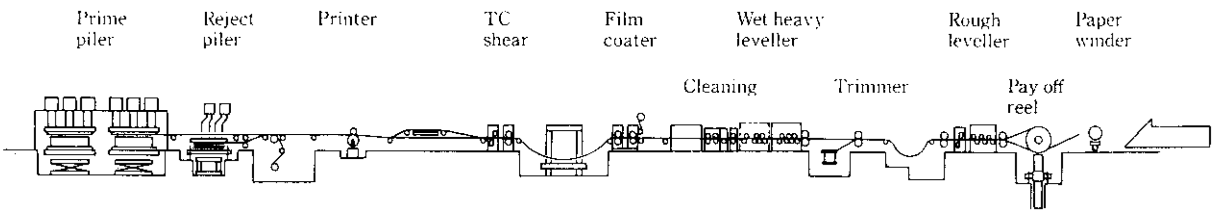

Fig. 13 Layout of the shear line

3.4 Automatic Coil Transportation System

Coils are automatically transported throughout the entire plant, including mother coil acceptance at the plant, charging coils to the various lines, and packed product delivery. The main design concepts of the system are to provides high positioning and timing accuracy, high speed and high reliability, and has sufficient flexibility to plan the optimum schedules.

The specifications and layout of the transportation system are shown in **Table 7** and **Fig. 14**, respectively.

Table 7 Specifications of the automatic transport system for stainless steel coils (SCAT)

Machine			Specifications
Automatic crane	Lifting weight	(t)	33
	Speed		
	Traverse	(mpm)	130
	Crab traverse	(mpm)	50
	Lifting	(mpm)	10
	Stopping precision		
	Traverse	(mm)	±50
	Crab traverse	(mm)	±150
Transfer/ traverser/ dolly	Lifting weight	(t)	33
	Speed		
	Parent	(m/min)	40
	Child	(m/min)	120
	Grand child	(m/min)	30
	Stopping precision		
	Parent	(mm)	±2
	Child	(mm)	±2
	Grand child	(mm)	±5
Stacking crane	Lifting weight	(t)	20
	Speed		
	Traverse	(m/min)	80
	Lifting	(m/min)	20
	Shift	(m/min)	20
	No. of coil racks		
	Large		92
	Medium		333
	Small		242

3.4.1 Outline of the system

An automatic overhead crane has been adopted in the storage yard for the mother coils, which offers a high utilization rate and low cycle time. A parent-child-grandchild type of vehicle is used for transportation to charge and deliver coils to and from various lines to prevent any transportation errors and ensure operational safety. A vertical automatic pallet system is used in the storage yard for a annealed materials, which offers a high utilization rate, low cycle time, and little chance of transportation defects. Automatic devices for coil banding, band cutting, turning, weighing and marking are also incorporated into the system utilizing the parent-child-grandchild type of vehicle. A coil to be transported weighs 30 t in the rolling yard and 20 t in the finishing yard, with a maximum width of 1 600 mm. Table 7 shows the specifications of the transportation system.

3.4.2 Coil transportation control

To avoid any traffic jams with multiple parent-child-grandchild type of vehicles travelling on the same railway track, a sectionalized control system has been adopted. Single-unit automatic devices such as the transportation system, storage yard and banding device can be used by expressing the degree of urgency of various transportation commands by the "transportation delivery time," the optimal transportation schedule then being automatically formulated on the procees computer (PC) by the "branch and bound" method. Appropriate facilities are selected and the transportation route matched with the "operating/down" condition of each machine by the PC expert system. **Table 8** shows an outline of the expert system rules.

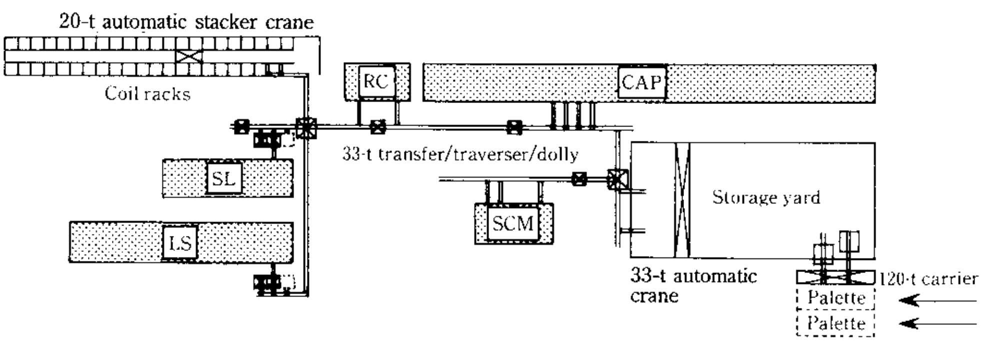

Fig. 14 Layout of the automatic transport system for stainless steel coils

Table 8 Rules of expert system installed in P/C software

Components	Target of inductive reasoning	Rules	Mean CPU time(s)
Select O/C command	Select O/C command	10	0.2
Select machines	Select available machines under O/C command	10	0.2
Induce transport route	Route available stations for each command from start to terminal	25	0.3
Select transport element	Select feasible transport element	25	0.5
Schedule transport element	Induce optimal schedule by the Blanch and Bound methods	80	20.0
Prevent deadlock	Insert traverse command in the schedule to prevent deadlock	20	0.3
Store the results	Store the schedule into the command queue for each machine	35	2.0

4 Production Control System

4.1 Concepts for System Development

The software for the production control system in the Stainless Steel Cold-Rolling Plant is based on the following concepts:

(1) Establishment of integrated production facilities ranging from steelmaking to hot rolling, cold rolling and delivery
(2) Framework for planned production
(3) Quality assurance system linking the process computer and sensors
(4) Smoothing material handling and distribution

Based on these concepts, the following measures were implemented for the cold-rolled stainless steel production control system:

(1) Adoption of a system to match the characteristics (small lot and short lead time) of stainless steel demand
(2) Expansion of automatic coil supply function and realization of higher automatic coil supplying ratio and reduction in surplus and unused coil stock.
(3) Implementation of an integrated rolling schedule covering stock, lead time, production, etc., and evaluation of the system itself by utilizing EWS (engineering work station)
(4) Synchronous operation based on the daily schedule
(5) Optimum control and analysis system functions, and the establishment of a precise control cycle

4.2 Outline of the System Configuration

Figure 15 shows an outline of the system configuration. The system is composed of the four hierarchies of C/C (central computer for execution control), O/C (online computer for operation control), P/C (process com-

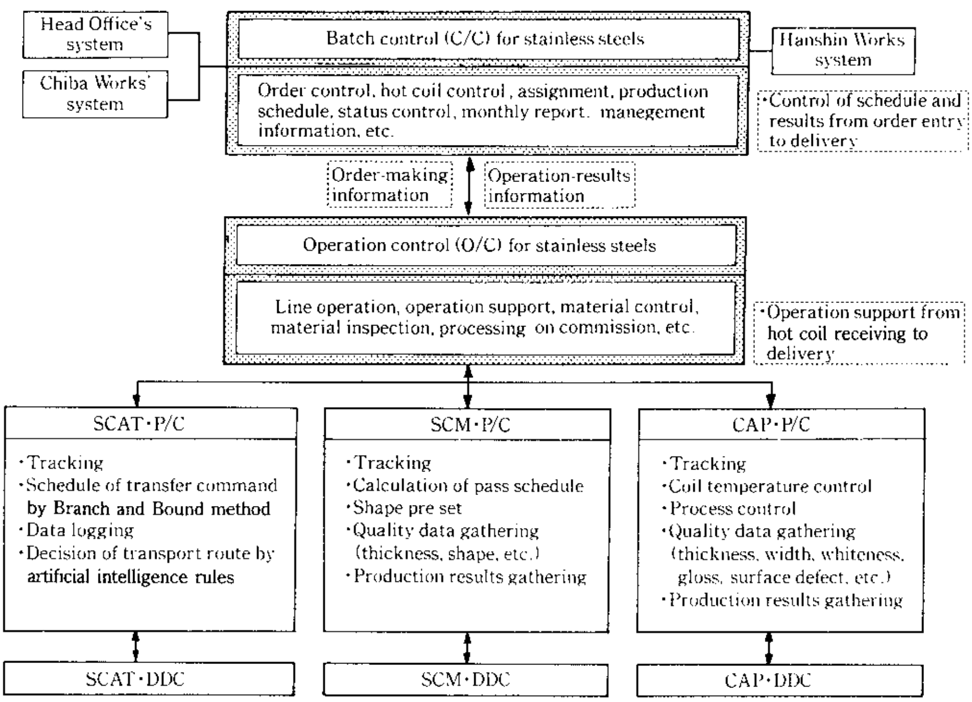

Fig. 15 Outline of system configuration

puters) and DDC (direct digital controllers). C/C is linked with the sales and production control systems at Head Office and with the serial systems (steelmaking, hot rolling, cold rolling, delivery and total information control) at Chiba Works.

(1) C/C: This consists of sub-systems such as order control, hot-rolled coil control, allocation, daily schedule, integrated progress control, receipt and shipment reports, and control information, and controls the planning and actual records ranging from order receipt to product delivery.

(2) O/C: This consists of sub-systems such as line operation, operation support (control for rolling rolls, auxiliary materials and dummy strip), short-haul transportation control, material control, material testing and processing on commission, and controls operations in the Cold Rolling Plant ranging from coil receipt to shipment. C/C and O/C are linked by operation instructions from C/C and operation results from O/C.

(3) P/C: This is composed of two P/C units for line operation control, and a third P/C for coil transportation control. P/Cs control timely coil acceptance, processing operations and delivery.

4.3 Configuration of the Automatic Quality Assurance Equipment

To save energy, improve production and assure quality, various types of automatic quality assurance equipment are provided. This equipment is controlled by the line P/C or DDC, and the records derived by the line P/C are sent to O/C and C/C and effectively utilized as operation result information, feed-forward information and control information.

5 Measures to Ensure a Better Workshop Environment

The external design of the plant building features rounded corners, dark-colored stripes on the light-gray background, and the blazing "K" corporate symbol. This appearance achieves harmony with the urban surroundings, and the building has been designed to create a mechanically clean space and a psychologically bright and comfortable working environment. The building has no windows and cleanliness is ensured by using double doors and sealing all construction joints. The lines are protected with tent in order to exclude dust and insects, the volume of dust inside the building being 1/10 of that in the outside air. To ensure that the working area would not become too hot due to such heat sources as the annealing furnace and sunlight, coolers have been installed inside the line tent and rest areas, and spot coolers are provided at various locations inside the working area. The plant roof is provided with water sprays for cooling, and external air is brought into the open work area by fan blowers after filtering to maintain adequate ventilation in the closed plant. The internal temperature is only 1–3°C higher than the external temperature and the air velocity is 0.4–1.6 m/s. Light through the roof creates a bright and uniformly-lit plant.

6 Conclusions

The cold rolling stainless steel manufacturing facilities at Chiba Works comprise the cold rolling mill commissioned in March 1991, and the finishing plant and automatic coil warehouse commissioned in September 1992.

These manufacturing facilities together with an advanced production control system have firmly established the integrated manufacturing of stainless steel at Chiba Works.

(1) The use of a 12-high cluster-type cold rolling mill (SCM) has enabled high productivity and high quality to be achieved.

(2) Directly connected to the continuous annealing and pickling line are the entry-side cleaner, laser-beam welder, improved Ruthner-type pickling tanks, skin-pass mill and finishing facility.

(3) The finishing facility incorporates all the necessary fundamental functions to ensure cleanliness.

(4) Artificial intelligence has been actively utilized for material handling and distribution inside the plant for cold-rolled coil transportation and delivery to and from the warehouse, precluding the need for any operators.

(5) Small-lot and early-delivery production control have been implemented by improving the assignment and daily scheduling.

(6) The entire plant building has been designed to achieve high airtightness and prevent dust.

All the facilities have been operating successfully, and production sharing with the works in Nishinomiya is under way according to the original plan.

The commissioning of these new facilities of Chiba Works and the completion of the two-base setup (east and west) for joint stainless steel manufacture with the works in Nishinomiya enables Kawasaki Steel to supply stainless steel products that will provide greater satisfaction to customers in the future.

Finally, the authors express their deep appreciation to the various companies that have provided valuable cooperation in the course of constructing these plant facilities.

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