Abridged version

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Full Continuation of Descaling and Cold Rolling Mill

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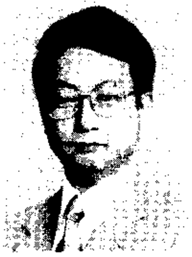

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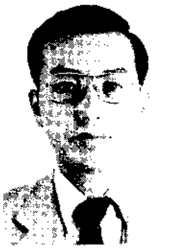

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1 Introduction

Cold rolled steel sheets for applications such as automobiles and household electricals are processed, when received from the hot rolling line, by pickling, cold rolling, cleaning, annealing, temper rolling, and recoiling. Important tasks, with the aim of increasing product uniformity and reducing defects, lead time, and costs, have been process simplification and process continuation. At the Mizushima Works, simplification of the processes after cleaning was achieved when the KM-CAL began operation in February 1984[1]. However, there remained the problem of connecting the pickling line for descaling of hot rolled coils with the cold rolling mill, which finishes products to proper thicknesses.

It was essential, in order to realize continuous pickling and cold rolling, to develop operation and speed adjustment techniques for the two lines. New techniques were particularly important for pickling, for example, high efficiency descaling[2] to cope with increased scale produced by the KM-CAL, and chance-free edge trimming[3], which is the second purpose of pickling. The No. 1 tandem mill at the Mizushima Works had been a chance-free, high productivity rolling mill since the introduction of an HC mill to the No. 5 stand and digital ASR[4] in October 1981, and the introduction to all stands of AGC (ATGC),[5] including a flying-gauge change function in July 1982. However, in the conventional rolling technique including threading and tail out, occurrence of improper thickness at top and tail ends cannot be avoided; work rolls can easily be damaged at threading and tail out, and, further, the flatness of the ends is not stabilized.

As the subject of this report, new techniques for pickling have recently been developed, and the No. 2 pickling line and No. 1 cold rolling mill made continuous in order to solve the limitations of the batch-type cold tandem mill. Operation of these lines began in June 1985. This report describes the outline of these facilities and the newly developed techniques for continuous

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Table 1 Main specifications

Entry section		Descaling section		Trimmer section		Mill section	
Line speed	620 m/min	Line speed	320 m/min	Line speed	380 m/min	Mill speed	1 930 m/min
Loop car capacity	480 m	Loop car capacity	200 m	Loop car capacity	350 m	Cutting speed	400 m/min max
Welder	(1) Laser (2) Flush-butt (KMW)	Descaling equipment	(1) Tension leveler (2) Mechanical descaler (ISHICLEAN) (3) HCL	Trimmer	Tarret trimmer	#1	4 Hi with WR shift
						#2~4	4 Hi
						#5	6 Hi
Coil weight Size	35 t max 1.6~6.0 mm × 600~1 630 mm	—	—	—	—	Coil weight Size	50 t max 0.15~3.3 mm × 600~1 630 mm

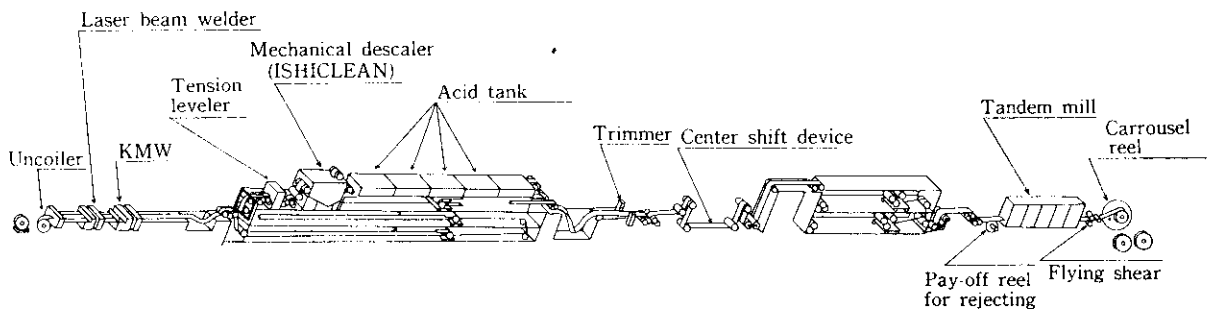

Fig. 1 Outline of fully continuous descaling and cold rolling mill

operation.

2 Outline of Facilities

2.1 Line Specifications

The main specifications of the line are shown in **Table 1**. This line consists of an entry section provided with 2 welding units which continuously connect hot rolled coils, a descaling section, a trimmer section for edge trimming, and the mill section. Between neighboring sections, a looper is provided to compensate for differences in operational rates between the sections. An overall view of the construction of this line is shown in **Fig. 1**.

2.2 Entry Section

In this section, a laser beam welder for silicon steel[6] as well as a flush-butt welder for low carbon steel is provided. The flush-butt welder is a compact type of the conventional fully automated welder.

2.3 Descaling Section

In order to connect pickling and cold rolling, high-speed operation of this section is essential. For this

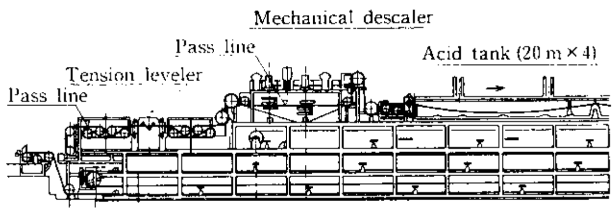

Fig. 2 Layout of descaling equipment

purpose, this section consists of the following devices:

(1) A tension leveler for cracking surface scale of hot rolled strip by tensional bending
(2) A mechanical descaler for grinding the cracked scale by liquid honing (ISHICLEAN developed by IHI Co., Ltd.)
(3) Hydrochloric acid tanks for removing scale completely

The construction of this section is shown in **Fig. 2**; the specifications of the descaling devices described above are shown in **Table 2**.

2.4 Trimmer Section

There are several reports concerning improved edge trimming techniques, for example, a method for reduc-

Table 2 Specifications of descaling equipment

Tension leveler	1. Elongation ratio	4% max
	2. Stretching work roll	80 mmφ × 2
	Leveling work roll	80 mmφ × 1
	3. Motor power	
	Main motor	1 000 kW
	Stretching motor	110 kW
Mechanical descaler (Ishi-clean)	1. Water pressure at outlet of spray nozzle	350 kg/cm² max
	Plunger pump	13 plungers
	Motor power	3 000 kW
	2. Slurry quantity	22 t/min max
	Motor power	330 kW
Acid tank	20 m × 4 Tanks	

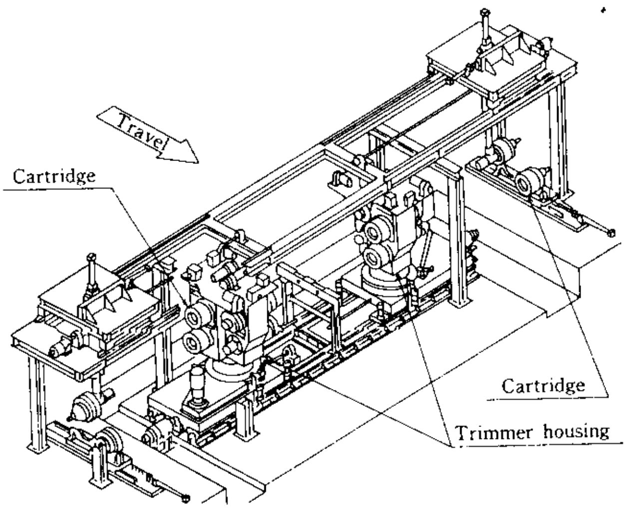

Fig. 3 View of trimmer

ing problems of the strip edge coming off the edge trimming round blade (edge choke up)[7]. However, these techniques cannot be applied without line stops during trimming and do not solve the problems connected with edge trimming. In this project, a completely new trimmer has been introduced to radically improve the trimming technique for continuous pickling and cold rolling. This trimmer provides the following functions:

(1) Flying width change
(2) Automatic blade change
(3) Minimization of edge choke up

A schematic drawing of the trimmer is shown in **Fig. 3**.

2.5 Facilities Connecting Pickling and Cold Rolling

The center lines of the No. 1 cold tandem mill and No. 2 pickling line are parallel, but 500 mm apart. This offset is absorbed by inclining two deflector rolls, as shown in **Fig. 4**. Between the trimmer and mill sections,

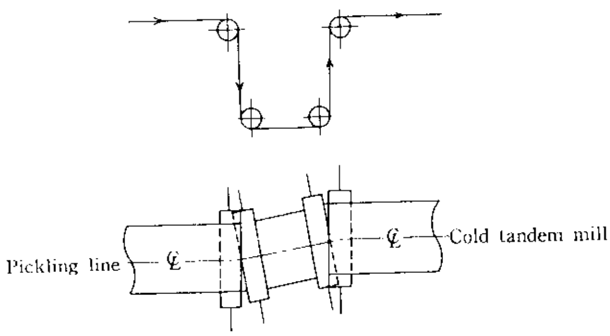

Fig. 4 Strip shifting device for coupling of pickling line and cold tandem mill

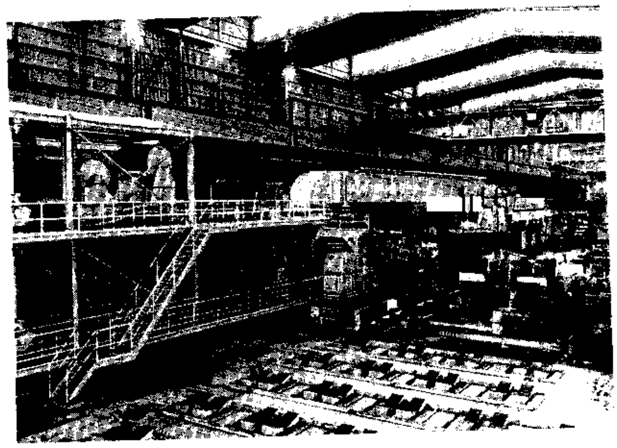

Photo 1 View of mill section from No. 3 looper

multi-strand looper cars consisting of two looper cars, each with 4 strands, are used. A temporary gate-type crane was used for constructing the looper instead of the mill yard cranes; therefore it was possible to carry out the construction without affecting mill operation. The appearance of the No. 3 looper is shown in **Photo 1**.

In a fully continuous pickling and cold rolling process, attention must be paid to dummy strip treatment during work stops. The uncoiling machine at the entry side of the existing rolling mill was improved to make recoiling of dummy strip possible. In addition, because it was made possible to exchange rolls requiring frequent exchange with strip in place, the frequency of cutting dummy strip was reduced.

2.6 Rolling Mill

With customers requiring improved gauge accuracy of sheet materials, particularly silicon steel sheets, the No. 1 stand was modified to use electromagnetic servo hydraulic screw-down instead of the conventional mechanical servo hydraulic screw-down, and the Kawasaki Steel work roll shift mill[8,9] was introduced for cold rolling for the first time in the world.

2.7 Exit Side Devices

At the exit side of the rolling mill, a drum shear and carrousel tension reel were installed; therefore, shearing and coiling during flying were made possible. Coil handling at the exit side, including provision of spools for thin materials, was fully automated to reduce labor on the mill floor.

2.8 Process Computer System

In order to carry out process control over the entire line, the existing process computer (V-90) for the cold rolling mill was extended to cover the pickling line. This process computer has microcomputers (H08L) at both the pickling and mill sections for weld point tracking operation, and performs, based upon this operation, computation of setup of the uncoiler through the carrousel tension reel, and coil tracking from the entry side conveyor to the exit side conveyor. Six weld point detectors are installed just before the plastic deformation equipment (i.e., tension leveler, trimmer, and rolling mill). At the pickling side, a descaling control computer (ADSC—Automatic Descaling Controller—H08L) has been introduced for effective use of the tension leveler, mechanical descaler, and hydrochloric acid tanks.

In the DDC system, three H08L's are installed for AGC and ASC, seven MICREX's at the pickling line, and six H04E-M's at the rolling mill on the electric circuit side. To achieve full automation, the conventional oilman panels were removed and the oil-celler and pickling instruments have been put under control by CRT and keyboard. The layouts of the process computer system and instrumentation devices are shown in **Fig. 5**.

3 New Technology for Connecting Pickling and Cold Rolling

3.1 Development of High Speed Descaling Technique

3.1.1 Necessity of high speed descaling technique

With the KM-CAL operation started, production of materials which are difficult to descale, including super low carbon steels, has increased. **Figure 6** shows the relation between scale thickness and required pickling time

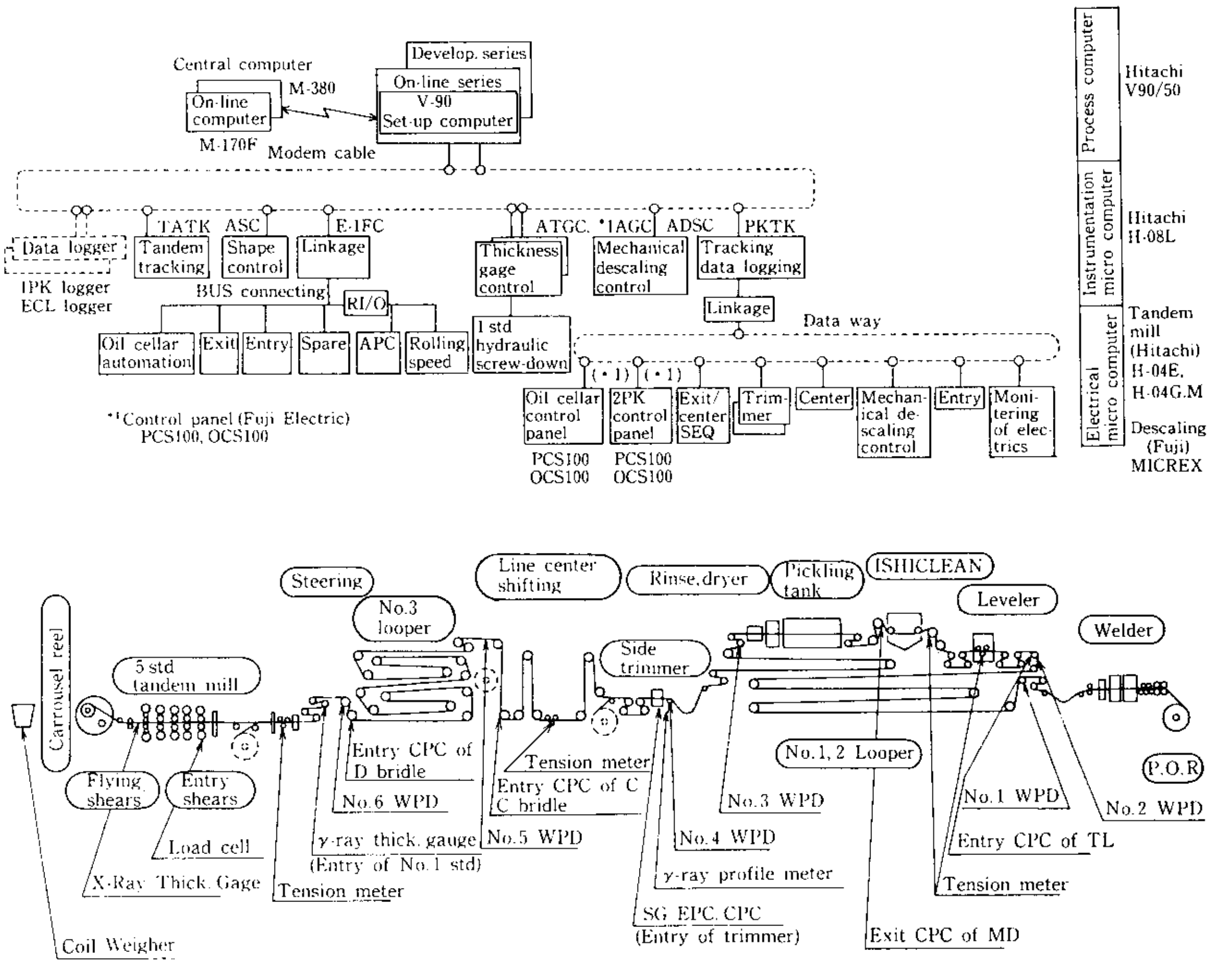

Fig. 5 Process computer system and layout of instrumentation device

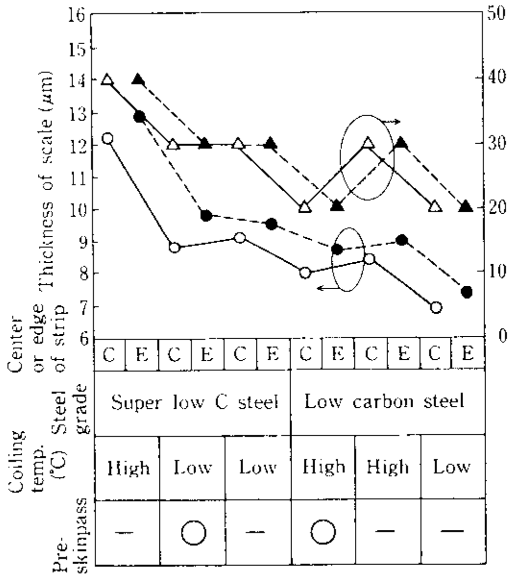

Fig. 6 Relationship between scale thickness and descaling time (5% HCl)

for several materials. As is clear from this figure, high temperature coiled super low carbon steels require about twice the pickling time of low temperature coiled low carbon steel. Though skin pass treatment has some effect as a pretreatment, lead time is increased because of the increase in the number of processes. Accordingly, it was necessary to develop a high speed descaling technique. A combination of tension leveler and ISHICLEAN was adopted based on the results of investigation of scale breakers and mechanical descalers[10].

3.1.2 Performance of descaling facilities

Concerning the performance of the descaling facilities, **Fig. 7** shows the relation between stretching ratio and descaling speed when only the tension leveler is used; **Fig. 8**, when the leveler is used in combination with the mechanical descaler. The effect of the tension leveler increases with stretching ratio, but reaches its maximum effective point at stretching ratios of around 2%. On the other hand, the combined effect, when the leveler is used with the mechanical descaler, is remarkable: descaling speeds as high as 270 m/min are achieved at the center of the strip length. This is more than three times greater than the speed of 80 m/min when the hydrochloric acid tanks are used alone.

3.1.3 Descaling Control

Descaling is carried out by tension leveler, mechanical descaler, and hydrochloric acid pickling. The concentration and temperature of hydrochloric acid have large control time constants; therefore, it is not easy to control these factors dynamically. For the tension leveler, intermesh and stretching ratio are set for

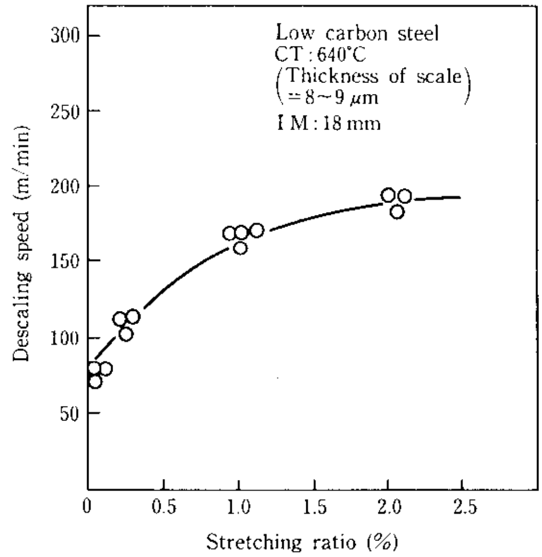

Fig. 7 Effect of stretching ratio in tension leveller on descaling speed

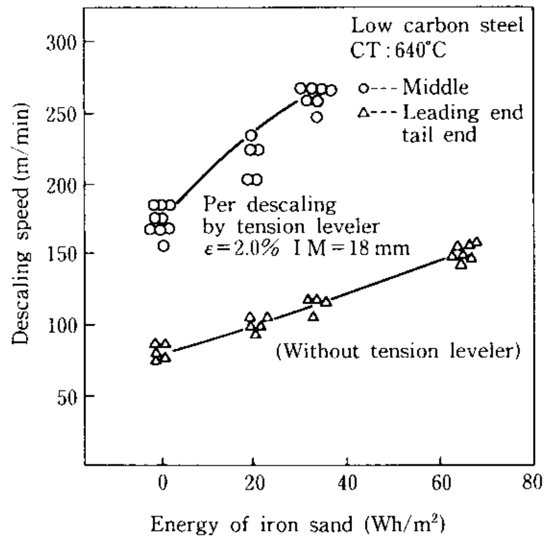

Fig. 8 Effect of mechanical descaler on descaling speed

each coil. Consequently, it is mechanical descaler's power and descaling speed that can be dynamically controlled in response to descaling conditions.

The concept of ADSC is characterized by the fact that independent and combined descaling effects of the tension leveler, the mechanical descaler, and hydrochloric acid pickling are formulated as functions of surface scale amount, and mechanical descaler and descaling speed are controlled so that the residual scale amount on the strip becomes zero at the exit of the hydrochloric acid tnaks. The functions of ADSC are as follows:

(1) Scale Amount Tracking

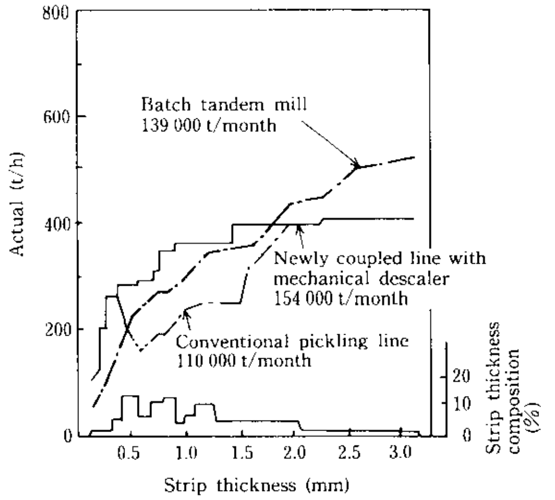

Fig. 9 Comparison of rolling capacity between conventional lines and newly coupled line

The strip, between the tension leveler and the exit of the hydrochloric acid tanks, is divided into 1 m sections, and these sections are tracked as they pass through each device, deducting a residual amount of scale in each case on the basis of a formulation of the descaling effect.

(2) Determination of Mechanical Descaler's Power
Mechanical descaler's power is determined from the residual scale amount and descaling speed at the entry of the mechanical descaler so that the residual scale amount at the exit of acid tanks becomes zero and the maximum efficiency is achieved.

(3) Determination of Descaling Speed
In the outermost loop, the residual scale amount for each section in the acid tanks is estimated on the basis of the results of previous mechanical descaler's power and the duration of acid dipping for the section; descaling speed is determined appropriately for the required pickling time for the section.

With the development of the high speed descaling technique, descaling efficiency has increased by 25% over that achieved when hydrochloric acid is used alone. This improved efficiency is very advantageous for connecting cold rolling mill and descaling line. **Figure 9** compares the capacity of the conventional hydrochloric acid pickling line and that of the new line in which the descaling facilities has been installed.

3.2 Development of Technique of Flying Width Change in Trimmer

3.2.1 Necessity of flying width change technique

In the conventional trimmer for each strip width change, the strip is clipped after welding at the entry of the pickling line and stopped when it has passed to the

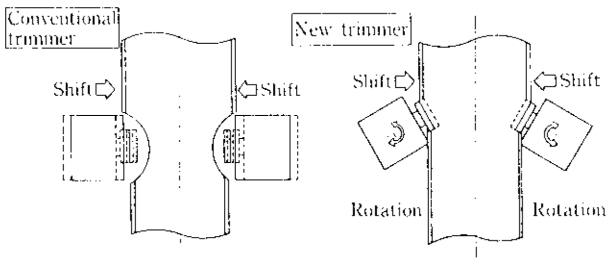

Fig. 10 Comparison of width change methods between conventional trimmer and new trimmer

trimmer position; the trimmer width is adjusted, after which strip travel resumes. Since the clipping time at the entry side is added in the welding time and the line is stopped for the trimmer width change operation, trimmed materials required a 10% longer process time than nontrimmed ones. Because of the longer process time for trimmed materials and the difficulty of automation of the trimmer width change operation, development of a flying width change technique was desired. Fundamental experiments were performed for two years and an epoch-making flying width change technique was developed and introduced into practical operation. **Figure 10** compares the width change methods of the conventional and new trimmers.

3.2.2 Flying width change function

Flying width change is performed by linking the housing rotation and width change functions of the turret type trimmer. The flying width change function is described below, with reference to **Fig. 11**. Angular speed ω and shifting velocity V_T of the trimmer housing satisfy the following formula, as can be seen from the geometric relation.

$$\tan\theta = \frac{V_T + R\omega\sin(\Theta + \theta)}{V_L + R\omega\cos(\Theta + \theta)} \cdots\cdots\cdots (1)$$

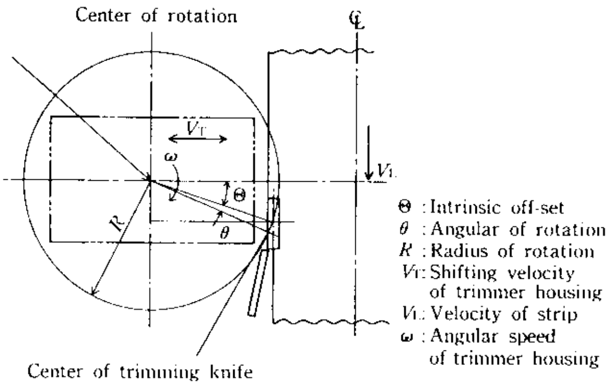

Fig. 11 Definition of symbols in relation to flying width change

If the following notations,

$L(t)$: strip moving distance

$T(L)$: trimmer housing moving distance

$\theta(L)$: trimmer housing rotation angle

are introduced, V_T and ω can be correlated by V_L as follows:

$$V_L = \frac{dL(t)}{dt} \quad \cdots\cdots(2)$$

$$V_T = \frac{dT(L)}{dt} = \frac{dT(L)}{dL} \times \frac{dL}{dt} = \frac{dT(L)}{dL} \times V_L \cdots(3)$$

$$\omega = \frac{d\theta(L)}{dt} = \frac{d\theta(L)}{dL} \times \frac{dL}{dt} = \frac{d\theta(L)}{dL} \times V_L \cdots(4)$$

In the newly introduced flying width change control, the time-independent terms in Eqs. (3) and (4) are calculated using housing rotation speed patterns, and housing shifting velocity is calculated so that Eq. (1) is satisfied; these values are summarized in a table using strip moving distance as a parameter. In flying width change control, which is performed at a constant strip velocity, real strip velocity compensation is used to cope with strip velocity changes. In addition, since offsets occur in the shifted position and rotation angle when only the housing shifting and angular speed are controlled, the APC loop for shifted position and rotation angle is also used to compensate for slight offsets according to detected values of positional errors.

3.2.3 Control effect

An example of the shearing locus, when flying width change control is applied, is shown in **Fig. 12**. As a result of this control, a maximum width change of ±100 mm, a width-changed length of 1 000 mm, and a width change accuracy of 0.2 mm are possible.

It is also possible to control rotation angle to give the trimmer blade a relief angle relative to the shearing locus at the shearing point and to prevent interference between the blade and strip. **Figure 13** shows the effect of this interference correction technique.

Since introduction of the new trimmer, the rate of shutdown due to trimmer problems, including blade change, is nearly 0%, and the efficiency for trimmed materials is almost equal to that for non-trimmed ones.

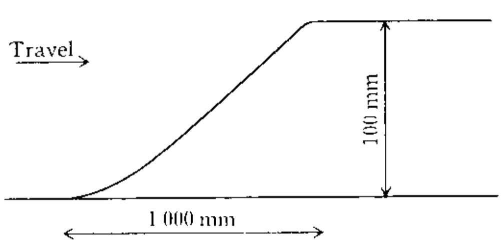

Fig. 12 Example of shearing locus

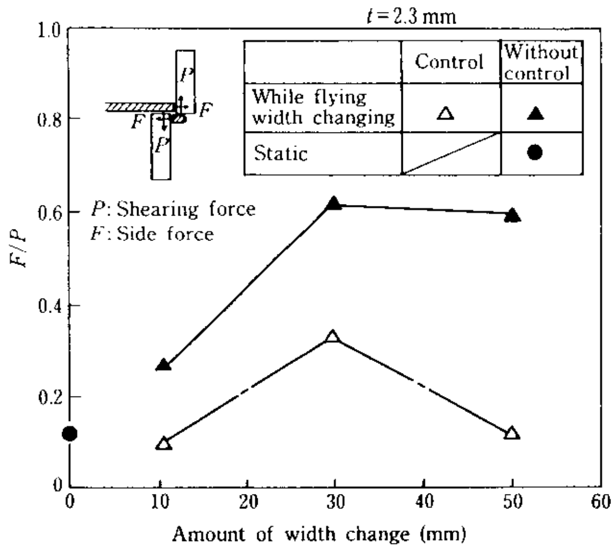

Fig. 13 Prevention of interference between blade and strip while flying width changing

3.3 Improvement of Flying Gauge Change Technique

The No. 1 cold tandem mill, is the only cold rolling mill in the Mizushima Works; therefore, it is used for strips of wide thickness ranges of 0.15–3.3 mm. In addition, various steels with a wide range of flow-stresses must be processed (**Fig. 14**). In the newly developed continuous line, flying gauge changing for large thickness differences and large flow-stress differences must be handled more frequently than before; therefore, the following two functions have been improved.

(1) Rolling force calculation

(2) Point tracking within the rolling mill

Concerning item (1), the conventional steel classification was sub-divided to give greater consideration to composition and hot rolling conditions. **Figure 15** compares the rolling stress calculation accuracies of the conventional and improved techniques. Concerning item

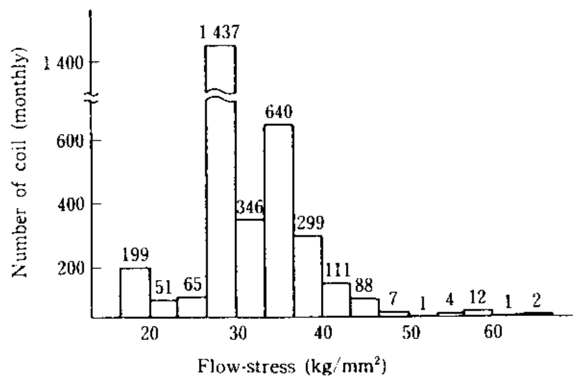

Fig. 14 Distribution of flow-stress

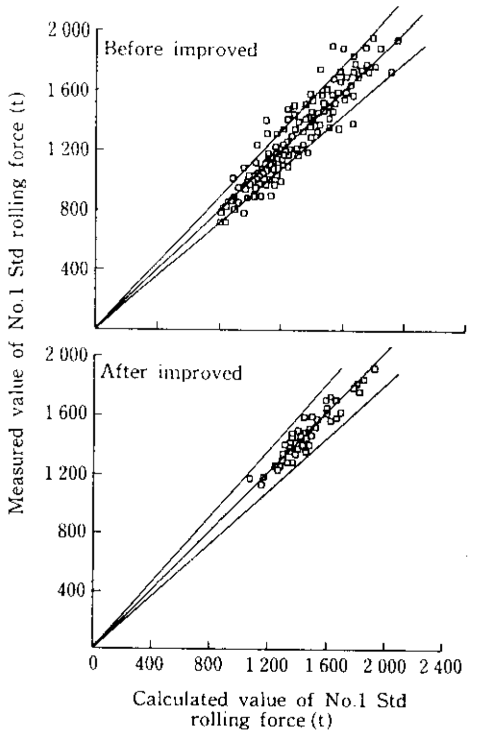

Fig. 15 Improvement in calculation method of rolling force

(2), accuracy has been improved by locating the weld point detector close to the mill and by dynamically correcting the strip velocity during flying gauge changing.

These improvements have made possible continuous rolling without problems, regardless of steel grade or sizes. For example, roll mark and off-gauge occurrence have been decreased to 1/8 and 1/7 respectively. These results offer some indication of the markedly improved results achieved in continuous rolling with the introduction of the techniques described above.

4 Conclusions

An outline of the fully continuous descaling and cold rolling mill at the Mizushima Works has been presented. This line makes possible excellent quality, high yield and productivity, and short production periods, all necessary to meet the demands of the times. The improvements made in the course of this project includes the developments of high speed descaling and of flying width and gauge change techniques. This line has been operating satisfactorily, with the expected results. Cold rolling operations at the Mizushima Works have been simplified into two process lines: the continuous descaling and cold tandem mill and the KM-CAL (February, 1984), which treats the processes from cleaning through recoiling in one line.

Finally, the authors must acknowledge Mitsubishi Heavy Industries, Ltd. for its cooperation in development of the tension leveler and new trimmer, Ishikawajima-Harima Heavy Industries Co., Ltd. for its help in the improvement of mechanical descaler efficiency, and also Kawasaki Heavy Industries Co., Ltd, Hitachi Ltd., and Fuji Electric Co., Ltd. for their efforts in the actual construction of the continuous facilities.

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