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Katsuhiko Iwanuma, Masayuki Morimoto, Shigeki Taniguchi, Tokumitsu Kimura, Yosho Izumiyama, Toshio Ichida

Synopsis :
The continuous tin-free steel line (TFL) and the shearing line were introduced in June 1983 to the cold rolling plant of Chiba Works at Kawasaki Steel and are now in smooth operation. They have the following characteristics: The adherence of coatings was greatly improved by the development of the reverse electrolysis method. The automatic analysis system for measuring solution concentrations includes ICP analyzing equipment, which was also developed. Its optimum operating conditions were set by the process computer. Consequently, all chromium coated steel products were able to bed manufactured by an automated process from entry to delivery. The new shearing equipment permits improvement in the accuracy of the cutting length by digital control systems developed. Equipment including no loop enhanced the accuracy of squareness and detection of surface defects of products. The piling process based on the high-speed no-lapping system prevents the occurrence of dents due to slippage of the strip. As a result, quality has been improved and stabilized.

The body can be viewed from the next page.

An Outline of New Continuous Tin-Free Steel Line and Shearing Line*

Katsuhiko IWANUMA** Masayuki MORIMOTO** Shigeki TANIGUCHI**
Tokumitsu KIMURA** Yoshio IZUMIYAMA** Toshio ICHIDA***

The continuous tin-free steel line (TFL) and the shearing line were introduced in June 1983 to the cold rolling plant of Chiba Works at Kawasaki Steel and are now in smooth operation. They have the following characteristics:

The adherence of coatings was greatly improved by the development of the reverse electrolysis method. The automatic analysis system for measuring solution concentrations includes ICP analyzing equipment, which was also developed. Its optimum operating conditions were set by the process computer. Consequently, all chromium coated steel products were able to be manufactured by an automated process from entry to delivery.

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1 Introduction

The continuous chromium coated tin-free steel line (to be abbreviated as TFL) and the shearing line were put to the commercial operation in June 1983, and have since been running smoothly. Previously, chromium-coated steel had been produced on the No. 1 electrolytic tinning line at Chiba Works. The TFL and the shearing line were constructed to meet the recent increase in demand and to improve the company's competitive position by the development of manufacturing technology.

In designing these lines, emphasis was placed on a stable production of high quality products and the reinforcing of quality assurance practices while full consideration was given to saving on energy and resources through automatization and manpower reduction.

The present report outlines the characteristics, initial operational results and product qualities of the TFL and the shearing line.

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** Chiba Works

*** Technical Research Laboratory

2 Outline of Equipment

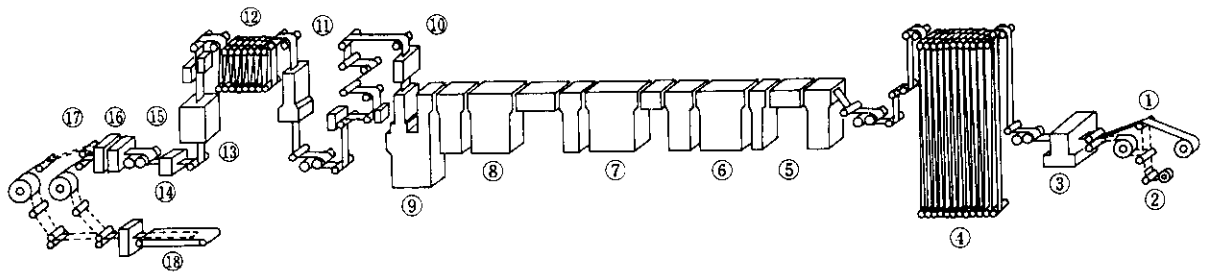
2.1 TFL Equipment

A line layout and an overall view of the TFL are shown in **Fig. 1** and **Photo 1**, respectively.

2.1.1 Entry section

The entry section, consisting of two pay-off reels, a reject reel, a welder and a looper, is designed to weld the skin-passed steel sheets one after another into a train of strip which is fed into the central section. The reject reel is placed between both pay-off reels so that it can receive the strip from either one of them. The welder is of a direct-current type lap seam welder, featuring an excessively low spatter generation during welding. It has a puncher for tracking welding point and a side clipping device for weld zone.

As a material coil is brought down on coil skid by the overhead crane, a series of entry section operations are performed automatically; starting with the proper transfer of coils, and setting a coil on the pay-off reel, the welding of a preceding coil and the next, feeding into the looper, and ending with the rejection of a preceding coil's end.



① No.1 and 2 pay-off reels
② Reject reel
③ Welder
④ No.1 looper
⑤ Cleaning tank
⑥ Pickling
⑦ Plating tank
⑧ Chemical treatment tank
⑨ Washing tank
⑩ Dryer
⑪ Oiler
⑫ No.2 looper
⑬ Inspection room
⑭ Gauge stand
⑮ Snip shear
⑯ Sheet sampling equipment
⑰ No.1 and 2 tension reels
⑱ Surface inspection table

Fig. 1 Schematic diagram of TFL

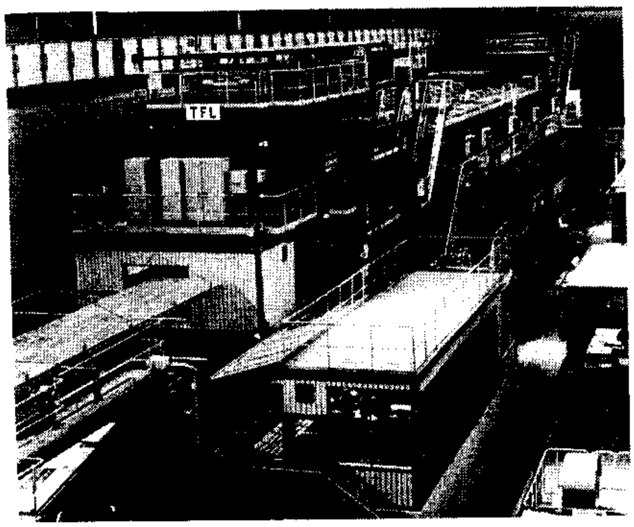


Photo 1 General view of TFL

2.1.2 Central section

Central section, consisting of a number of tanks and a drying unit and an oiling unit for post-coat strip, functions as degreasing, pickling, plating, and chemical treatment. The coating line has a coating unit using a reverse electrolysis method developed by the company for higher product quality.

In controlling many types of solution and rinses, an inductively coupled plasma (ICP) is adopted for automation, speeding-up and an improved concentration control accuracy. A computer-aided total instrumentation system automatically controls operational condition including the temperature, concentration and the amount of solution while valves and pumps are remote-controlled, with a series of solution-related operations including lifting and lowering of solution and cleaning of tanks automatically performed. Tank is of solution-tight design, a type for easy maintenance.

2.1.3 Exit section

Exit section, designed for product quality inspection, strip coiling and shearing, consists of a looper, inspection devices, a snip shear, and two sets of tension reels.

For inspection, particularly for surface defects detection, the flying spot type and the image sense type are used in combination to strengthen inspection capability. Further, the sampling of material, and the insertion of the welding point marking paper, and the coil end kinking prevention which used to be performed manually, have been mechanized so that a series of exit section operations are continuously performed automatically.

2.1.4 Production control system

The computer system for the present line is illustrated schematically in **Fig. 2**. The existing on-line production control system in the cold rolling mill is utilized for the TFL operation as the top of a hierarchy system as it is interrelated to TFL, covering process computer, electrical control DDC, instrumentation DDC, and further down to analytical control microcomputer, for an integral operation and quality control.

The principal functions of each computer are described below.

(1) On-line computer: to control the on-line production.
(2) Process computer: to collect operation data, totalization of inspection results and their transmission to central computer, quality monitoring (real time monitoring of operational conditions), preset control, automatic shearing of coil.
(3) Operation control DDC: to control principal para-

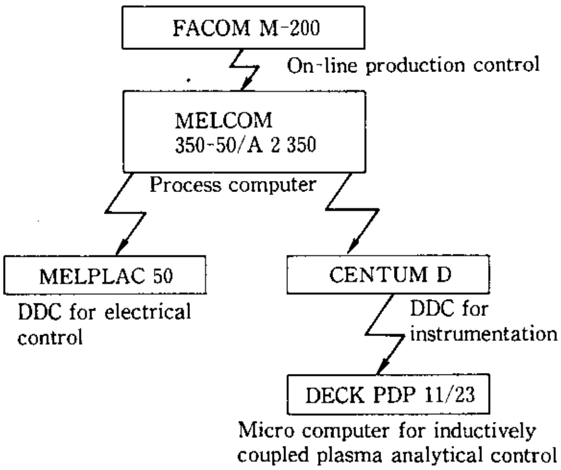


Fig. 2 Computer control system

Table 1 Specifications of TFL and shearing line

Item		TFL	Shearing line
Annual production (t/year)		144 000 (240 000 in future)	120 000
Strip	Thickness (mm)	0.1 ~ 0.6	0.1 ~ 0.6
	Width (mm)	457 ~ 1 067	457 ~ 1 067
Maximum coil weight (t)		21.0	21.0
Line speed (m/min)		Entry 540 Center 450 Exit 540	Before shear 300 After shear 400
Sheet length (mm)		—	457 ~ 1 100
Line length (m)		96.77	45.43

meters for line operation (such as speed, tension, etc.), plating current, and entry and exit side automatic operations.

(4) Instrumentation DDC: automatic control of temperature, concentration and level of individual solutions; sequence control for refilling, lifting, and lowering of solutions and rinsing of tanks; and CRT operation.

(5) Automatic analysis computer: analysis and control of concentration of individual solutions, transmission of analysis data to instrumentation DDC, monitoring of abnormalities with concentration analysis conditions and equipment.

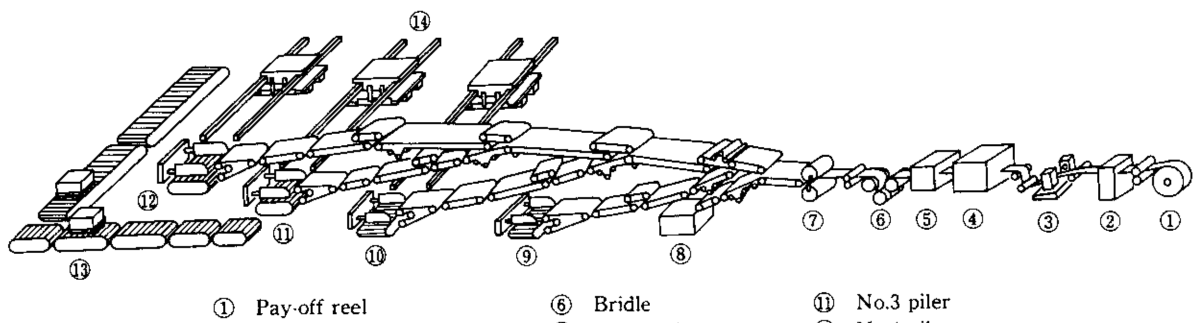
2.1.5 System specifications

The specifications for the TFL system is given in **Table 1**. While the production capacity is initially 14 400 t/year, it can be increased in future up to 240 000 t/year through the addition of plating sections.

2.2 Shearing Line

A line layout and an overall view of the shearing line are shown in **Fig. 3** and **Photo 2**, respectively. The shear which is the principal equipment of the shearing line is numerically controlled[1)] (NC shear) developed by Kawasaki Steel Corporation. The NC shear is equipped with a mechanical synchronizing device (non-circular gear) in the drum drive system. A low inertia servomotor makes it possible to obtain high accuracy shear length and fast shear speed comparable to the case of a mechanical shear. At the entry section of the shear, a bridle roll is provided to eliminate free loop, thus stabilizing the operations of inspection instruments and side trimming, and improving the right angle accuracy of products. The adoption of idle leveller roll contributes to reducing the roll diameter so as to improve the shape adjustment capability extensively in comparison with the conventional leveller.

In the piling operation, three product pilers are



① Pay-off reel
② Spot welder
③ Side trimmer
④ Inspection equipment
⑤ Leveler
⑥ Bridle
⑦ Rotary shear
⑧ No.0 piler
⑨ No.1 piler
⑩ No.2 piler
⑪ No.3 piler
⑫ No.4 piler
⑬ Conveyer
⑭ Skid feeder

Fig. 3 Schematic diagram of shearing line

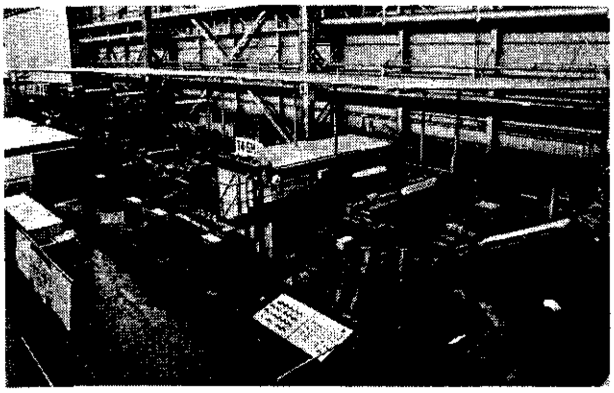


Photo 2 General view of shearing line

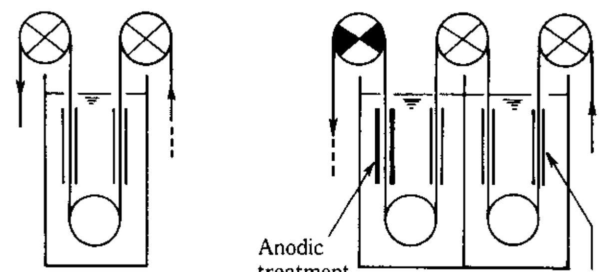


Fig. 4 Process of reverse electrolysis

installed, of which two are used under sequential change-over, and a high speed no-lap piling system is adopted so as to ensure high line speed without causing scratches.

As for the line automation, a series of operations from the entry section to the exit section are fully automatized, including coil transfer, insertion to pay-off reel, passing of strip, welding of a coil's tailend with the following coil's head end, position control of the piler side guide end and the back stopper, setting of skid, and transfer of piled products lot to the packaging line.

The basic specifications for the shearing line are shown in Table 1.

3 Features of Lines

3.1 Features of TFL

3.1.1 Reverse electrolysis method

The advent of cemented cans came to highlight chromium electroplated steel as the stock for can body of various types of beverage cans. It often occurs, however, that the high temperature sterilization (retort treatment) required in the case of some canned contents resulted in loss of adhesiveness between chromium-coated steel and lacquer. This may be attributed to peeling off at the boundary between the hydrated oxide film on the steel surface and the lacquer owing to the dissolution of water-soluble anions such as sulfate and fluoride ions out of the film. On the other hand, chromium plating bath having no addition of auxiliary agents such as sulfate and fluoride fails to provide necessary quantity of metallic chromium and uniform appearance. In order to solve this problem, a new plating method using the reverse electrolysis has been developed[2,3]. The plating process is schematically illustrated in **Fig. 4**.

(1) The strip is cathodically treated in a plating bath both containing sulfate and fluoride ions to secure a specified amount of metallic chromium.

(2) In the same bath, the strip is anodically treated to dissolve and eliminate forcibly the superficial hydrated chromium oxide film which contains a large amount of anions.

(3) After drag-out and water-rinsing, the strip is subjected to electrolytic chromate treatment (chemical treatment) in a bath free from the addition of sulfate nor fluoride.

The chromium coated steel obtained in this way has a high purity hydrated chromium oxide film at the surface and the contents of sulfate and fluoride ions are reduced to about 1/4 of the conventional product, presenting excellent adhesion force.

3.1.2 Automatic solution concentration control system with ICP

The TFL uses a great variety of solutions for various processes, such as degreasing, pickling, plating and chemical treatment. The control of concentration, temperature and level of individual solutions is highly important for ensuring a uniform product quality. Particularly, the control of concentration of micro components in the plating and chemical treatment solutions is of critical importance in both quantity and quality in making uniform hydrated chromium oxide film which seriously affects the adhesion force. In the concentration control, the selection of sensor suited for the continuous measurement and measuring items has been problematic. In the present system, the ICP analyzer is introduced first to the plating line for the purpose of monitoring the concentration and solved its problems.

The automatic concentration control system is schematically illustrated in **Fig. 5**. This system permits a fully automated control of the concentration of solutions, covering pressurized solution feeding, volumetric dispensing, dilution, spectral analysis by ICP, and calculation of concentration including correction for coexisting elements, in combination with a solution refill calculation, valve operation and the solution feeding volumetric pump operation all using the instrumentation

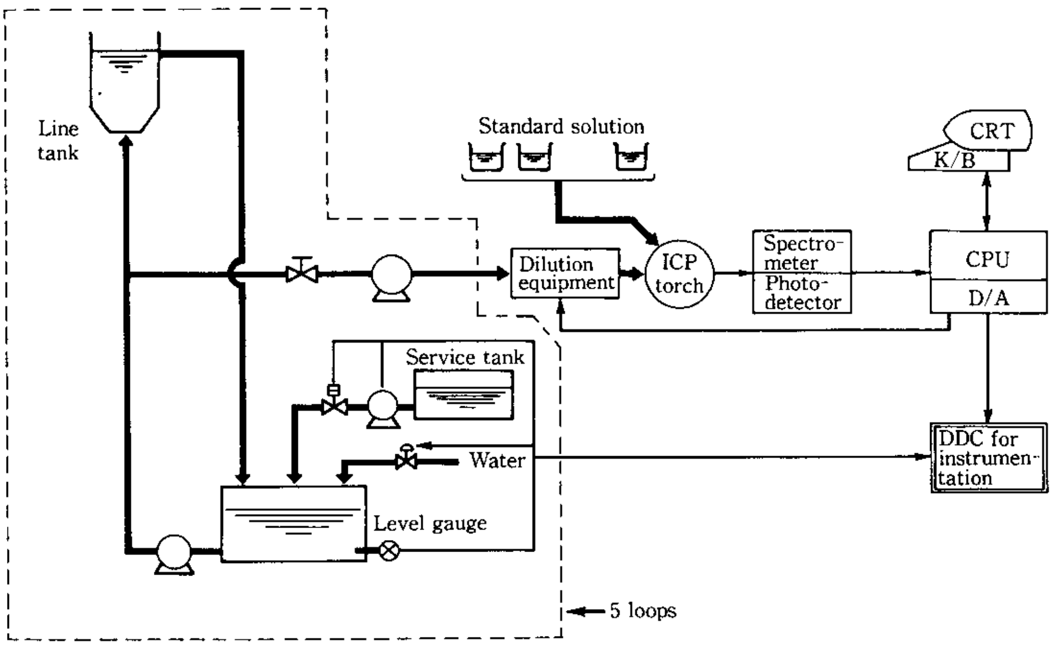


Fig. 5 Automatic concentration control system

DDC. The successful development of this system has permitted a stable manufacture of high quality products.

3.1.3 Overall quality control system

Since chromium coated steel is frequently used for beverage cans, demands for its quality are extremely severe. It is essential, therefore, to establish a quality control system ensuring the uniform quality over the entire length of coil. In order to meet these requirements, the most effective means is a continuous on-line quality monitoring by measuring the characteristic values of products.

In the TFL, principal operation control items are selected for stabilizing the characteristic values of products, and these items are measured at intervals of 25×10^{-3} s to monitor the quality. In this setup, the operational conditions set by the process computer based on given specifications for coil are compared, with the operational results obtained from the operation control and instrumentation DDCs. This monitoring covers not only the constant speed operation but also the accelerated and/or decelerated operation. The principal monitoring items include electro-plating current, chemical treatment current, and the amount of chromium deposit.

The measured data are constantly registered with a multi-pen recorder. Whenever any of parameters deviates out of the normal range, it is notified to the operator either by alarm or by logging, so that a proper remedial measures may be taken immediately.

3.1.4 Automatic specimen sampling

Formerly, specimens for testing the product quality have been taken by cutting out a piece from the outer layer of a wound coil by uncoiling it manually, which has posed some safety problems. In the TFL, a snip shear is provided to cut strip continuously, with a sheet sampling device installed on the exit side of snip shear, so that specimens can be taken automatically from the running strip. The sheet sampling device is illustrated schematically in **Fig. 6**.

3.1.5 Automation of entrance and exit side operation

In the conventional process lines, the entry section operations covering from coil insertion to strip welding, and the exit section operations covering specimen sampling from strip in coil, prevention of coil end kinking and the dismounting of coil have not been fully auto-

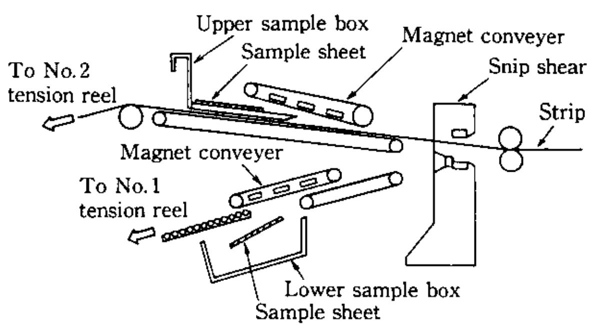


Fig. 6 Sheet sampling equipment

matized. With the entry and exit section operations, mentioned above, mechanized for automation, and moreover, with automatized setting of electroplating conditions using process computer, a full automated line has been achieved. That is, a coil placed on the coil skid at entry section comes out at exit section as finished product in full-automatic operation. The details of automation of entry and exit section operations are shown below.

(1) Entry section
- (a) A coil placed on the skid is positioned at the center of pay-off reel and set on it.
- (b) The coil's head end is put into the reject reel to coil off-gage segment.
- (c) The coil's head end from which defective portion is removed is advanced to the stand-by position in front of the welder.
- (d) The preceding coil is automatically decelerated to stop.
- (e) The following coil is welded to the preceding coil, and both edges of welded zone are side-clipped.
- (f) The remaining portion of the preceding coil is fed into the reject reel and coiled.

(2) Exit section
- (a) When a specified length of strip is coiled up, on a tension reel the strip is sheared on-line, and the following strip is fed into the tension reel in stand-by. During shearing, specimens (500 mm long) are automatically sampled on-line, if necessary.
- (b) Upon finishing coiling, the coil is automatically decelerated to stop.
- (c) The coil end is fed into the inspection table, and after the inspection, the coil is re-rolled.
- (d) A magnet to prevent kinking of coil end is attached and the coil is taken out.
- (e) When a weld zone is rolled into the coil, a weld point marking paper is automatically inserted.

3.2 Features of Shearing Line

The purpose of shearing line is to cut steel sheet to specified dimensions and to check the outer appearance and flatness so that defect-free products alone will be delivered. The characteristic equipment installed in the shearing line are described below.

3.2.1 Loopless shearing line

The conventional shearing line includes a shear unit combined with a feed leveller. In the shear of this type, if the leveller roll is depressed extensively, the strip meanders to deteriorate the accuracy of the length and the right angle of a sheared sheet. Moreover, a free loop provided in front of the feed leveller worked against raising a defect-detecting accuracy of the inspection instruments, because the loop tended to cause strip vibration.

In the present shearing line, the NC shear is adopted and the strip is fed into the shear through a pinch roll. Moreover, by newly installing a bridle roll and by applying tension between the bridle roll and the pay-off reel, the loop from the entry side of the shear is eliminated[4]. This came to prevent the strip from meandering when passing between the levelling rolls meshed relatively strongly or side-trimmed, ensuring excellent accuracies for shear length and right angle. Besides, the vibration of strip passing through the inspection instruments such as the automatic surface defect inspection system is reduced, and the inspection accuracy is improved.

3.2.2 High speed no-lap piling system

Since the chromium-coated steel sheet is inferior to the tin plate in sliding property, scratches tend to occur by making a physical contact with each other[5]. For this reason, in the present shearing line, a high speed no-lap piling system is adopted, eliminating contact between steel sheets from the shear to the piling and ensuring high productivity[6]. The speed of piling sheets into the piler is limited by the rigidity of steel sheet.

In the conventional system, steel sheets come into contact with each other, as the sequential deceleration of the conveyer speed to match in piling speed makes the sheets lap over each other. If two pilers are used simultaneously so that steel sheets are piled alternately, the shearing speed can be twice as fast as the piling speed. This is the high speed no-lap piling system. In order to keep the high speed piling running while the piled lot is being transferred, the line is provided with five pilers; three for acceptable products, one for light defect sheet and another for serious defect sheet pilers. The piling system is illustrated schematically in **Fig. 7**. In order to change over the pilers alternately, the responsiveness of the gate roll is improved, together with its heat insulation measures, and the guide and feed rolls are improved. For the products less prone to scratches, the conventional lap piling system is also possible. That is, three methods are available for piling: lap piling, no-lap piling and high speed no-lap piling.

3.2.3 Automatic skid feeding

Formerly, when the piled products are transferred to the conveyer, the wood skid (20–40 kg) for the next piling is fed into the piler manually. In the present shearing line, not only the skid feeding operation is mechanized and automatized, but also position controls for skid feeding and for piler guide devices are automated. The skid feeder is illustrated schematically in **Fig. 8**. Skids previously prepared off-line are processed by the skid feeder one by one and transferred to the piler. After the skid center is aligned to the piler center, skids are fed

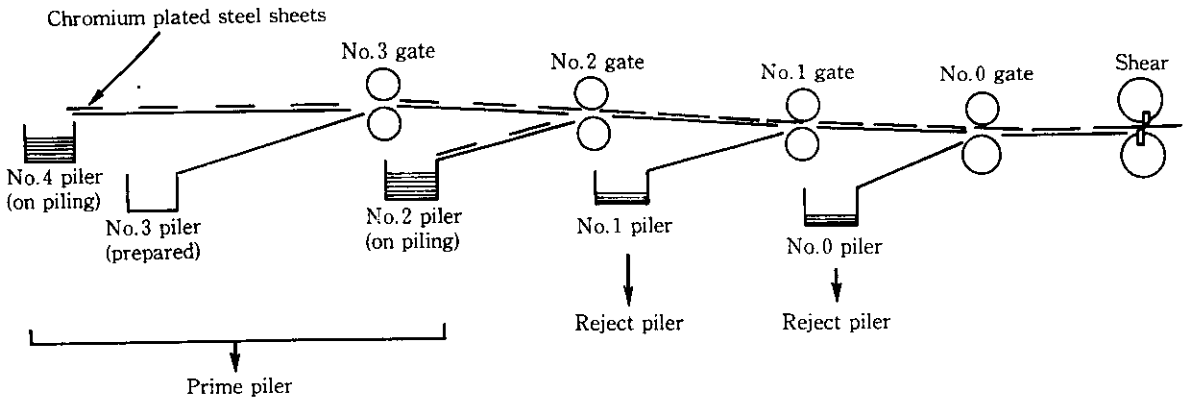


Fig. 7 Piling system of chromium plated steel sheets

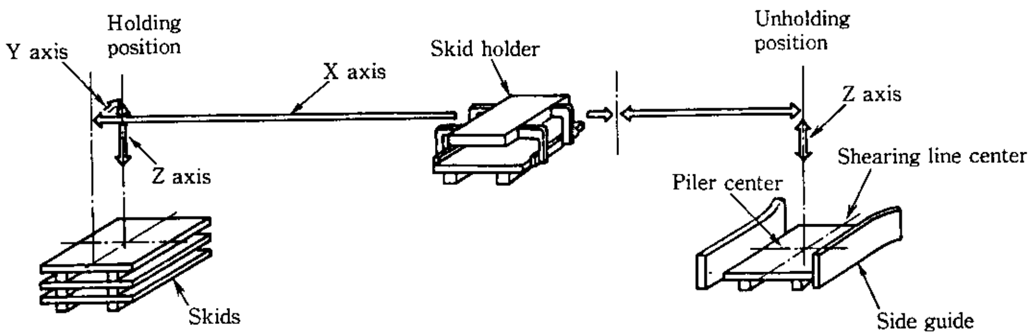


Fig. 8 Skid feeder

into the piler. The side guide, end stopper and back stopper of the piler are positioned by the signals from the process computer at a pre-set point according to the product width and shear length.

3.2.4 Improvement of inspection instruments

For the present shearing line, the following instruments have been newly developed and installed in combination with the existing ones: automatic surface defect inspection system using CCD camera to detect minute defects by deflected light, automatic surface defect inspection system for coil edge to check the appearance of coil edge emphatically, edge pinhole detector to check pinholes at the coil edge.[7)]

The inspecting systems installed in the present shearing line are listed below.

(1) Automatic surface defect inspection system (flying-spot type)
(2) Automatic surface defect inspection system using CCD camera.
(3) Automatic surface defect inspection system for coil edge
(4) Pinhole detector
(5) Edge pinhole detector
(6) γ-ray thickness gage

Owing to the effects of these inspection devices and the loopless shearing line described in 3.2.1, the level of quality assurance has been much improved than in the conventional shearing line.

4 Operational Achievements

The output of the TFL and the shearing line has been increasing steadily since the start of the operation in June 1983, with product quality proved excellent. The output and the quality characteristics are described below.

4.1 Output

The monthly output and availability data for the initial four months are shown in **Fig. 9**. The availability reached 90% in only three months after the start, and the production level is rising smoothly.

4.2 Quality Characteristics

The quantity of metallic chromium deposit and the chromium content in the oxide film on the TFL sheet are shown in **Fig. 10**. The quantities are characterized by smaller fluctuation than in the existing electrolytic tinning line (ETL) and meet the quality requirements adequately.

The sheets sheared by the subject shearing line have

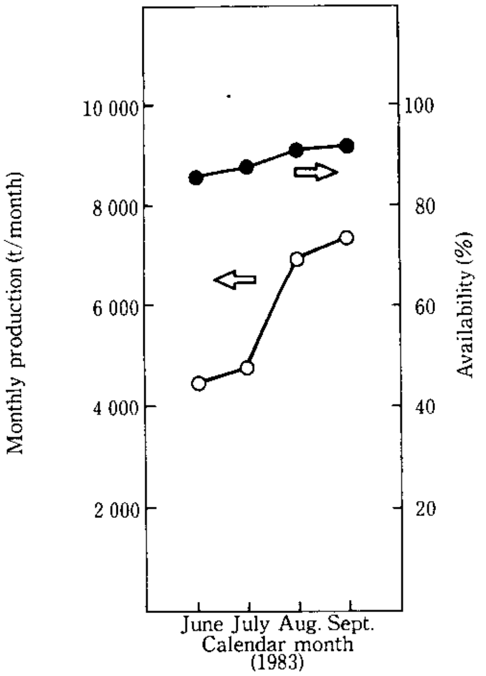


Fig. 9 Start-up performance of monthly production and availability

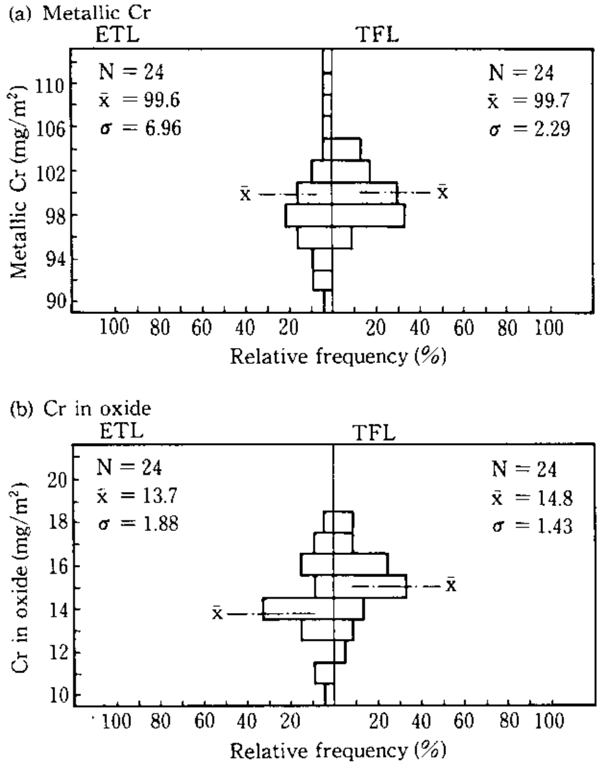


Fig. 10 Chemical properties of chromium coated steel

length accuracy of ±0.4 mm for 457–1067 mm in length, and right angle accuracy, which is shown in the difference of length between two diagonals, less than 0.3 mm/m. These values also showed smaller fluctuation than in the existing shearing line.

5 Conclusions

The characteristic features, initial production level and product quality of the TFL and shearing line have been reported.

With the TFL, a stable manufacture of products of excellent lacquer adhesion was possible through the reverse electrolysis method. The automatic concentration analysis system using the ICP analyzer is now in an unmanned continuous operation. The automated systems perform the initially planned functions adequately and are operating smoothly.

With the shearing line, the length accuracy is controlled within ±0.4 mm, and the right angle accuracy is 0.3 mm/m or better. Scratches that occurred in the conventional piling system were completely eliminated. The full line of inspecting equipment contributes greatly to the reinforcement of quality assurance.

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