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New Technologies for Connecting Process Lines by Means of Air Floating Helical Turners

Yoshun Yamashita, Tadaaki Yasumi, Masato Iri

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New Technologies for Connecting Process Lines by Means of Air Floating Helical Turners*



Yoshun Yamashita
Chief Line Manager, Cold Rolling Sec., Cold Rolling Dept. I, Chiba Works

Tadaaki Yasumi
Manager, Technology & Quality Control Dept., The Siam United Steel (1995) Co., Ltd.

Masato Iri
Staff Assistant Manager, Equipment Technology Sec., Equipment Technology Dept., Chiba Works

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At the No. 1 Cold Rolling Mill in the Chiba Works, Kawasaki Steel, we have successfully connected a continuous annealing line, the No. 2 CAL, and an existing skinpass mill using two sets of air floating helical turners, because the center lines of the two process lines did not coincide with each other. Furthermore, we have installed new finishing equipments. Air floating helical turner was the first in the world of its kind. In achieving non-touch uniform levitation, we have solved various problems that had not been experienced with conventional floaters floating control by devising various technologies including optimization of the nozzle design and even floating control. Furthermore, for high-speed processing of thin strip, we have renewed inverters for helper rolls of the annealing furnace and achieved high accuracy in the tension control. In addition, in relationship to strip surface quality, we have improved the defect-free skinpass method at weld lines.

1 Introduction

The No. 1 Cold Rolling Mill in the Chiba Works is used mostly for producing steel strips as the materials for cans such as tin plates and tin-free steel. No. 2 and No. 4 CALs are in operation as continuous annealing facilities in this mill. The No. 4 CAL had an in-line skinpass and processing function, however, the No. 2 CAL had only a continuous annealing function, therefore, many separate skinpass mills and processing lines were necessarily in operation for finishing.

For the purpose of continuing the process, we have connected the No. 2 CAL to an existing skinpass mill with a center line different from that of the No. 2 CAL by means of air floating helical turner. In this paper, we will outline the newly installed equipment, details of developing the air floating helical turners and operation of the No. 2 CAL after connection.

2 Study of the Equipment Layout

In planning to make the skinpass and processing in line, we examined two ideas. The first was to newly install a processing equipment at the delivery side of the No. 2 CAL on the same center line and the second was to connect the No. 2 CAL to an existing mill installed in parallel to the No. 2 CAL in the adjacent yard using two sets of helical turners as shown in **Fig. 1**.

The second idea was judged superior than the first idea considering the required time and the cost of investment although there were many elements which would need to be developed. Therefore, we developed the air floating helical turners and then began their construction.

The basic specifications of the newly installed equipment and a bird's eye view of the equipment are shown in **Table 1** and **Fig. 2**, respectively.

3 Development of Air Floating Helical Turners

As explained above, the main technology for connect-

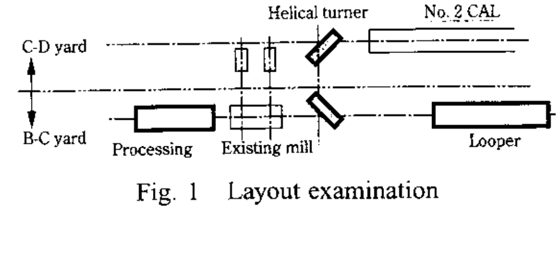

Fig. 1 Layout examination

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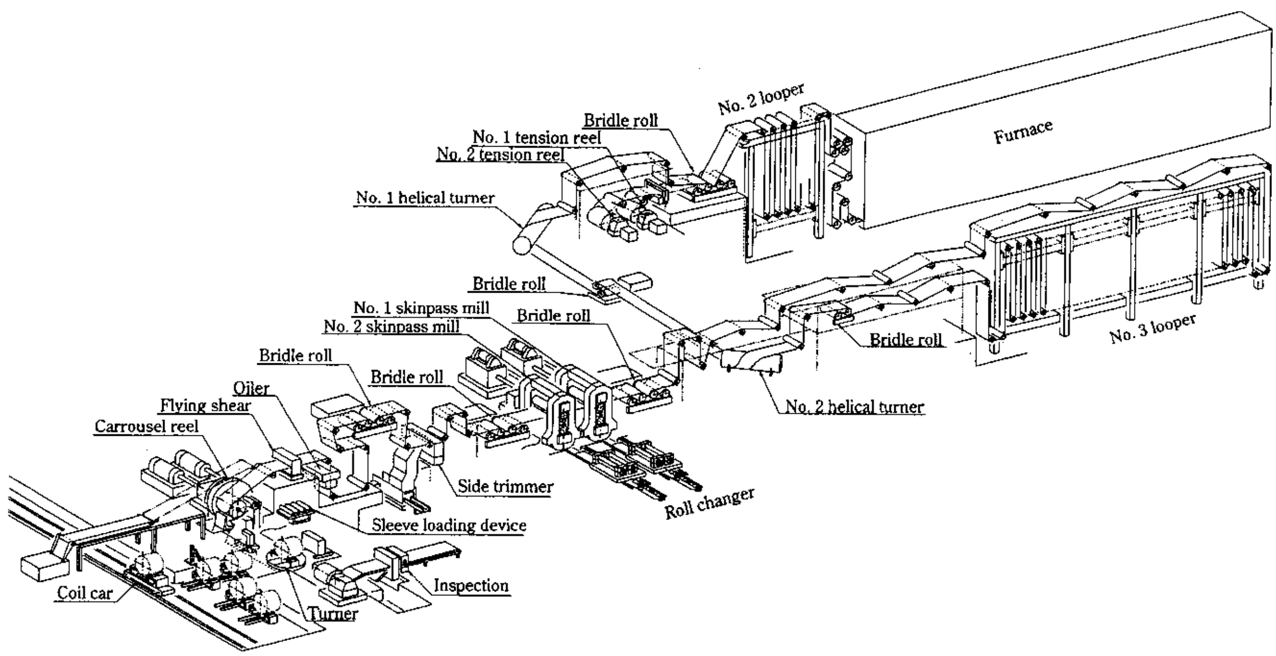


Fig. 2 Bird's eye vies of new equipment

Table 1 Basic specification

Thickness		(mm)	0.15~0.60
Width		(mm)	600~1 300
Maximum coil weight	Entry	(t)	21
	Delivery	(t)	21
Inner diameter	Entry	(mm)	419, 508, 660
	Delivery	(mm)	406, 419, 508
Maximum line speed	Furnace	(m/min)	720
	Delivery	(m/min)	940

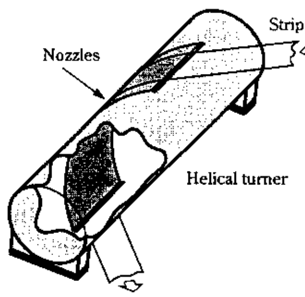


Fig. 3 Helical turner

ing the No. 2 CAL and the existing mill is the non-touch helical turners. The details of developing the helical turners are explained in this chapter.

3.1 Developmental Background

Various types of direction converters have been designed for strip processing previously and for connecting pickling processes and cold rolling processes, in particular, those using many rollers of small diameter have been commercialized.[1,2] However, for strips as the material for cans, which are thin and the surface quality is regarded as important after annealing, therefore, even small defects, such as dents due to point supported by rollers, scratches due to even very minor slipping, and lubricating oil splashed by the high speed rotation of rollers, result in serious defects and it was difficult to use direction converters of these types. Accordingly we decided to develop air floating helical turner.[3]

3.2 Outline of Air Floating Helical Turners

As shown in **Fig. 3**, the helical turner is composed of a cylindrical header as the main body with many nozzle arranged on the surface. Steel strips are rounded, over the header with a helical angle of 45° and the helical turners and designed to convert the direction of processing by 90° with one unit while levitating the steel strips without any contact by blowing air out of the nozzles. Atmospheric air is used for the air blown out against the steel strips.

The previous floater had been commercialized as alternative to deflect rolls and as supporting devices in horizontal paths where surface quality is considered to be important. For developing air floating helical turners, we had many problems, which is not encountered in the case of previous floaters, and we carried out various experiments on elements as well as those on actual scale. Some examples of encountered problems and countermeasures for solving these problems are explained hereunder.

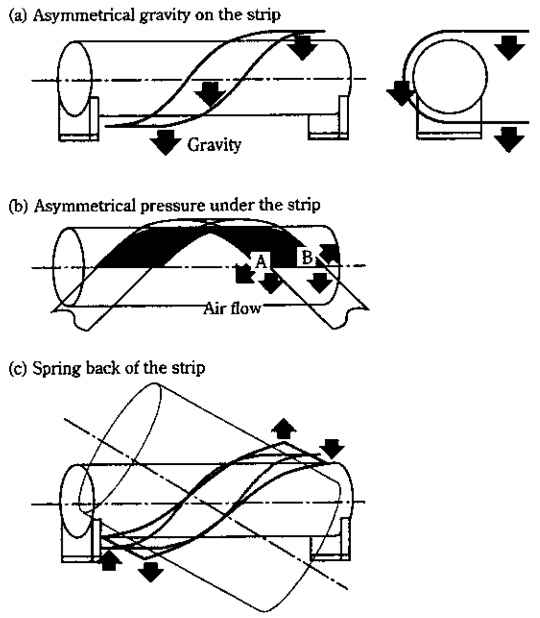
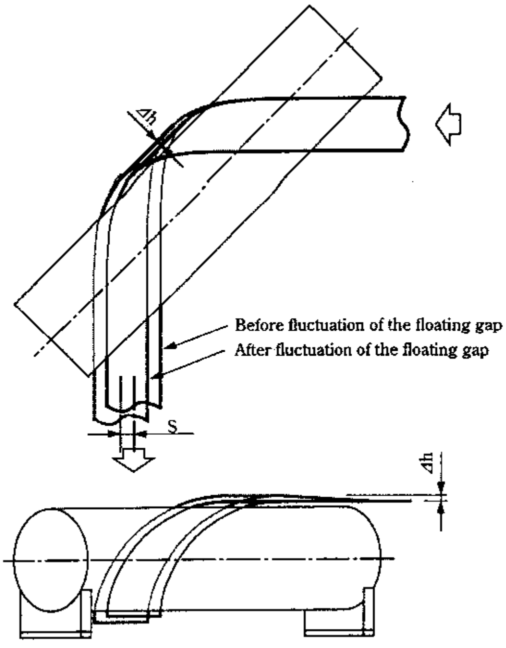


Fig. 4 Asymmetrical forces on the strip



$s = 2\pi\Delta h/\sqrt{2}$

s ; Displacement of the pass-line at the delivery position
Δh; Fluctuation of the floating gap between the strip and the surface of helica turner

Fig. 5 Influence on the floating gap on the pass-line

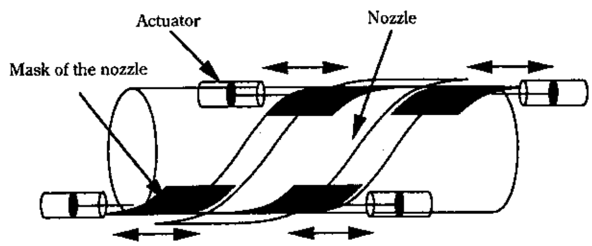


Fig. 6 An example of pressure distribution control system

3.3 Developed Technologies for Air Floating Helical Turners

Various asymmetrical forces shown in **Fig. 4** are applied to the steel strips supported by the helical turners, therefore, it becomes necessary to think out some means in order to achieve even floating.

(1) Gravity
(2) Air force which is generated due to the difference in the shapes of air space between the turner's main body and steel strips (A and B parts shown in Fig. 4 (b)) and is supporting the strips
(3) Force due to the rigidity of the steel strips (To change the shape from the helical shape in parallel to the cylinder to a stable shape with a larger curvature and smaller bending strain energy.)

In addition, the floated strips are spiral in shape and the floating gap seriously affects to the position of the strips in the width direction at the delivery side of the turner as shown in **Fig. 5**. Therefore, technology for even floating is extremely important without meandering or one-sided leaning, for stable processing the strips.

We developed the following measures to deal with these problems. We designed the header in a way combining round hole nozzles and slit nozzles and optimized the tension on the strips as well as air flow supplied to the nozzles. We constructed the floating control system by monitoring the floating gap in the width direction for strips and adjusting the supply air flow in the width direction of the strips using a masking mechanism which covers a part of nozzles according to the floating gap. (**Fig. 6**) Furthermore, if slanting, meandering etc. occur with the steel strips at the entry side, the floating condition at the turners, on the contrary, may be affected. For this problem, we built up our efforts in developing technology for designing the turner itself as well as peripheral equipment including rolls and established the control system to integrate the entire system. As a result, we could successfully complete the helical turners as direction converters.

3.4 Effects of the Technologies Developed

An example of measuring the distance from the header surface to the steel strips at the point where the strips pass the width changing position is shown in **Fig. 7**. It can be found from this figure that very stable non-touch floating was actualized through application of the newly developed technologies including welding point pass treatment.

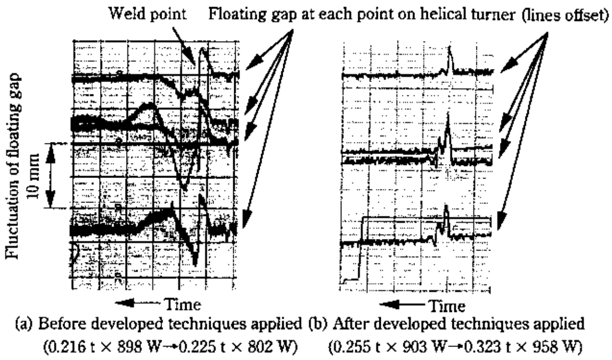


Fig. 7 An example of chart of floating gap during the welding point pass

4 Special Features of Other Facilities

In relation to the line connecting equipment described in this paper, we have also developed many new technologies in addition to the helical turners. Some examples of these developments are explained in this chapter.

4.1 Techniques for Connecting Existing Mills to a CAL

The specifications of the connected skinpass mill are shown in **Table 2**. The existing facilities are used for the housing and electric-driven screwdown system as they are, however, the following matters need to be considered for the weld line skinpass that becomes indispensable in connecting the lines. That is, in order to prevent the defects on the work rolls and defective shape (wavy edge, cross-bow and so on) when passing weld lines, large changes in the rolling force must be achieved at high speeds and with high rate accuracy, however, when using an electric-driven screwdown system, the controllability of the rolling force was not sufficient due to hysteresis caused by the screw backlash. In order to solve this problem, a control circuit was designed as shown in **Fig. 8** as a screwdown control system that compensates for backlash. The circuit calculates the screwdown speed of the electric-driven screwdown equipment on the basis of the deviation of the actual force from the reference force. As a result of incorporating this control circuit, it has become possible to change the rolling force at an accuracy of ±5 t within 10 s as shown in **Fig. 9**.

4.2 Reduction of the Weld Line Overlapping Length

As a countermeasure for preventing defects on the work rolls mentioned in 4.1 above, it is important to reduce the thickness at weld lines, and direct current welders are commonly used. Furthermore, it is known that the thickness at weld lines is closely related to the overlapping length. Renewing the welders to those of the above-mentioned type, we developed the following two items and reduced the overlap from the conventional

Table 2 Principal specification of skinpass mill

Item		Specification
Mill type		2 stand tandem (4-Hi)
Rolling mode		Dry skinpass
Work roll diameter (mm)		510~580
Backup roll diameter (mm)		1 300~1 420
Motor power (kW)	No. 1 stand	600
	No. 2 stand	900
Work roll bearing type		Tapered roller bearing
Backup roll bearing type		Roller bearing
Type of screw down		Elecric drive screw down
Bending force (tf/chock)		+60 (Inc.)

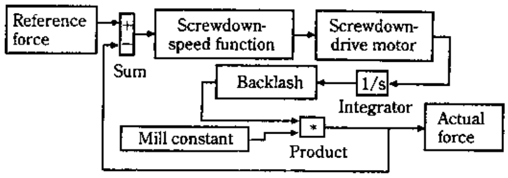


Fig. 8 Developed screwdown control system

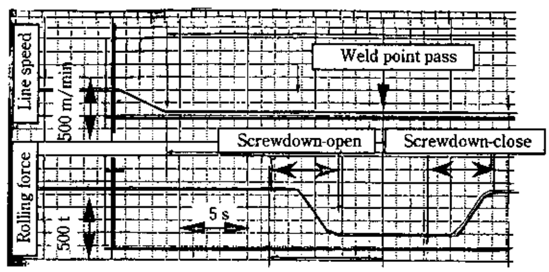


Fig. 9 Line speed and No. 1 stand rolling force

level of 1.0 mm to 0.5 mm.

(1) reduction of distance between cramps at the entry and delivery.

(2) Reduction of the sliding resistance of the electrode pressurizing mechanism

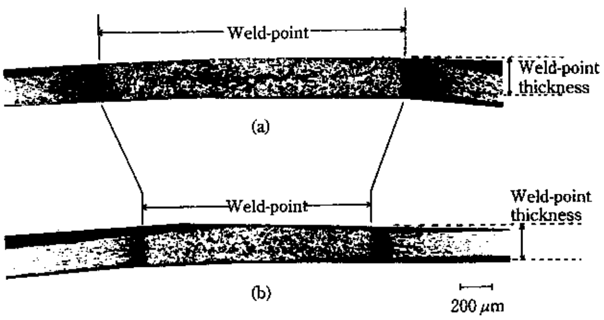
Photographs of cross sections at weld lines after taking the above measures are shown in **Photo 1**. We could reduce the thickness and the length of the heat-affected zone and as a result, it has been made possible to prevent work roll defects by means of technologies.

4.3 Automatic Equipment

Considering CAL-FINAL for materials for cans, we incorporated various automation equipment including an inner diameter changing system, weld point indicator and automatic transfer system to the packing line, all of which are considered useful.

4.4 Outline of the Electric Equipment

Thickness of materials for cans are getting thinner in recent years, high accuracy tension control is indispensable as a means for stable processing in the annealing



(a) Previous continuous skinpass mill, overlap = 1.0 mm
(b) Improved No. 2 CAL, overlap = 0.5 mm

Photo 1 Comparison of weld line length (cross section view)

furnace. Therefore, we carried out renewal of inverters (INV) for helper rolls in the furnace. Furthermore, with respect to the newly installed facilities, we planned to make the electrical equipment simple and their arrangement optimum for the purpose of cost minimization while following the control method nearly established with the CAL of our company in principle.

4.5 Outline of the Control System

The configuration of the control system is shown in **Fig. 10**. Through the line connecting modification work, almost all control equipment of a level lower than process computers (P/C) was renewed except those on the entry side.

In this system, a common use LAN (Ethernet) is used for sending and receiving information between the major equipment (P/C, electrically programmable logic controllers: PLC). Furthermore, we worked to make the system open by unifying the transmission procedures between equipment by using the MELSEC Protocol. In addition, we combined transmission and unit automation equipment such as weld point indicators and automatic coil transportation systems which had been interfaced (I/F) individually with each P/C and PLC in the past and installed a NET supervisory PLC for I/F with each P/C and PLC, thus avoiding increasing the load on the LAN. As for the electric PLC, we planned to decentralize the function of the entry side PLC, a newly installed section, to the main PLC which takes charge of main control, tracking process, etc. and small PLCs that take change of driving control for each unit of equipment and I/F processing with field equipments.

5 Line Connecting Modification Work and Operation Records after Commissioning

In order to minimize the stoppage period of the No. 2 CAL and the existing mill, the line connecting work was carried out according to the following procedures:

(1) As the first step, the control system of the existing mill was renewed and put into operation as an independent mill.
(2) While carrying out the above, additional louvers and adjusting lines were installed.
(3) At the final stage of the work, the No. 2 CAL and the existing mill were stopped and the helical turners and new equipment before and after the turners were installed.

Since completion of the work, the No. 2 CAL has been in commercial operation successfully since May 1998. The results of operation are also satisfactory with the amount of products increasing as indicated in **Fig. 11**.

6 Closing Remarks

We have successfully developed technologies including the air floating helical turners and have connected the No. 2 CAL and an existing skinpass mill. Application of helical turners is expected to be a wide use tech-

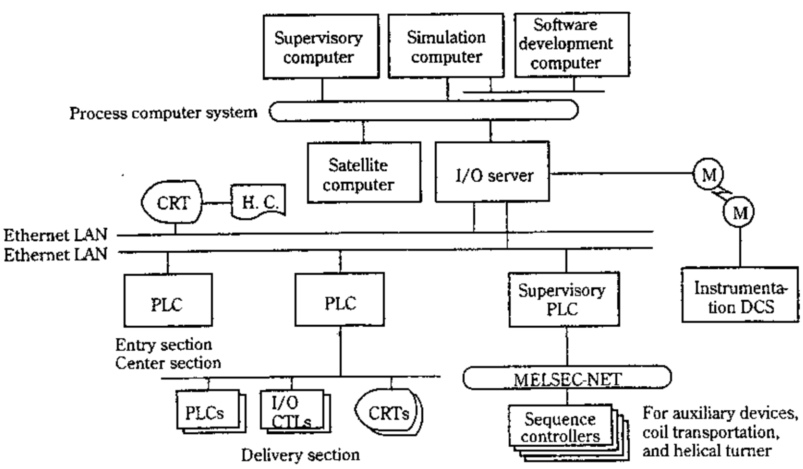


Fig. 10 System configuration of No. 2 CAL

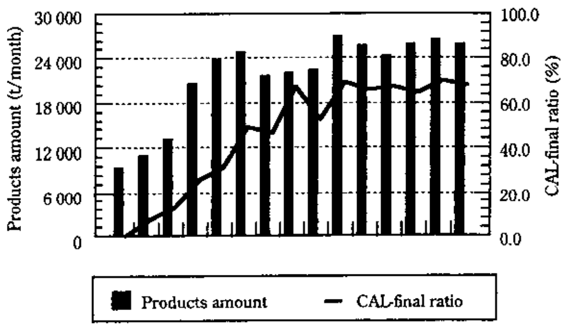


Fig. 11 Trend of products amount and CAL-final ratio

nology to improve flexibility of line arrangements in connecting high speed processing lines in the future.

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