World's First Sendzimir Tandem Mill

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The continuous sendzimir tandem cold mill at Nisshin Steel has tripled the plant's rolling capacity of stainless sheet gages. This unique arrangement features four Z mills in combination with 2-high mills.

NISSHIN Steel Co. placed the world's first sendzimir tandem mill into operation at the Shunan works in 1969. Located in Nanyo the plant occupies a site of approximately one third sq mile. The maximum finished monthly production capacity totals 18,300 net tons—35 percent 400 series and 65 percent 300 series stainless steel.

Before Nisshin Steel's tandem mill concept was considered, only a few sendzimir mills were used for reducing sheets or skinpassing on a once-through basis. The majority of these mills were for reversing operation to achieve high reductions on material which quickly work-hardened, where high quality surface was essential and where close tolerances had to be maintained.

In 1958, Nisshin began operating the first wide (50-in.) high-production sendzimir mill in Japan, a ZR 22-50 cold reversing mill. In 1961, the first ZR 21-50 (at that time the largest and most powerful sendzimir reversing mill ever built) was installed in the Hanshin works near Osaka. This mill was equipped with twin drive; the first time such a drive arrangement was incorporated in a mill of this type and size with a 5000-hp main motor taking the mill up to 2800-fpm top speed. The Hanshin plant is geared for production of low-carbon steel.

In 1964, a second ZR 22-50 mill with solid winders was put into operation thereby increasing wide stainless strip capacity of 56,000 net tons per year.

In 1969, manufacture of stainless by the BOF process was successful, subsequently leading to installation of two 40-ton converters in 1970. In September 1969, the sendzimir cold tandem installation, built exclusively for production of stainless strip, began operation. This installation made it possible to more than triple production capacity.

DESCRIPTION OF INSTALLATION

The tandem installation is the first one designed for continuous cold rolling of stainless coils up to 50-in. wide and weighing a maximum of 24 net tons. Most of the hot band (either 300 or 400 series stainless ranging in thickness from 0.255 to 0.063 in.) comes from the reversing hot mill at the Shunan works. Also, some hot band is supplied by the Kure works of Nisshin Steel. Strip off the tandem ranges from 0.158 to a minimum of 0.012 in. The maximum rolling speed is 1969 fpm.

The Nisshin installation is truly a fully continuous rolling facility where incoming coils are fed from payoff reels through a welder which joins the head and tail of consecutive coils thereby eliminating tail-out and the necessity of rethreading.

In actual operation, rethreading of the mill is seldom required. Only in cases when the strip breaks between stands or after a lengthy shutdown is rethreading necessary. When the operation is required, however, the first strip passed through the line is a leader which is threaded all the way through from the payoff to the exit winder. The tail of the leader is brought into positioning for welding to the head of the first production coil after shearing of the ends. After joining is completed, rolling starts with the mill stands screwed down immediately after the first weld passes each respective roll bite. After the leader is fully taken up by the tension reel, it is sheared from the production material and stripped. Full production rolling then commences with consecutive hot band

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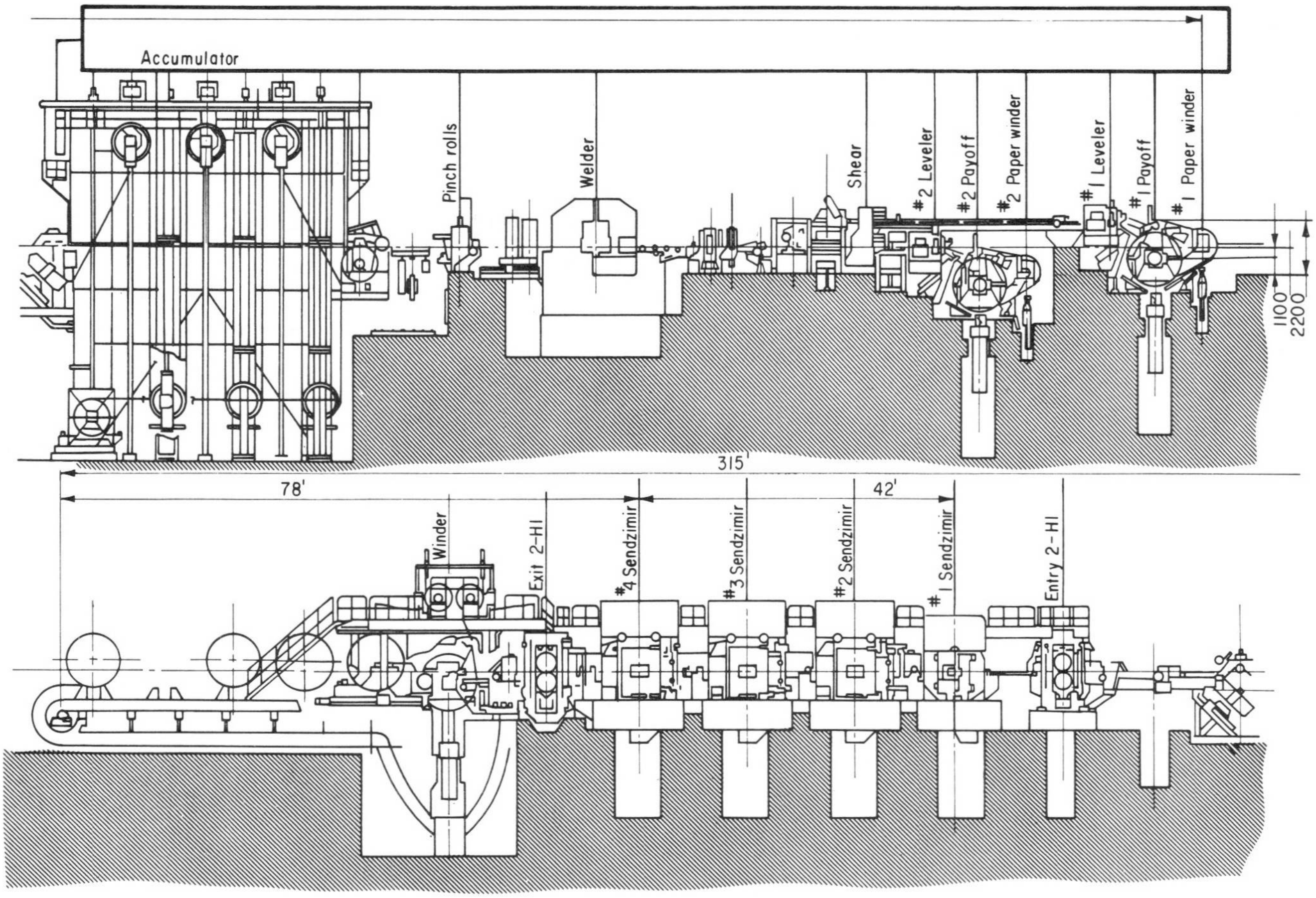


Figure 1 — General arrangement of entire installation.

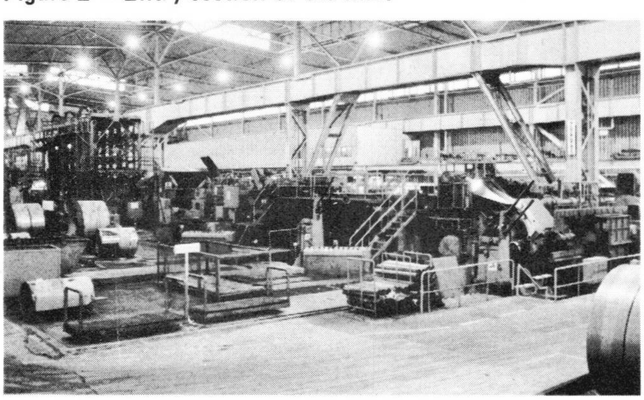
coils payed off, welded end to end, rolled and sheared, exiting as intermediate or finish gage cold rolled stainless coils.

When a mill shutdown is anticipated, to avoid the necessity of rethreading the line, a leader is welded to the tail of the last production coil rolled. After completion of this final coil the leader is sheared remaining in the line until the next scheduled production run. The general arrangement of the entire installation is shown in Figure 1.

ENTRY SECTION

The entry section (Figure 2) contains two coil skids, one for each payoff reel. Each consisting of one fixed and one roller type with polyurethane covered rolls powered to rotate the coil for proper positioning of the strip end. The two coil transfer cars have V-type hydraulic elevator. Two payoff reels are designed to accommodate 20-in. ID x 87-in. maximum OD coils up to 50 in. wide. Each reel is connected to a 330-hp drag generator geared to supply a maximum back tension of 11,000 lb up to the maximum payoff linear speed of 985 fpm. Driven hydraulically loaded polyurethane coated snubber rolls contain the coil wraps after removal of the bands. The drag generators are mounted in fixed positions with a sliding coupling connected between the onput shafts and the reducers thereby permitting a 5-in. axial movement on either side of the centerline for automatic maintenance of strip centering. Reels to take up the paper interleaving in the coils are also provided.

Figure 2 — Entry section of the mill.



Two levelers flatten the head and tail of the incoming coils. Each is driven by a 50-hp a-c motor and consists of one set of pinch rolls and five leveling rolls, all hydraulically operated.

An hydraulic double-cut shear squares the ends of the coil and succeeding coil simultaneously in one single up-cut stroke prior to the welding operation which can be either a flash butt weld or a resistance seam weld.

At the present time each coil coming to the mill is already built up from three individual coils at the beginning of the pickling line, i.e., two welds in

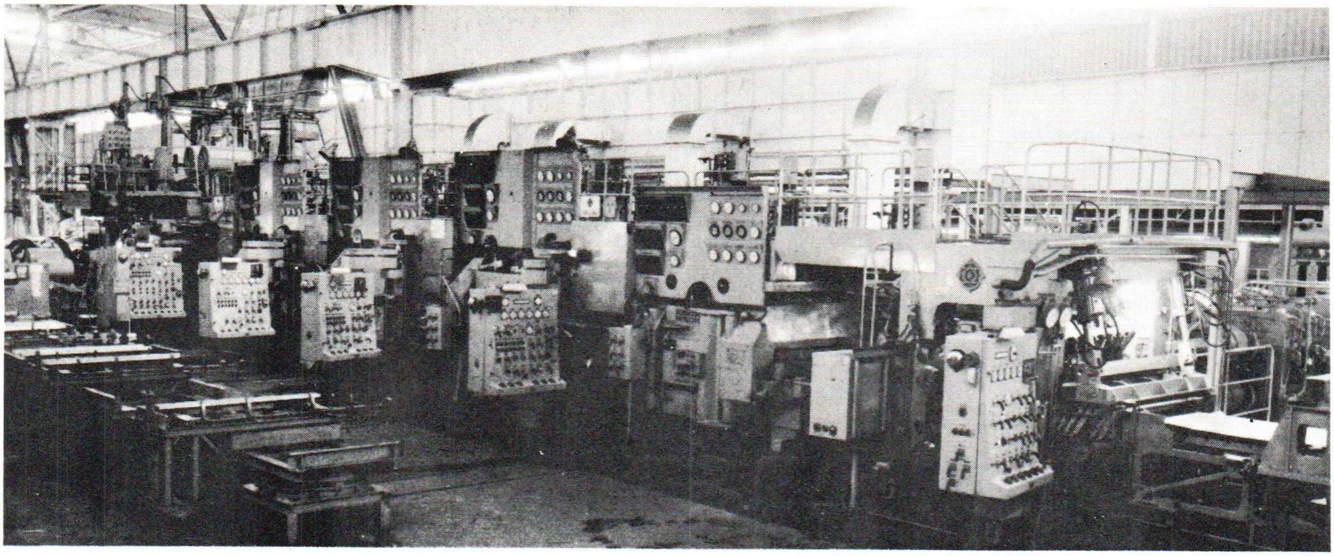


Figure 3 — Four sendzimir stands in tandem: one ZR-22N-50 and three ZR-21B-50.

every incoming coil. Consequently, at the tandem mill only every third weld is made.

ACCUMULATOR

A vertical accumulator permits stoppage of the line, allowing sufficient time for completion of the welding operation. The amount of storage capacity was selected on the basis of the minimum rolling speed at which the automatic speed regulating (ASR) system would perform effectively. It was felt uneconomical to provide sufficient capacity for high-speed operation.

The accumulator design, therefore, consists of three 5-ft diameter rolls on top and bottom with a maximum storage capacity of 220 ft of strip. Deflector rolls, also 5 ft diameter, are situated at the entry and exit of the accumulator, the exit is unpowered and the entry one is powered with a 100-hp d-c motor acting as a bridle roll. An automatic strip centering roll is also incorporated at the exit side of the accumulator to assure proper tracking of the strip through the stands. A total of nine 5-ft rolls are incorporated in the accumulator unit.

FOUR SENDZIMIR STANDS

Occupying about 18 percent of the 315-ft total installation length, are four sendzimir stands, one ZR-22N-50 and three ZR-21B-50 (Figure 3).

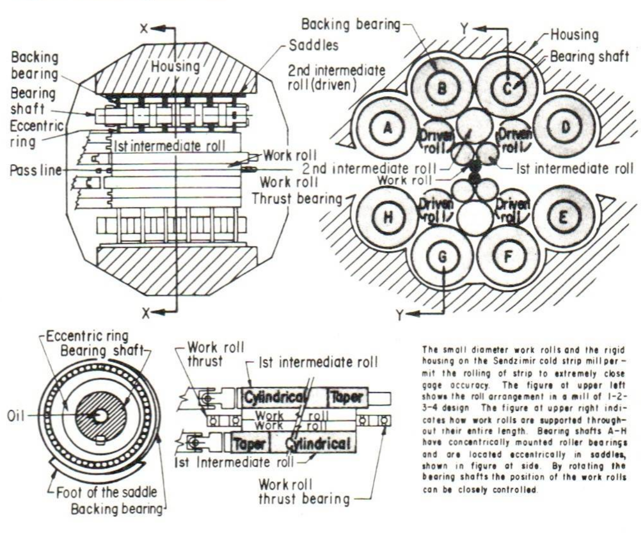
There are several arrangements of sendzimir mills which have been developed, but the predominant layout is the 1-2-3-4 configuration which provides the smallest possible diameter roll for any given backing bearing diameter. This type was selected for this installation.

In the classical 1-2-3-4 arrangement (Figure 4) there are eight backing shafts, numbered A to H in the clockwise direction. Shafts B and C are the main screwdown shafts, equipped with large hydraulic cylinders on the top of the mill. These shafts have roller bearings in the saddle rings and can be easily rotated under heavy screwdown pressure. All other shafts have plain bearings in the saddle rings and can be rotated only under no-load conditions. The other shafts are also self locking, i.e., in order to open or close the mill, the shafts have to be positively moved.

Shafts A and H are moved by an electric motor located in the back of the mill, also shafts D and E are moved by a similar motor. These shafts are brought closer together or further apart, depending on the size of the rolls in the mill.

Shafts F and G, the two bottom shafts, are moved by hydraulic cylinder located in the front of the mill. These shafts are opened or closed in order to change the work rolls in the mill. The movement of these shafts in the conventional sendzimir installation serves two purposes: first, it brings the bottom work roll to the passline of the mill, therefore, provides an even bearing of the work roll end surfaces against the thrust bearings located in the front and back of the mill; second, the closing of the bottom rolls, takes out all the slack between the rolls and enables the full travel

Figure 4 — In the classic 1-2-3-4 arrangement, there are eight backing shafts.



The small diameter work rolls and the rigid housing on the Sendzimir cold strip mill permit the rolling of strip to extremely close gage accuracy. The figure at upper left shows the roll arrangement in a mill of 1-2-3-4 design. The figure at upper right indicates how work rolls are supported throughout their entire length. Bearing shafts A-H have concentrically mounted roller bearings and are located eccentrically in saddles, shown in figure at side. By rotating the bearing shafts the position of the work rolls can be closely controlled.

TABLE I

Tandem Mill Characteristics

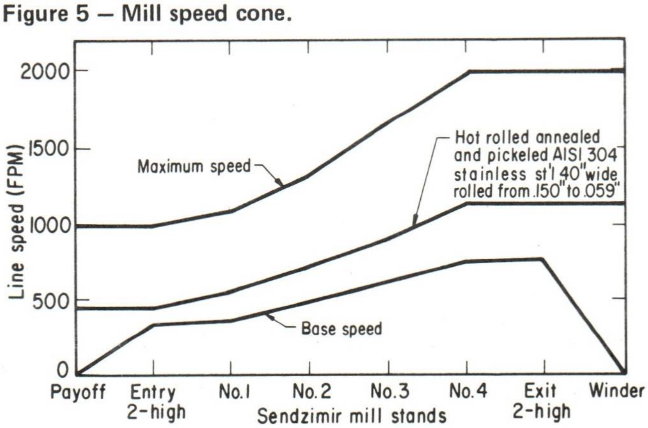
Equipment	Type	Work roll diameter, in.	Rolling speed, fpm	Motor, hp	Maximum interstand tension, tons
Payoff reel	Overhung mandrel 20-in. diameter	. . .	0/985	330	
Entry 2-high	Hydraulic screwdown 440 tons	30	0/328/985	2X440	5½
No. 1 sendzimir	ZR22N-50	2.68	0/330/1080	2X940	44
No. 2 sendzimir	ZR21B-50	3.38	0/480/1310	2X1610	66
No. 3 sendzimir	ZR21B-50	3.38	0/610/1640	2X1610	66
No. 4 sendzimir	ZR21B-50	3.38	0/740/1969	2X1610	66
Exit 2-high	Hydraulic screwdown 440 tons	30	0/740/1969	2X1000	66
Tension reel	Overhung mandrel 20 in. diameter	. . .	0/1969	2X1340	22

of the top screwdown of the mill. This permits the operator to reduce heavy hot rolled gage down to the thinnest gages without changing the work rolls.

In the tandem installation, the design of the lower F and G shaft assembly differs from the classical sendzimir reversing mill in that these shafts were equipped with roller bearings in the saddle rings as in the upper B and C screwdown shafts. This special feature was incorporated to provide as much flexibility as possible into the stands to reduce the occurrence of strip breakage at the welds. The lower screwdown, depending on the weld condition, can be operated to provide either constant roll pressure or constant roll gap in addition to the conventional fixed position locked system. To accomplish the first two operational modes, two large hydraulic cylinders substantially the same as the upper screwdown system were utilized on each stand replacing the single small cylinder used in the conventional arrangement.

Most of the modern sendzimir mills utilize "As-U-Roll" adjustment, activated through small hydraulic motors which can be controlled from the operating pulpit during rolling. This adjustment is provided on shafts B and C acting simultaneously through a very small secondary eccentric gear train. The adjustment can be made under load, therefore, the operator can change the shape of the strip while the mill is rolling.

Figure 5 — Mill speed cone.



The first intermediate rolls can be axially adjusted from the front of the mill, and on bigger mills this adjustment is motorized necessitating only pushbutton control. This mechanism shifts the rolls to the front or the back of the mill, which is very important for the operation of the mill since these rolls are ground with a taper. The top rolls have a taper from the front side and the bottom rolls from the rear side. In this way, with an independent movement of the top and the bottom rolls, it is possible to control the shape of the edges of the strip to an extremely fine degree. The combination of the crown control and axial shift of the intermediate rolls gives an operator a means of controlling shape and producing extremely flat strip.

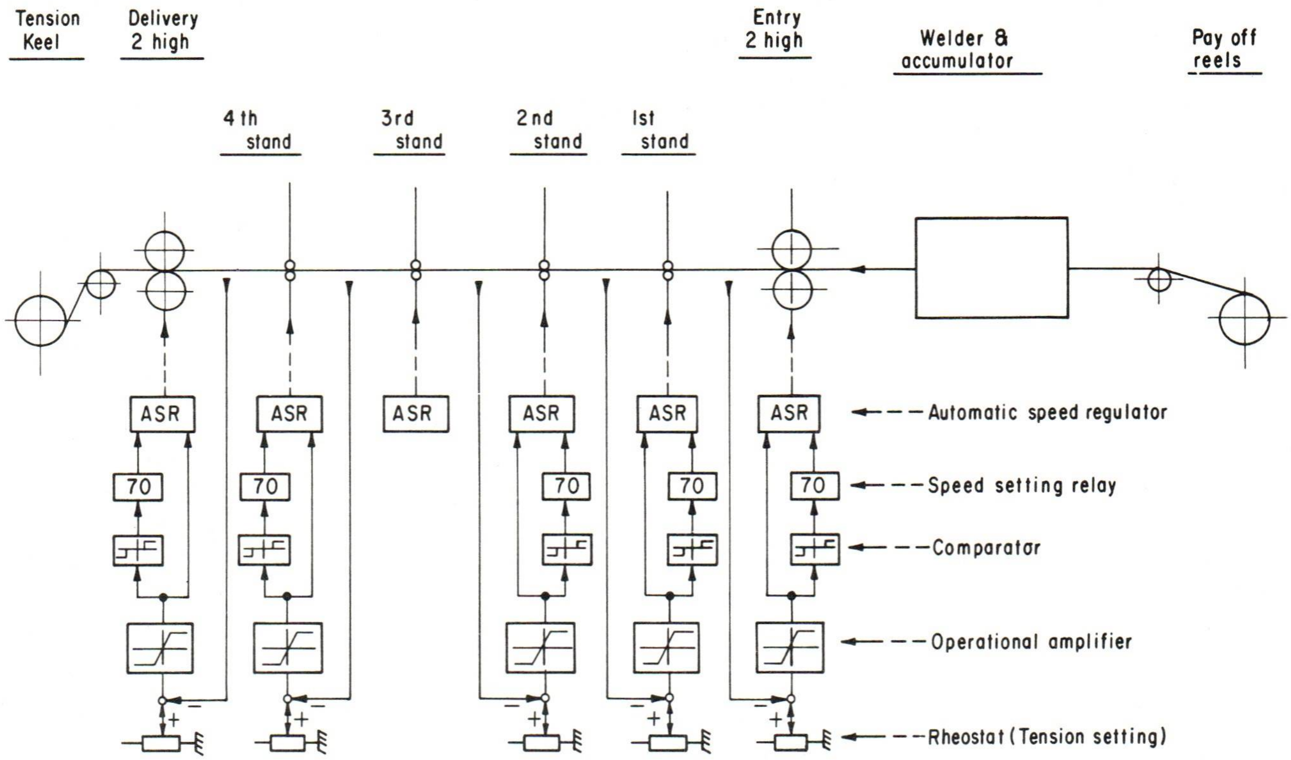
The roll separating force on the 1-2-3-4 mill is distributed from the work rolls to the intermediate rolls and then to the backup shafts in such a fashion that the outer shaft takes a heavier force component, i.e., absorbs more load than the center shafts. The driven rolls in the mill are the outer second intermediate rolls. The choice of driving these rolls enables the designers to incorporate larger size pinions, therefore, the mill can transmit more torque.

The sendzimir mills in the tandem installation have all the modern features listed above.

Table I lists the characteristics of the mill and Figure 5 shows a speed cone for the different stands. Breakdown rolling of hot band is done within the base speed range of all the motors, and higher speeds are used for second and third rolling.

EXIT 2-HIGH MILL

The design of the exit 2-high mill is basically the same as the one situated at the entry side. The essential difference is that it is powered by two 1000-hp d-c motors connected in series yielding a maximum tension capability of 44 tons. A hydraulic up-cut shear between the mill proper and the exit side deflector roll cuts the strip after the required coil buildup has been achieved on the winder.



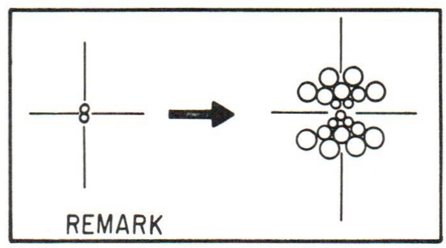


Figure 6 — Schematic of electrical control system.

EXIT SECTION

A single 20-in. diameter collapsible block winder is provided with an outboard bearing for additional support during operation. The mandrel is driven through a gear unit by two 1350-hp armatures providing a maximum tension of 22 tons up to the maximum installation exit speed of 1969 fpm.

To overcome the collapsing pressure on the winder block due to buildup of large coils of thin strip, the collapsible mandrel design has been provided. This mandrel differs from conventional designs in that the drum in its expanded position is virtually filled with solid heat-treated alloy steel as the strip is being coiled.

Because the mill was designed for continuous operation, a hydraulically operated horizontal-type two-strand belt wrapper initiates coiling.

A single coil transfer car similar in design to those at the entry side payoffs moves the completed coils from the mandrel to the coil conveyor.

The chain-type coil conveyor is equipped with coil supporting saddles and has an overall length of approximately 52 ft. Full-size coils having a maximum diameter of up to 89 in. are transferred at a speed of approximately 33 fpm to the fully automatic binding machine.

PAPER WINDING AND PAYOFF EQUIPMENT

To protect the material surface from damage, equipment for paper interleaving has been provided. Each payoff reel at the entry side of the installation is equipped with a double-cone, head-type paper rewinder driven by 15-hp d-c motors. At the exit side of the installation, a fully automatic paper payoff reel interleaves paper throughout the wraps of the completed coil.

LUBRICATION AND HYDRAULIC SYSTEMS

Two soluble oil roll coolant and backing bearing spray systems are installed: one services the entry 2-high mill along with the first and second sendzimir stands, the other services the third and fourth sendzimir stands. No. 1 system has a 50,000-gal receiving tank and 41,000-gal clean tank; system No. 2 has capacities of 40,000 and 33,000 gal, respectively. Filtration of the oil is by flat bed filters with system capacities of 2300 and 2900 gpm for systems No. 1 and 2, respectively. In total, the entire system consists of two receiving tanks, two clean tanks, six filtering pumps, six spray pumps, six bearing pumps and two two flat bed filters.

Lubrication at the exit 2-high stand is provided

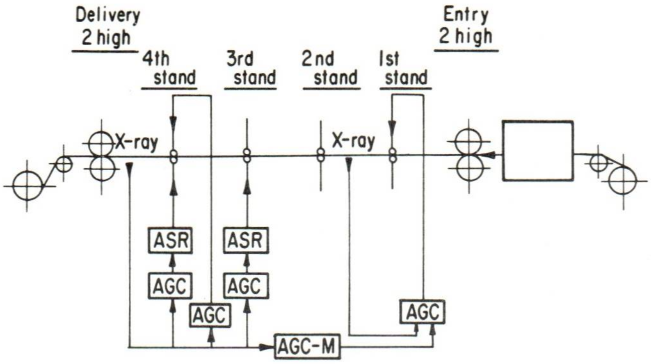


Figure 7 — Schematic of automatic gage control system.

by a relatively small separate self contained system.

Lubrication of the backup bearings in the sendzimir stands is supplied by three oil mist lubrication units servicing each stand.

The hydraulic service is split into three separate systems:

1. Hydraulic system for the sendzimir mill screwdowns consisting of three double-rotary vane pumps, accumulators and filters supplying oil to each stand at maximum pressures of 1000 psi and 610 psi.
2. Hydraulic system for the 2-high mill screwdowns consists of two rotary plunger pumps, etc., for a maximum operating pressure of 3000 psi.
3. Hydraulics for the auxiliaries are supplied from an additional self contained 1000-psi system.

ELECTRICAL CONTROLS

Tension control between each stand is absolutely necessary in order to obtain good gage tolerance and good strip shape (Figure 6). Combined with AGC, constant value tension control is provided for all stands to closely work together with the control of strip thickness. Consequently, good results have been obtained.

Automatic speed regulations (ASR) and the drooping characteristics are important because of the small work roll, and rigid mill housing. The drooping characteristic is provided in addition to ASR for avoiding the strip breakage at the starting time of control.

Automatic gage control has no special characteristic compared with conventional type (Figure 7). This system consists of:

1. Screw-down control at stand No. 1 (by an x-ray gage at the exit of stand No. 1).
2. The screw-down control at stand No. 4 (by an x-ray gage at exit of stand No. 4).
3. The speed tension control at stands No. 3 and 4 (by an x-ray gage at the exit of stand No. 4).
4. The circuit designed for feeding back from the exit side control system to the entry side control system.

Thyristorized Ward Leonard system is adopted in order to allow high response of speed control systems.

START-UP AND OPERATION

Installation of the tandem mill started in the middle of March 1969 and was completed by the middle of August. No-load test of each piece of equipment was made between the middle and the end of August 1969.

The adjustments of the control systems for the winding reel control, accumulator control, speed matching control, strip guiding control, etc., have been made by using both 2-high mills and without making any reduction on the Z mills which were run idle. This cold run period lasted from September 1 to 7 and was followed by live rolling of low-carbon strip on September 8. This trial rolling produced strip with good shape without any breakage. This first strip rolled was of 43-in. wide, 0.126-in. hot band reduced to 0.040 in. The test run with low-carbon steel strip was continued until September 20, 1969, in order to adjust tension and speed control.

On September 21, rolling of AISI 430 stainless steel strip commenced with 0.140-in. strip reduced to 0.071 in. in one pass. A total of 550 tons of low-carbon steel and 300 tons of stainless were produced during the 15 days following mill start-up on September 8. During this period, sufficient number of welds were rolled and verified to be in good condition.

Some problems were encountered but solutions were found.

Chatter marks were observed on strip following the No. 1 stand due to the setting of tension between the stands. This was eliminated by changing the amount of tension on both sides of the mill.

Difficulties were experienced with centering of the strip at the entry of the 2-high mill. This problem was solved by means of adding another EPC device to the deflector roll at the exit of the accumulator.

FIFTH ZR STAND

Nisshin Steel installed a 4-stand sendzimir tandem mill but provided space for a future stand. It was felt necessary to study how many stands (four, five or six) represent the best solution. One has to bear in mind the material to be rolled, its hot rolled gage, finished gage, product mix and the total production volume of the various materials to be rolled. However, the company is convinced that from the point of view of production capacity and cost, it seems desirable to add one extra stand in order to roll 0.150-in. AISI 304 stainless steel down to 0.047 in. in one single pass.

FUTURE POSSIBILITIES

All ZR 21-type stands would be acceptable. At Nisshin in consideration of the speed cone, torque capacity and cost of facilities, Shunan works decided to adopt ZR 22N-type for the first stand.

Mill power of 3200 hp is most suitable for maximum speed of 1960 fpm.

The capacity of the entry accumulator should match the lowest speed of AGC in which the AGC operates effectively. Since the line speed is fast, it is considered uneconomical to use an accumulator for saving the stopping time required for coil feeding and coil welding, provided, of course, that sufficiently large coils are available. In order to avoid any mill stop, one could consider to either install an accumulator between the exit 2-high mill and the tension reel, or to install a flying shear at the exit of the 2-high mill and install two tension reels to coil the strip alternatively. In any case, however, it is necessary to stop the mill to change the work rolls in order to obtain fine finish on stainless steel, therefore, the merit of installing such equipment will be substantially reduced.

SUMMARY

At the time when the first wide sendzimir mill went into operation in 1955, the idea of putting ZR stands in tandem became apparent. There are two points which made it possible to materialize the idea; the threading of the mill with small work rolls which could be accomplished by suitable welding of the ends of each strip and the adoption of accumulators. Secondly, improvement of the electrical control means had to be made.

In order to better utilize the advantage of small work rolls more effectively and especially for the materials which are difficult to roll, great tension can be obtained when using the entry and exit 2-high mills. Under normal circumstances, the tension provided by a tension reel is limited due to the strength of the reel. Moreover, by installing a 2-high mill at the entry side, it is not necessary to utilize pressure pads for obtaining back tension which not only improves surface condition of the strip but also eliminates maintenance and lost time in exchanging the lining of pressure boards.

The second advantage is the improvement of the production capacity which can be shown by comparing the installation cost of a reversing mill with that of a 4-stand tandem. Assuming that the installation cost of a reversing mill is 1, then for a 4-stand tandem it is 2.4. However, the production capacity of a 4-stand tandem mill is four times greater, i.e., the production ratio is 4:1. Combining these ratios provides an increase of production capacity as compared with the initial cost of the equipment is 1.67:1. The tandem mill needs only one winder for several mill stands while a reversing mill needs two sets of winders and motors for each stand.

Labor saving costs are also important because instead of using three full-time workers required for a single reversing mill, the 4-stand tandem requires seven full-time workers per shift. Considering the auxiliary equipment, such as roll grinding, etc., the resulting actual labor productivity will be in the ratio of 2:1.

The most remarkable merit of the continuous mill is its production capacity. In order to take advantage of this high capacity, it is very important that as many as possible mill stops be eliminated. In this way, the change in gage produced by the mill will be reduced. Secondly, single coils of 50 tons or more, without welds, would be desirable.

For companies which produce a variety of stainless steel gages and sizes, the best and most effective use of the tandem mill is to install it in combination with two or three reversing mills. ▲