KAWASAKI STEEL TECHNICAL REPORT
No.11 (March 1985)

An Outline of Temper and Processing Line for Steel Coils

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Synopsis :
At Chiba Works, the newly designed line, named "Temper & Processing Line (TPL)," started its operation in April 1983. TPL has a 2 stand-6 high skinpass mill, combined with a high speed coil preparation line and a packaging line, and produces ultra-thin cold-rolled steel for tin plates, black plates and tin-free steels. To actualize a continuous and high speed line, the technique of skinpass rolling on the weld line, method of eliminating the stop mark and a high-speed side-trimmer of 1600 m/min, the highest in the world, were developed. Carrousel reels, adopted as pay-off and tension reels, and newly designed automatic instruments are combined with the process computer system and contribute largely to high quality, high yield and labor saving.

The body can be viewed from the next page.

An Outline of Temper and Processing Line for Steel Coils*

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At Chiba Works, the newly designed line, named "Temper & Processing Line (TPL)," started its operation in April 1983. TPL has a 2 stand-6 high skinpass mill, combined with a high speed coil preparation line and a packaging line, and produces ultra-thin cold-rolled steel for tin plates, black plates and tin-free steels. To actualize a continuous and high speed line, the technique of skinpass rolling on the weld line, method of eliminating the stop mark and a high-speed side-trimmer of 1 600 m/min, the highest in the world, were developed. Carrousel reels, adopted as pay-off and tension reels, and newly designed automatic instruments are combined with the process computer system and contribute largely to high quality, high yield and labor saving.

1 Introduction

The No. 1 cold rolling mill of Chiba Works produces ultra-thin-gage cold-rolled steel sheets, such as feedstock coils for tinplates, tin-free steels and galvanized sheets. To increase the tempering and finishing capacity of the mill, a new temper and processing line (TPL) was constructed and was brought into commercial operation in April 1983. This report presents an outline of the line.

2 Background of Construction

In addition to the requirement for an increase in production due to the increasing demand for tinplates, black plates, and tin-free steels, there have increasingly severe requirements for high quality, shorter delivery time, and cost competitiveness. The line was constructed to meet these various requirements.

Especially to reduce costs and delivery time, there has been a recent tendency in the iron- and steel-making process toward labor-saving, yield improvement, and process omission by integrating multiple processes. Steelmakers are vying with each other in installing new continuous lines or remodeling existing lines into continuous ones. The TPL was made by directly connecting the conventional two processes, i.e., tempering and coil preparation, into one continuous line. In addition, since ultra-thin feedstock coils are processed on the line, it was necessary to adopt many new techniques in its construction. The objectives were to develop high-speed processing techniques, necessary for directly linking line of different maximum speeds and for processing ultra-thin materials at high efficiency, welding techniques, to eliminate the threading operation, and a skinpass rolling technique on seam-welding line. At the same time, increasingly severe quality requirements had to be remembered.

Furthermore, it was important to put various types of labor-saving automated equipment into practical use, to arrange automatic instruments rationally for quality control in the continuous line, and to connect them to a computer system consisting of an online computer for process control, a process computer for operation control and DDCs (direct digital controllers) for automatic operation. In this manner it was possible to improve quality control accuracy and bypass processes by automation.

3 Outline of Equipment

3.1 Specification of TPL

Table 1 shows the specifications of the line. This line produces mainly feedstock coils for tinplates, including black plates; therefore, the whole line is designed to process coils with a maximum width of 1 100 mm[1].

In linking the temper mill and the coil preparation line (CPL), the speed of the new line was designed to

* Originally published in *Kawasaki Steel Giho*, **16**(1984)2, pp. 93-101
** Chiba Works

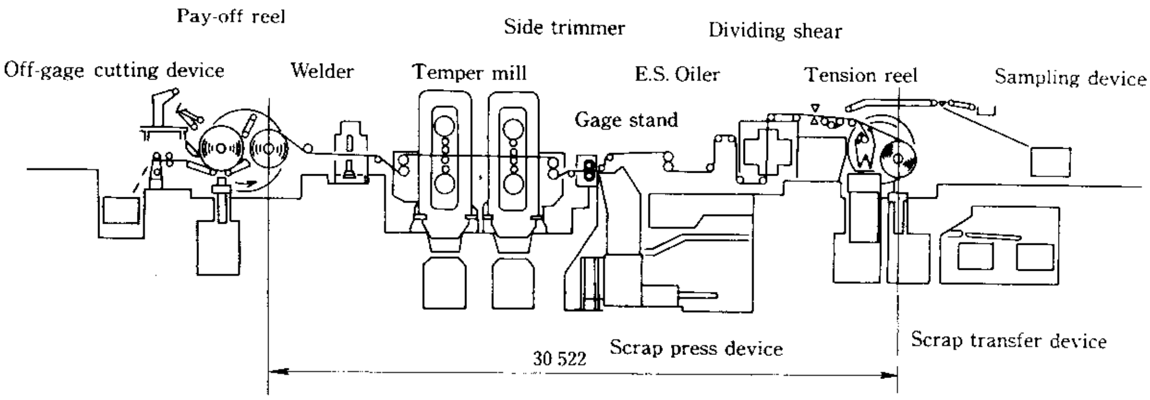


Fig. 1 Layout of TPL

Table 1 Specifications of TPL

Item			Specification
Strip	Thickness		0. 15 ~ 0.60 (mm)
	Width		580 ~ 1 100 (mm)
Coil	Weight (max.)		21 (t)
	Outer diameter (max.)		2 134 (mm)
Rolling	Speed (max.)		1 600 (m/min)
	Productivity		37 000 (t/mon)
Mill	Type		2 stand 6-high mill
	Roll dimension (Nos. 1, 2 std.)	WR	460 ϕ (mm)
		IMR	460 ϕ (mm)
		BUR	950 ϕ (mm)
	Motor power (Nos. 1, 2 std.)		1 120 (kW) each
Reel	Pay-off reel		Carrousel type
	Tension reel		Carrousel type
Oiler	Type		Electro static type
Packing	Line capacity		3 (min/coil)

be 1 600 m/min maximum, which is as much as 20% higher than 1342 m/min of the existing CPL (No. 3 CPL at the Works). This is the world's highest speed for a line having the functions of CPL.

3.2 General Layout of TPL

Figure 1 shows the general layout of the line. Since carrousel reels have been adopted as the pay-off reels and tension reels, the line is simplified and the automatic handling of coils on the entry and delivery sides is easily conducted. This is one of the features of the line. In the mill section, 6-high mills (HC mills) are used in the No. 1 and No. 2 stands to improve shape control capability at heavy reductions. **Photos 1** and **2** show the entry section and mill section, respectively.

A tempered sheet is stably trimmed to the product width at a high speed of 1 600 m/min. After surface inspection, rust-proofing oil is uniformly applied to the trimmed sheet by an electrostatic oiler, then the finished

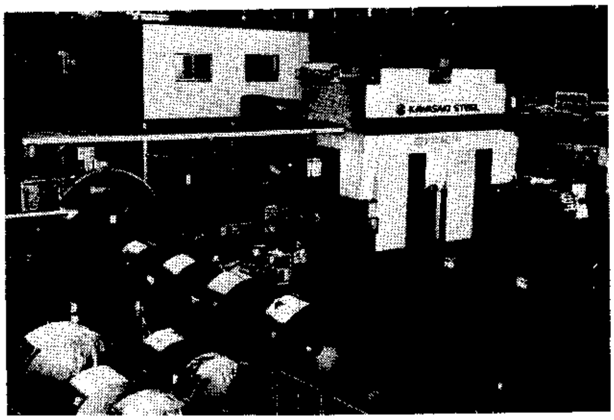


Photo 1 View of entry section

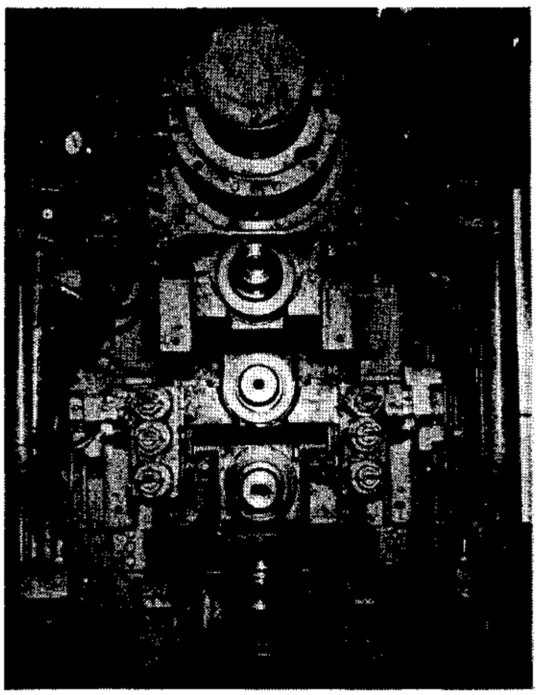


Photo 2 View of 6Hi mill

coil is produced.[2] The distance from the pay-off reel to the tension reel is 30.5 m and the sheet length within the line is approximately 45 m, which means that the line is compact and, as a continuous line, its layout is rational.

Coiling and delivery of products can be monitored from the main pulpit, which is located before the tension reel.

The TPL and No. 3 CPL are adjacently located in parallel to each other. Finished coils from the two lines are automatically transported by walking beams and coil transfer bogies to the coil packaging line, where they are immediately packed for shipment.

3.3 Entry Equipment

As shown in Photo 1, the entry equipment is composed of entry walking beams, a coil charging car, carrousel pay-off reels, a leading end and tail end off-gage processing device, a hoop cutter, a spool housing device, and a welder. The automation of the coil handling on the entry side will be described later. The welder has the following features:

(1) This is a DC seam welder using a thyristor as the DC power source. Weld beads are smooth because uniform continuous welding is possible.
(2) Just after the electrode is located a pair of planishing rollers, which reduces the thickness of the weld portion by rolling weld beads.
(3) An automatic electrode cutting device is provided to insure that the electrode wheel surfaces are in the best possible condition.
(4) Optimum welding conditions are automatically preset by the process computer.

3.4 Temper Mill

The temper mill is the 2-stand 6-high mill shown in Photo 2. The distance between the centers of the two stands is 3 400 mm, which is 867 mm shorter than that of the existing 2-stand 4-high mill in the plant. Both the No. 1 and the No. 2 stands have hydraulic screw-downs and are provided with hydrostatic bearings, work-roll chock clamps, and fully automatic roll changers that can change work rolls and intermediate rolls while the sheet is kept on line.

The pass line can be kept constant by a combination of rocker plates, wedges, and adjusting liners so that there will be no variations in shape resulting from pass line changes.

The backup rolls, intermediate rolls, and tension bridle rolls on the delivery side are equipped with roll polishers. Furthermore, in order to prevent the adhesion of oil to the sheet, which may occur in dry tempering, the design is such that the hydraulic cylinders and hydraulic piping are not installed above the sheet.

3.5 Finishing Equipment

3.5.1 Side trimmer

Two-head turning side-trimmers were adopted so that careful blade adjustments can be made on the standby trimmer head, resulting in shortened blade changing time. Furthermore, a motor-driven adjustment mechanism for blade clearances and overlaps permits remote control, and trimmer width settings are automatically changed using the process computer. A device for eliminating backlashes is incorporated to improve setting accuracy.

3.5.2 Rust proofing oil applicator

Rust proofing oil is uniformly applied by an electrostatic micron oiler. The oil volume and the width of applied oil are automatically set by the process computer, and the changing of oil type and pipe flushing are also automatically conducted. The construction of the oiler is such that the oiler proper can retract while the sheet is kept on line when a changeover is carried out from oiling to unoiled treatment, or vice versa.

3.6 Electrical Equipment, Instrumentation, and Computer Systems

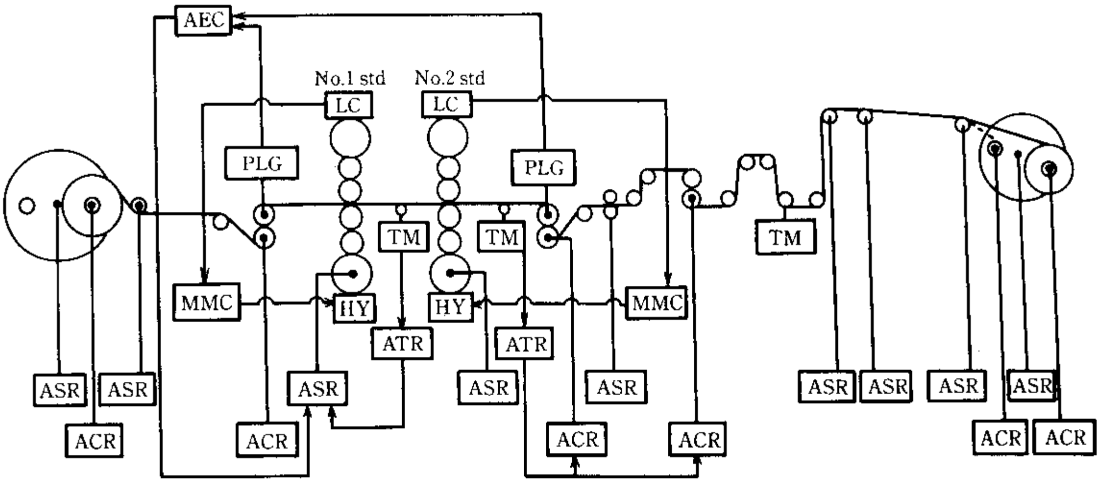
3.6.1 Electrical equipment

Figure 2 schematically shows the electric control system of the line. The mill section is provided with digital automatic speed regulators. Three load cells are installed; one between the stands, another on the delivery side of the mill, and another before the tension reel, so that unit tensions can be indicated on the tension meters, and that actual inter-stand tension and the mill delivery side tension can be controlled by feedback signals from the respective tension meters.

3.6.2 Automatic measuring instruments

Figure 3 shows the layout of automatic measuring instruments. The line has three γ-ray thickness gages, one for leading end off-gage cutting, the second for tail end off-gage detection, and the third for product thickness inspection. The automatic measuring instruments further include an entry width meter, a pinhole detector, a delivery width meter, a cross bow detector, an online surface roughness meter, a coil marking device, and a coil scale.

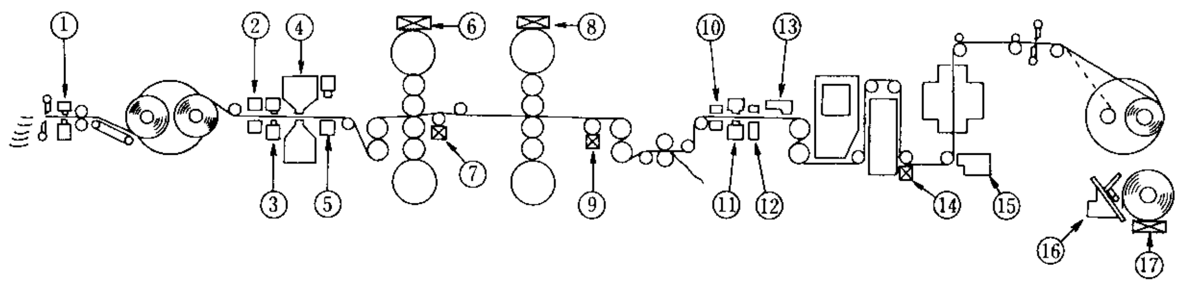
Both the No. 1 and No. 2 stands are provided with hydraulic screw-downs (HYROP-F), which are used for constant position control in dry tempering. However, these hydraulic screw-downs also have a mill modulus control function in consideration of future wet tempering.



ASR: Automatic speed regulator
ACR: Automatic current regulator
ATR: Automatic tension regulator
AEC: Automatic elongation regulator
MMC: Mill modulus control

HY: HYROP-F
LC: Load cell
TM: Tension meter
PLG: Pulse generator

Fig. 2 Schematic diagram of electric control system



① No. 1 thickness gage
② Center position control
③ No. 2 thickness gage
④ D.C. welder
⑤ Entry width meter
⑥ No. 1 std load cell
⑦ Inter-stand tension meter
⑧ No. 2 std load cell
⑨ Delivery tension meter
⑩ Pin-hole detector
⑪ No. 3 thickness gage
⑫ Delivery width meter
⑬ Cross bow detector
⑭ Coiling tension meter
⑮ On-line surface roughness measurement system
⑯ Coil marking device
⑰ Coil scale

Fig. 3 Layout of automatic measurement instruments

3.6.3 Computer system

Figure 4 shows the configuration of the computer system. The process computer for operation control (HIDIC-80E) transmits data to the host online computer for process control, setup data transmission to the DDCs, coil tracking, automatic setting of automatic measuring instruments, gathering of operation results, and preparation of documents.

The linkage controller (HIDIC-08L) controls data transmission from the process computer to the DDCs and also has the function of monitoring problems in automatic sequence control. A signal multi-transmission device (STU) serves to transmit data between the linkage controller and the DDCs.

The functions of the four DDCs (HISEC-04E) are master control, tension control, elongation control, and the sequence control of auxiliary automated equipment on the entry and delivery sides of the mill.

4 Techniques for High Speed and Continuous Operation

4.1 High-Accuracy High-Speed Carrousel Reels

The adoption of carrousel reels is effective in the simplification and automation of equipment. However, vibration and horizontality and parallelism during revolution pose problems because of the complex rotation transmission system. For this reason, carrousel reels

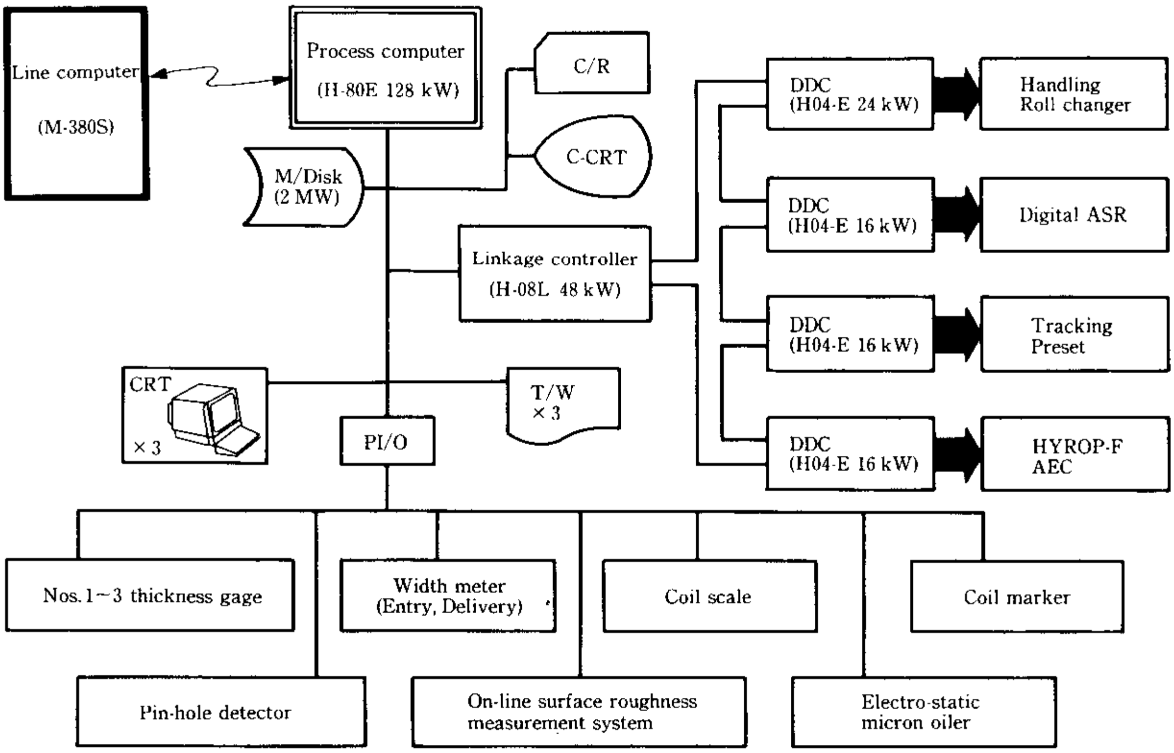


Fig. 4 Configuration of computer system

have so far been installed only on the delivery side of cold rolling mills when high speeds are required.

The line processes materials that have softened in the annealing process. Therefore, in installing the high-speed carrousel reels, design attension was paid to minimize machine vibrations and backlashes which adversely affect surface quality. Main measures taken for this purpose are:

(1) An adjustment mechanism was installed to increase the accuracy of the parallelism and to improve squareness between the reel mandrel and the line center.
(2) The dimensional accuracy of the reel mandrel was enhanced.
(3) Bearing clearances were minimized.
(4) Vibration of the push rod for opening and closing the reel was prevented.

These made it possible to coil the sheet as high as at 1 600 m/min even during the revolution of carrousel reels. **Photo 3** shows carrousel tension reels and a finished coil.

4.2 High-Speed Trimming Techniques

When the temper mill and the coil preparation line are integrated into one continuous line, the difference in the maximum line speed between the two poses a problem. The line speed is limited by the trimming speed. The conventional trimming speed is 1 342 m/min maximum. In this new line, the following measures were taken to permit stable high-speed trimming at a maximum trimming speed of 1 600 m/min, a 20% increase from the conventional speed.

(1) Blade vibration
To reduce blade vibration, the dimensional accuracy of each part was increased, and clearances such as those of bearings were minimized.
(2) Trimming tension
With the conventional side trimmers, the only tension working on the sheet was the coiling tension of the reel. In the line, however, a side trimmer was installed between the tension bridle rolls as shown in **Fig. 5** so that appropriate trimming tension can be

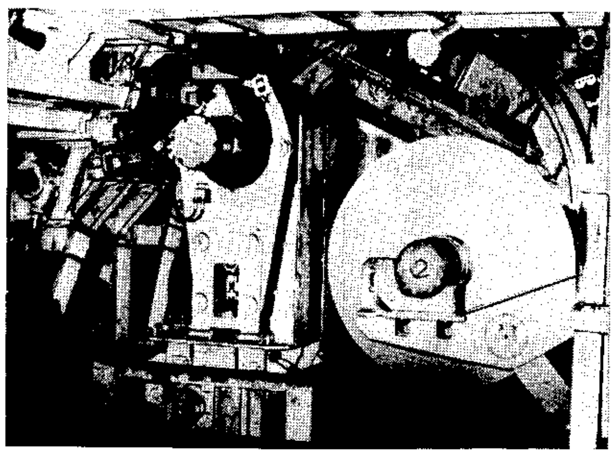


Photo 3 View of carrousel tension reels

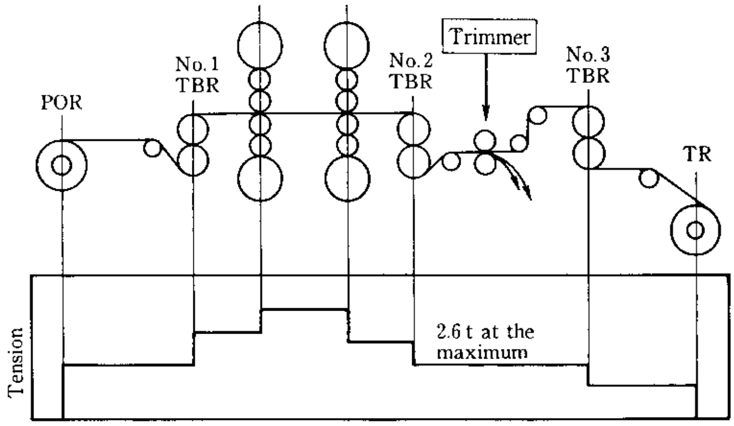


Fig. 5 Tension map of TPL

constantly applied to the sheet.

(3) Reduction in variations in clearance during operation

During operation, the clearance between the upper and lower blades changes due to the heat generated by bearings of the shafts to which the blades are attached. When ultra-thin-gage sheets are trimmed, as in this line, it is necessary to keep a clearance of about 30 μ. For this reason, it was necessary to reduce both the increase in shaft temperature and the temperature difference between the upper and lower shafts.

Conventionally, shaft bearings are prelubricated. In this lubrication method, bearing clearances change due to nonuniform amounts of grease and a temperature rise resulting from high-speed operation. In this line, therefore, a forced lubrication system with an oil cooling device is employed, and low-viscosity oil is used. As a result, the bearing temperature can be held at a lower level than in the conventional prelubrication method as shown in **Fig. 6**

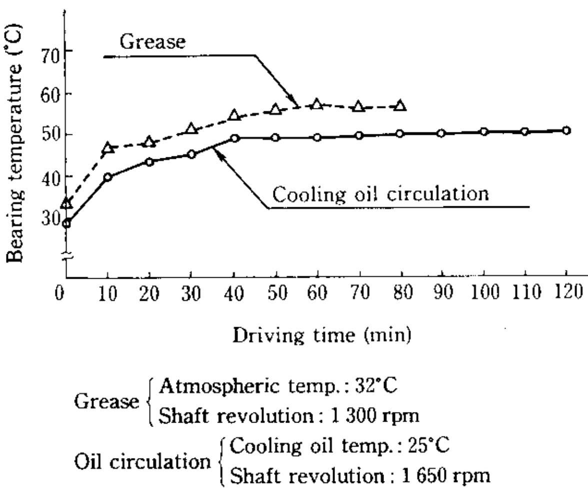


Fig. 6 Effect of driving time on bearing temperature

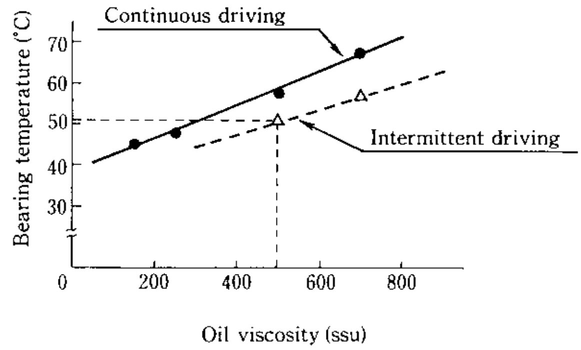


Fig. 7 Effect of oil viscocity on bearing temperature

and 7. In the forced lubrication system, however, oil leaks from the shaft neck. This oil leakage was completely prevented by installing a labyrinth oil thrower and adding oil seals.[3)]

4.3 Skinpassing Rolling Technique on Seam-Welding Line

When the tail end of the preceding sheet and the leading end of the following sheet are seam-welded on the entry side of the mill and the weld portion is skinpassed in this condition, the lap weld is printed on the work rolls.

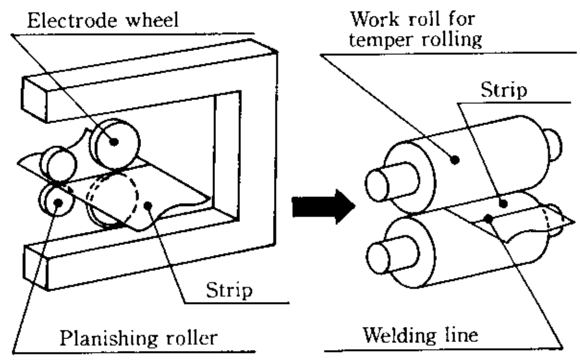
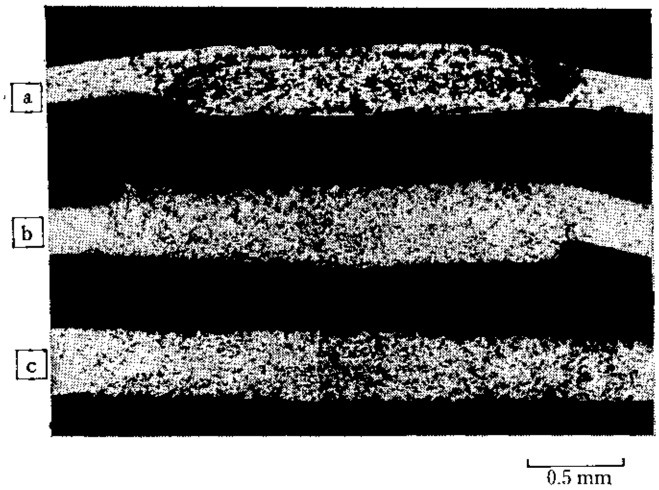


Fig. 8 Skinpass rolling on seam welding line



a: Ordinary AC welding
b: DC welding, as-welded
c: DC welding, after planishing

Photo 4 Comparison of weld thickness (cross section of welds)

To prevent this defect,[4,5] the specially designed DC welder with planishing rollers shown in **Fig. 8** was installed. **Photo 4** shows cross sections of a conventional AC seam weld, the DC seam weld of TPL, and the weld after planishing. The thickness of the weld can be substantially reduced by flattening it with the planishing rollers placed just after the electrode. Thus, the skinpass rolling on seam-welding line is possible.

4.4 Stop-Mark Elimination Technique

Slip marks are formed in the areas of the work rolls in contact with the strip when the mill is stopped during operation and tension is removed. In a continuous line with no looper, the mill must inevitabley be stopped during welding, roll changes and inspection, so the formation of such stop marks becomes a problem. In this line, the formation of stop marks is prevented by maintaining some definite proportion of rolling tension as a stationary tension even during mill stops[6].

5 Automation Techniques

5.1 Entry Coil Preparation

Figure 9 shows the entry coil preparation equipment. Carrousel reels are used. **Figure 10** is an automatic operation flow chart.

The coil awaiting rolling on the entry walking beam is automatically charged into the center of the reel in the rejecting position after height adjustment by the coil car. If coils are fastened with steel hoops as are batch annealed coils, these steel hoops are automatically removed by a hoop cutter, which also disposes of hoop scrap. The off-gage of the leading end of the charged coil is cut by a flying shear while being checked by the No. 1 γ-ray thickness gage.

On the reel for running, the speed is automatically decelerated near the tail end and the mill is stopped when the off-gage of the tail end is detected by the No. 2 γ-ray thickness gage. This off-gage is cut out by a shear installed in the welder and the sheet is rewound on the reel. After that, the carrousel reels revolve and the next coil that has been prepared is threaded and welded to the preceding sheet.

The rewound off-gage is cut out by the flying shear during operation. When a spool is used, it is automatically removed and deposited in a receptacle.

Figure 11 shows a time chart of entry coil preparation. The off-gage treatment of both ends of a coil can be conducted during the operation of the line. Charging the coil onto the reel for running is quickly accomplished with the rotation of the carrousel reels.[7]

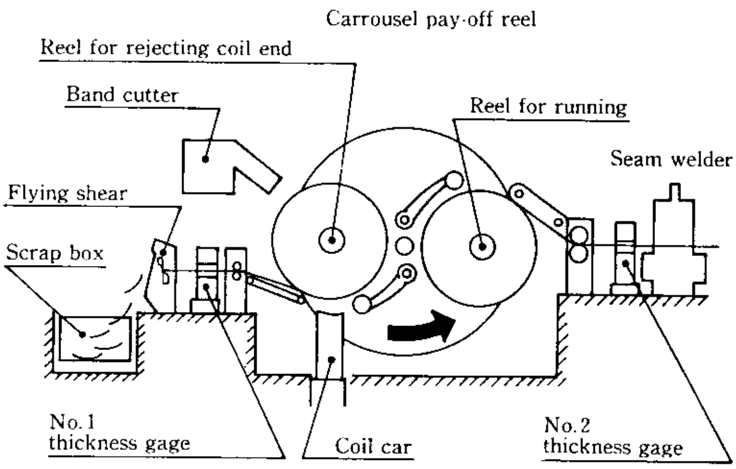


Fig. 9 Layout of entry section

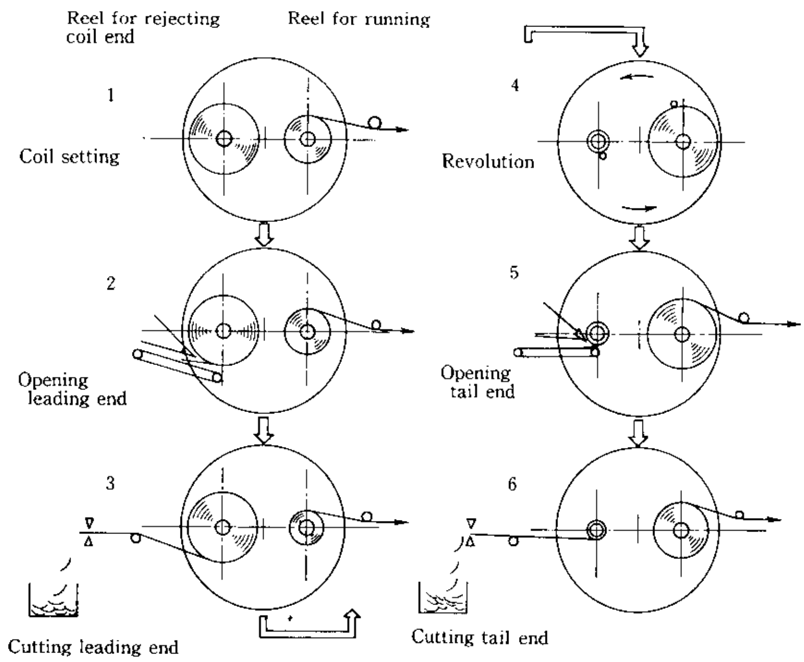


Fig. 10 Coil Preparation in entry section

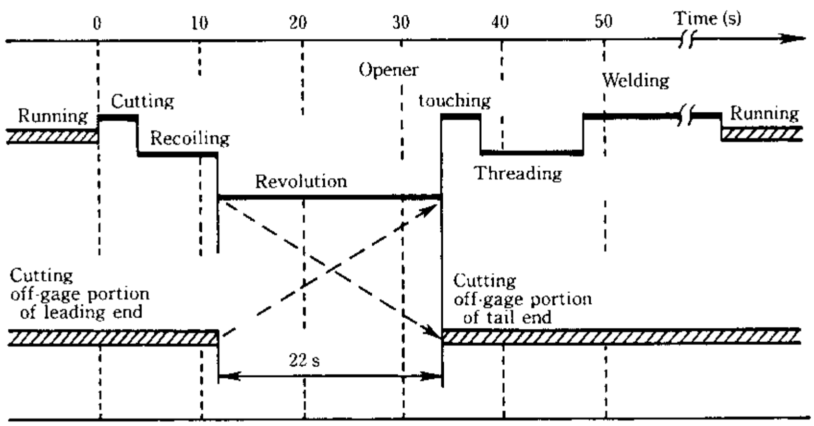


Fig. 11 Time chart entry preparation

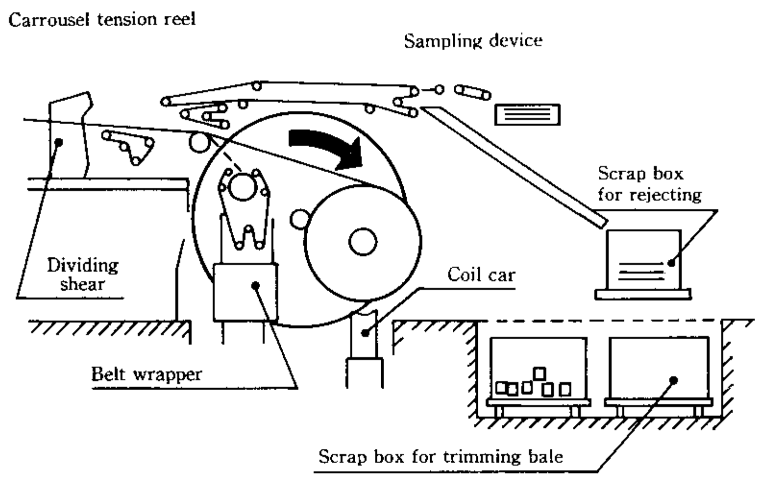


Fig. 12 Layout of delivery section

5.2 Delivery Coil-Dividing

Figure 12 shows the delivery coil-dividing equipment, using carrousel reels. As shown in **Fig. 13**, automatic dividing is performed by the process computer, which makes judgments regarding range of coil weight, the number of welds and so forth. At the dividing point, it is possible to take samples. An automatic spool insertion device is provided for cases where a spool is necessary to protect the inside portion of the coil.

The tail end of the sheet cut by the delivery shear is controlled so that the cut end stops at a predetermined position on the coil after coiling. The coil is automatically weighed after removal, and actual weights are transmitted to the host online computer through the process computer.

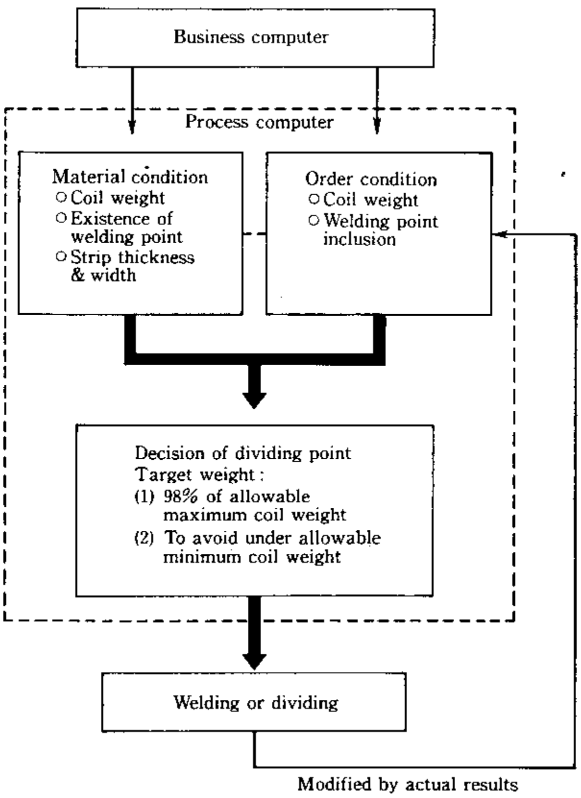


Fig. 13 Schematic flow of coil dividing

Finally, a newly developed coil marking device fixes the tall end of the coil in a predetermined position using two sheets of seals on which a delivery identification number is printed.

5.3 Fully Automatic Scrap Baler

Handling of trimmed scrap from the high-speed trimmer is fully automatically performed by a scrap baler consisting of three presses. **Table 2** gives the specifications of the scrap baler. The weight of trimmed scrap is constantly monitored by a DDC. When a set weight is reached, trimmed scrap is pressed into a square block, as shown in **Fig. 14**, and is automatically removed by a conveyor, as shown in **Fig. 15**.

6 Measures to Assure High Quality

6.1 Effect of Continuous Operation

Because the off-gages of the leading and tail ends of coil are threaded into a conventional temper mill, foreign matter adhering to the internal and external surfaces of the coil is brought into the mill. In this continuous mill, foreign matter is excluded from the mill because tempering is conducted after the removal of the off-gages of the leading and tailing ends of coil. As a result, roll-marks were greatly reduced.

The tempered sheet is coiled after rust-proofing oil is applied. This rust-proofing oil decreases the coefficient of friction between surfaces of the sheet. Therefore, its application eliminates the problem of scratches caused by friction between coiled strip surfaces.

Table 2 Specifications of press type scrap baler

Item		Specification
Capacity		3.2 t/h
Bale	Size	400 × 400 × 400 mm
	Weight	100 kg
Press cycle time		72 s
Press force	No.1 press	10 tf
	No.2 press	24 tf
	No.3 press	50 tf

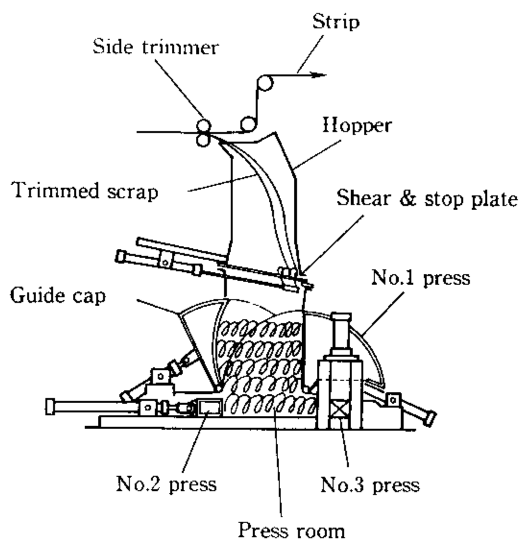


Fig. 14 Press type continuous scrap baler

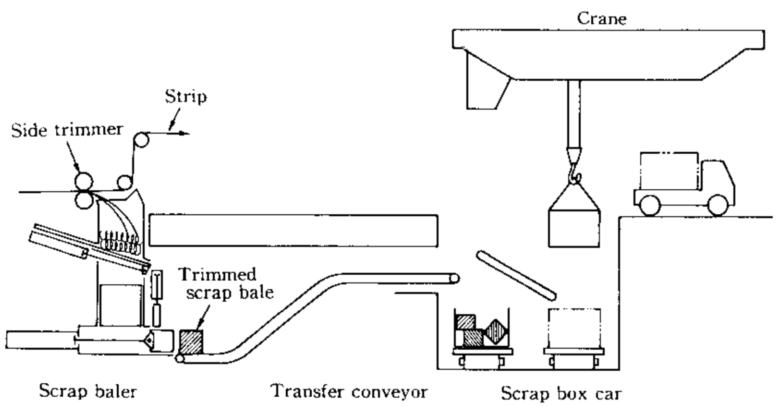


Fig. 15 Automatic trimmed scrap transfer device

6.2 Concept of Clean Mill

The problem of oil adhesion to the strip during dry tempering was solved by a clean mill design, in which hydraulic piping and hydraulic cylinders are not arranged above the pass line.

6.3 Improvement of Mechanical Accuracy

Variations in the sheet shape resulting from changes in the pass line were eliminated by adopting a mechanism for keeping the pass line constant even when roll diameters are changed.

Furthermore, the improvement of mill accuracy and the installation of clamping devices for work-roll chocks have eliminated differences in luster in the transverse direction caused by problems in the accuracy of roll arrangement and variations in longitudinal bow.

6.4 Improvement of Control Accuracy

Actual tensions are controlled by tension meters. Therefore, variations in longitudinal bow due to tension fluctuation were eliminated because tension is controlled at a predetermined level even during acceleration and deceleration of the mill.

Moreover, the pattern of coiling tension according to coil diameter was improved by use of the tension meter installed before the tension reels. As a result, the problems of coil collapse and coil deformation were solved.

6.5 Online Inspection Devices

A newly developed online surface roughness meter[8] and a laser cross bow detector[9] were put into practical use in the line. As a result, it has become possible to continuously control the surface roughness and cross bow of the sheet; thus, the accuracy of quality control has been improved.

7 Conclusions

Today, steel mills are required to increase their production of ultra-thin cold-rolled steel sheets, such as tinplate and black plate. To this end, a new temper and processing line for steel coils was constructed at Chiba Works to expand its tempering and finihing capacities and meet severe requirements for high quality, shorter delivery time, labor-saving, and cost competitiveness. This high-speed continuous line was realized by combining a variety of individual operational techniques with the mechanical and electrical equipment and instrumentation that have been developed in the mill for producing feedstock coils for tinplates, and by developing additional new techniques.

Customers' requirements will be more diverse, and even higher quality products will be demanded in the future. Steel mills will also be required to meet multi-specification production in small lots and higher quality. Given this changing situation, Kawasaki Steel intends to continue to improve and develop techniques for making products which are competitive in cost, able to meet strict delivery demands, and are of consistently high quality.

The authors would like to express their sincere thanks to all the persons concerned for their unstinting cooperation in the construction of TPL.

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