Recent Development of Skinpass Mill and Tension Leveler

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1. Introduction

Generally, the products produced in hot rolling mills and cold rolling mills (including surface treatment), where a thin metal sheet is subjected to a process of being wound in a coil, are made of a variety of materials such as a carbon steel sheet, a stainless steel sheet, aluminum, copper, and special alloy steel, and have been widened, in recent years, to be 0.05 mm to 16.0 mm in the sheet thickness, to be 300 mm to 2300 mm in the sheet width, and to be from 50 MPa to 1800 MPa in the yield stress. In various facilities producing these thin metal sheets, there are installed a wide variety of skinpass mills, tension levelers, or ones, each of which is of a combination of the both, for the purpose of shape-reforming, tempering, conditioning of surface properties after rolling or heat treatment.

Additionally, in recent years, a demand of producing a thin metal sheet having higher flatness and a finer surface more efficiently has increased along with demands of achieving a high quality of products using these thin metal sheets and of automatizing of the production. On the other hand, on the production side, the improvement of product quality and production efficiency have been pursued; continuous, automatic and higher speed operations of the facilities have been further advanced; and the facilities and technology of tempering and flattening have developed so as to keep pace with this.

Our company has developed the technology of skinpass mills and tension levelers by ourselves, and has delivered them to many customers. In regard to the tension levelers, the first machine of commercial-use tension leveler was developed and delivered ahead of

all others in the world in 1965. Likewise, in regard to the skinpass mills, our company's first machine developed by ourselves was delivered as in-line skinpass mill to a galvanizing line in 1970. In our company, a test machine comparable to an actual machine

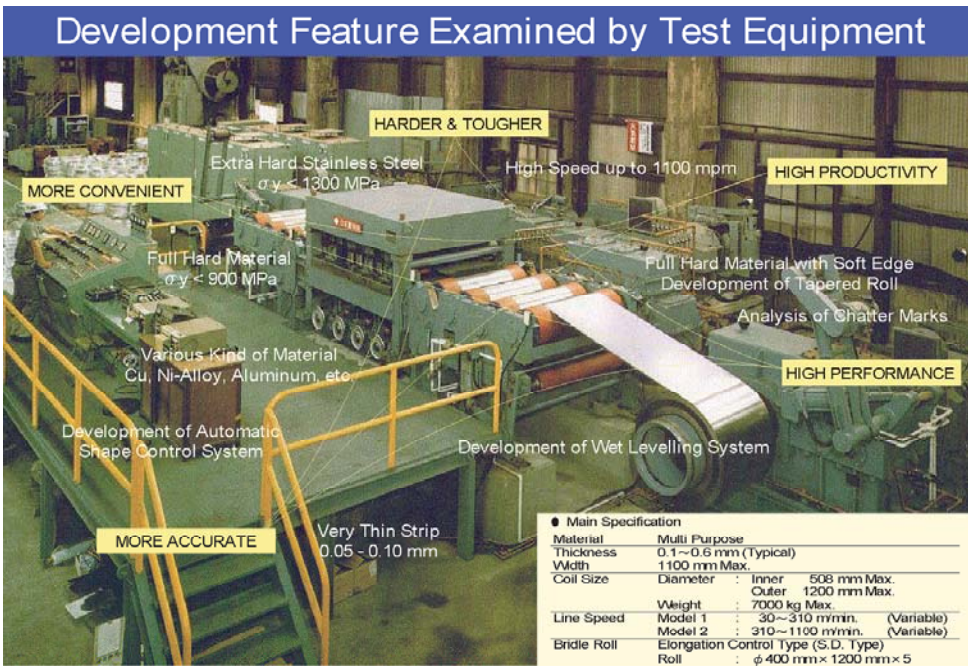

Fig1. Multi purpose tension leveling test machine

was installed in 1970 for the purpose of development and determination of optimum facility specifications with regard to the above increasing wide range of materials, yield stresses, sheet thicknesses, sheet widths. The photo and specifications are shown in Fig. 1.

New theories and techniques have been continuously developed by putting this test machine to full use. 190 sets of various tension levelers and 60 sets of skinpass mills have been delivered up to now. Among these, 36 sets of complex equipment consisted of a skinpass mill and a tension leveler were delivered. In this paper, the techniques of tempering, surface property conditioning, flatness correction and ancillary techniques through the delivery achievement of a variety of skinpass mills, tension levelers, and complex equipment consisted of these will be presented.

2. Types of skinpass mills

Skinpass mills are generally classified into three of 2Hi, 4Hi and 6Hi, and are further classified into fragments depending on the presence or absence of a hydraulic profile change roll, special profile roll shift, and the addition of high tension before and after the skinpass mill by bridle rolls. (refer to Fig. 2) The specifications and respective roll diameters of skinpass mills are subdivided depending on the sheet width, sheet thickness, required extension ratio, fore-and-aft tensile strength, object material, and the presence or absence of the cost of equipment, and also depending on the facility and the

No.	Type	Work roll diameter (mm)	Material	Applicable line
1	2Hi Reel to Reel	700~800	Stainless steel	OFF·Line mill
2	2Hi High tension	700~800	Stainless steel	OFF·Line mill
3	2Hi Bender	700~800	Stainless steel	BAL,APL,OFF·Line mill
4	4Hi bender	700~800	Carbon steel Stainless steel	CGL CAL CPL HSPL OFF·Line mill etc...
5	4Hi bender dual work roll	450~500/550~650	Carbon steel	CGL CAL
6	4Hi bender High tension	450~550	Carbon steel Stainless steel	CGL CAL CPL HSPL OFF·Line mill etc...
7	6Hi bender	450~550	Carbon steel	CAL OFF·Line mill
8	6Hi bender IMR shift	450~550	Carbon steel	CAL OFF·Line mill

Fig.2 Various type of Skinpass mill

material.

3. Roll arrangement of a tension leveler

There are various roll arrangements depending on materials and applications. When given with tension by extension rolls of a tension leveler in a state of being given with a bend, the processed material is extended and the rolling strain is corrected, but a strong residual curvature (longitudinal warp, width warp) and a residual stress occur. A roll arrangement is determined depending on the extent to which the residual curvature or the residual stress is required to be reduced. Recent typical roll arrangements are shown in Fig. 3. The diameter, number of rolls and arragement are determined from the mechanical properties of and required flatness for the metal material, and also limitations in terms of machinery installation. Some typical examples of skinpass mills and tension

levelers respectively having a roll arrangement shown in and Fig. 3 will be presented from one facility having the equipment installed to another facility.

4. Specifications and required product quality of a skinpass mill and a tension leveler to

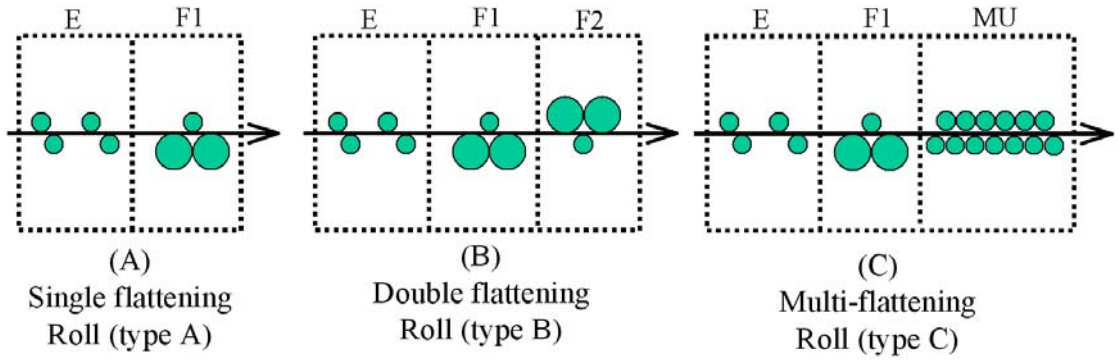

Fig.3 Leveling roll arrangement

be applied to respective facilities

(1) Skinpass mills and tension levelers used for hot rolling steel sheet

There are a skinpass mill and a tension leveler installed on the inlet side of a pickling section of a continuous pickling line (CPL) and a pickling and tandem cold mill (PL-TCM), and also a tension leveler installed in an off-line hot skinpass mill line (HSPL). The former has a descaling property as the main object, and the skinpass mill of 2Hi or 4Hi equipped with a bender and the tension leveler of type (A) of Fig. 3 are common.

The HSPL of the latter hitherto has been constituted of a pay-off reel, a 4Hi equipped with a bender, and a tension reel; however, a hi-tension hot mill line having a bridle roll and a tension leveler added to that also exists. The arrangement is shown in Fig. 4. Stable extension rate control and rolling of a thin high-tensile strength steel plate under high tension have become possible, and a flatness comparable to a cold rolled steel sheet can be obtained by the tension leveler. The line has the specifications of a plate thickness of 0.8 mm to 8.0 mm, a plate width of 600 mm to 1900 mm, the maximum line speed of 500 mpm, the tension of 420 KN, and the product flatnee equal to or less than 0.3% of steepness comparable to a cold rolled steel sheet.

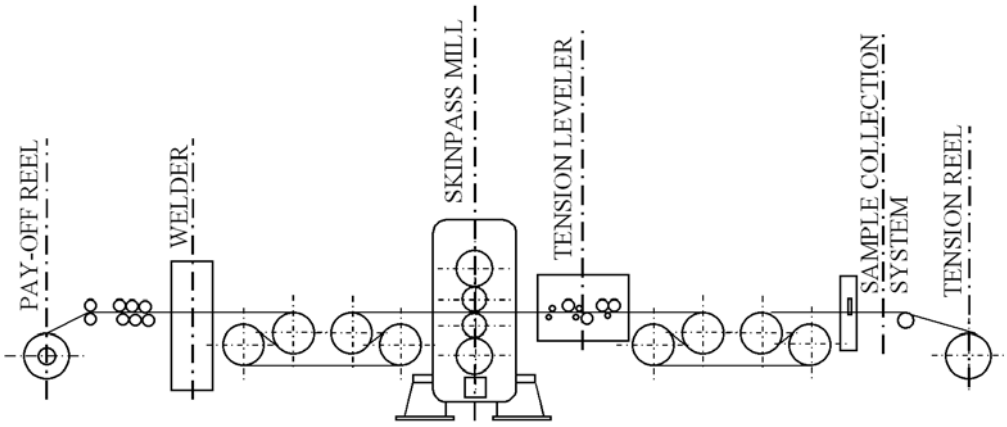

Fig.4 Layout of Hi-tension Hot Skinpass Mill line

(2) Skinpass mills and tension levelers used for continuous galvanizing

A skinpass mill and a tension leveler for a continuous galvanizing line (CGL) are both installed in the middle section.

The typical sheet sizes are 0.4 mm to 2.3 mm in the sheet thickness, 610 mm to 1830 mm in the sheet width. The line speed is 120 mpm to 200 mpm, and due to a problem of zinc powder adherence, wet rolling and wet leveling using water or an aqueous solution of skinpass oil are common. Although required product qualities of removal of yield point elongation and conditioning of sheet surface properties; 0.2% or less of the steepness; and 1 mm or less of the wave height (ear wave, middle elongation) are common figures, a high-tensile strength material having yield stress exceeding 800 MPa is included in the processed materials.

Hitherto, a 4Hi equipped with a bender has been common as a skinpass mill, but in recent years, skinpass mills are poles apart of the uses for high-tensile strength steel sheet made of a Hi-Ten material and for soft steel sheet like EDDQ; the diameter of a work roll for the former is desirable to be smaller and the diameter of a work roll for the latter is desirable to be larger for a stable operation, so the installation of a 4Hi dual diameter roll skinpass mill equipped with 2 kinds of work roll diameter is increasing. Likewise, in regard to the polishing method used for work rolls, a nylon brush roll method has been common up to now, but a high-pressure water spraying method (spraying pressure of 150 bar to 230 bar) is also employed.

Specification example of a skinpass mill:

Work roll: 450/610 mm x 2100 mm

Back up roll: 1000 mm x 2050 mm

Rolling load: Max. 1000 ton

Polisher for work rolls: a brush roll method and a high-pressure water spraying method

Polisher for back up rolls: a high-pressure water spraying method

On the other hand, tension levelers are of the type (A) and the type (B) of Fig. 3, and the variations of longitudinal warp and width warp according to the depression amount of leveling rolls after tension leveling of a high-tension material are shown in Fig. 5. Since the type (A) having only one set of leveling roll unit is impossible to deal with the warp correction of a high strength material, the type (B) is normally employed for tension levelers for CGL[1)]. This is due to utilization of such an emphatic difference between longitudinal warp and width warp that, although both the longitudinal warp and the width warp vary in the case of strong bend when being subjected to tension, the variance of the width warp is extremely small in the case of a slight curvature.

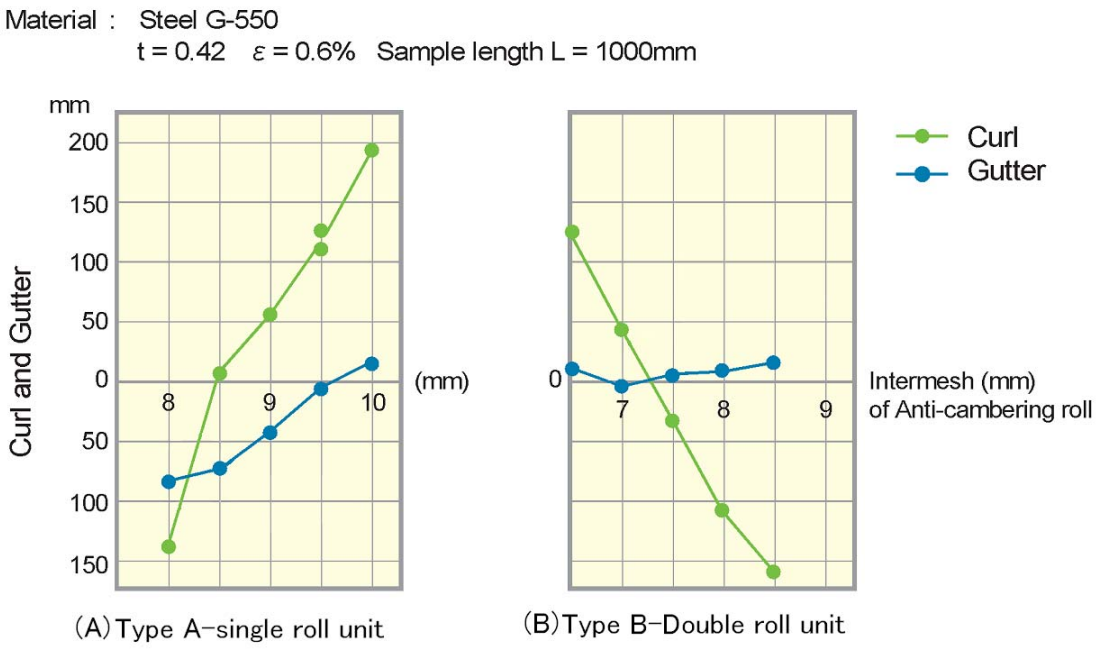

Fig.5 Effect of flattening roll intermesh on Curl and Gutter

(3) Skinpass mills and tension levelers used for general cold rolling steel plates

There are a skinpass mill and a tension leveler installed on the outlet side of a continuous annealing line (CAL), or there is a tension leveler installed on the inlet side of the line with a purpose of improvement of traveling stability in the furnace by carrying out the shape correction of a material before being annealed. In the case of being used off-line, there are a skinpass mill and a tension leveler installed in a temper process line (TPL).

In regard to the skinpass mill, various types of a 4Hi equipped with a bender, or a 6Hi with an intermediate roll shift + a bender are employed depending on the material, the timing of installation and so on. Additionally, there is a case in which a 4Hi dual work roll type is employed as with a skinpass mill used for a galvanization line. Regarding the type of tension levelers, the type (B) is common as with that used for the galvanization line.

In the case of TPL used off-line, an arrangement of a pay-off real, a 4Hi equipped with a bender, and a tension reel is common, but there are also cases of a hi-tension type having a bridle roll installed, of employing a 6Hi, and of having a tension leveler for obtaining a high flatness.

An example of TPLs having the function of a Re-Coil line by installing a tension leveler is shown in Fig. 6. The line has the specifications of a plate thickness of 0.3 mm to 3.2 mm, a plate width of 700 mm to 1640 mm, the maximum line speed of 900 mpm, and the product flatness equal to or less than 0.2% of steepness.

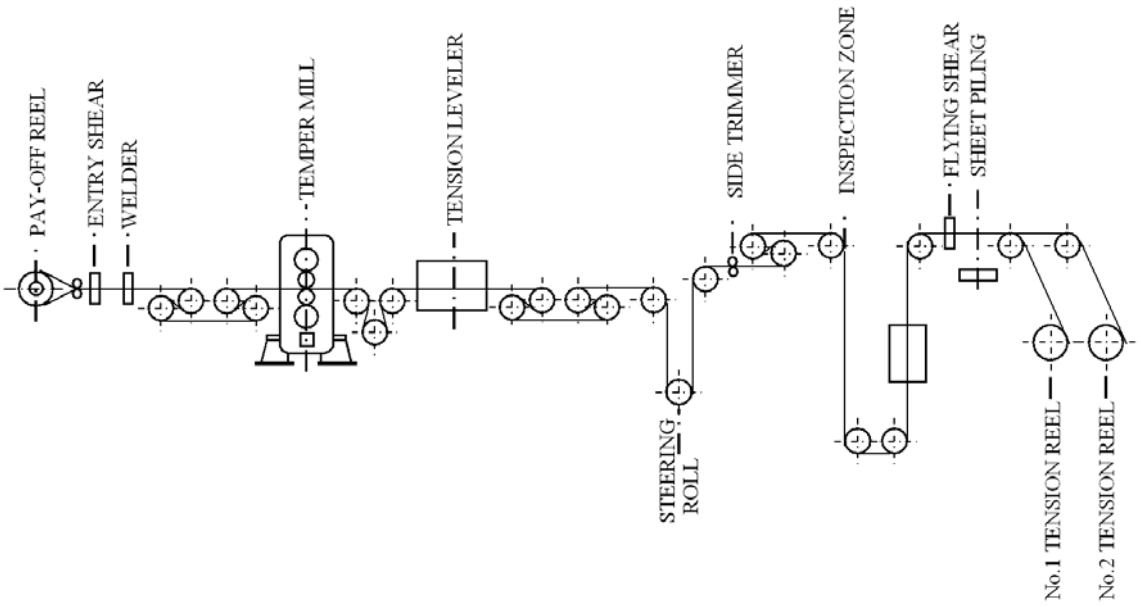

Fig.6 Layout of Temper Process Line (TPL)

(4) Tension levelers used for cold rolling steel plates (raw sheet before electrolytic tin plating)

These raw sheet are subjected to shape correction by means of a tension leveler in a coil preparation line. The typical sheet sizes are 0.1 mm to 0.5 mm in the sheet thickness, 500 mm to 1220 mm in the sheet width, 150 MPa to 600 MPa in the yield stress, and 500 mpm to 1200 mpm in the line speed (max. 1340 mpm in the case of our company).

Required flatness is as follows:

Flatness: 0.2% or less of steepness

Wave height: 0.5 mm or less

Longitudinal warp: 50 mm/m or less

Width warp: 10 mm/m or less

Blank warp: 3 mm or less/ L 700 mm x W 200 mm

In regard to the material used as a can material, it is required to keep the blank warp, which arises when cut into small pieces for being deep-drawn, at an allowable value or less with stability. That is, stable reduction of a residual curvature and a residual stress are required, so a tension leveler of the type (C) of Fig. 3 is employed.

Concerning warp correction by means of the type (B), the test data of which are shown in Fig. 5, in the case in which an allowable warp value of ± 40/1000 mm is required, an appropriate intermesh amount is ± 0.2 mm, which is so narrow as to be nearly unattainable in an actual operation. Moreover, since both the thickness and mechanical properties vary depending on positions along the length of a coil, even though the insured value is attained at the initial setting time, a variance arises in the warp and, even within the identical coil, a portion going out of the target value becomes present. A roll arrangement devised in response to such high level requirements is the type (C). The influence of intermesh amounts of this equipment is shown in Fig. 7. It is known that the severe requirement value is satisfied with an enough allowance[1)].

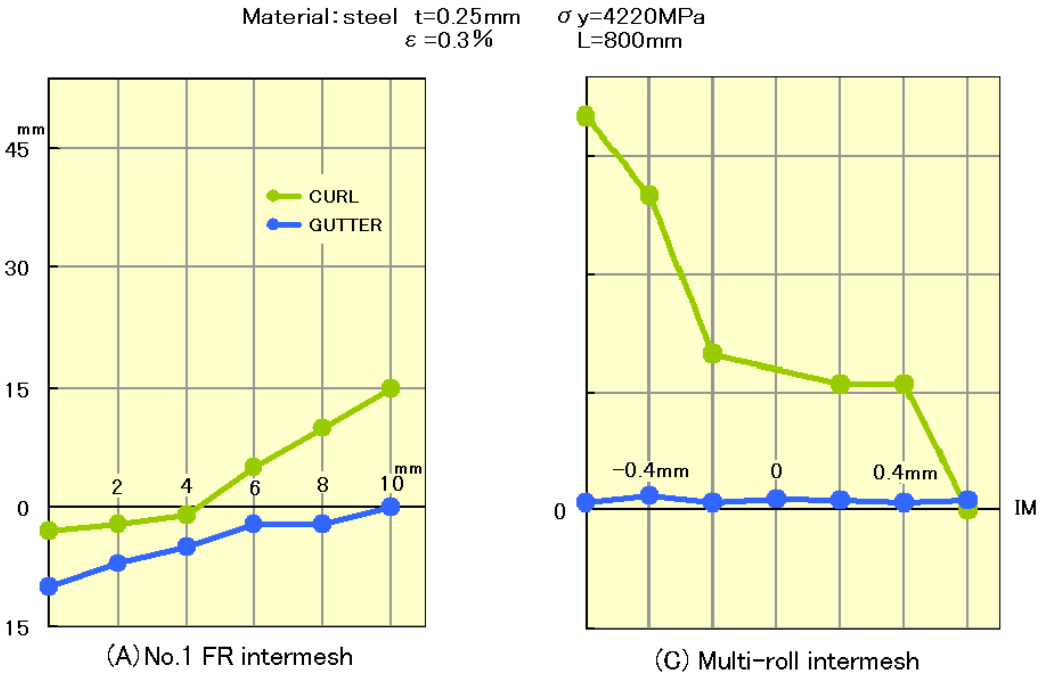

Fig.7 Effect of Flattening roll intermesh on Curl and Gutter

(5) Tension levelers used for coated steel plates

A tension leveler used for a continuous coating line (CCL) is installed on the inlet side of the line in the case of aiming to improve a coating function, but it is occasionally installed on the outlet side of the furnace in the middle of the line in the case of aiming shape correction after baking of the coating film. The typical sheet

sizes are 0.2 mm to 1.2 mm in the sheet thickness, 610 mm to 1220 mm in the sheet width.

Line speed: 60 mpm to 120 mpm

Required flatness,

Flatness: 0.2% or less of steepness

Wave height (ear wave, middle elongation): 1 mm or less

The Tension leveler of the type (A) of Fig. 3 is common.

(6) Skinpass mills and tension levelers used for stainless steel

In the case of usage for stainless, the specifications of a skinpass mill and a tension leveler vary depending on facilities as with the usage for steel sheet.

A skinpass mill and a tension leveler are installed on the outlet side of a bright annealing line (BAL). The typical sheet sizes are 0.4 mm to 1.5 mm in the sheet thickness, 1000 mm to 1550 mm in the sheet width.

Yield stress: Max. 400 MPa

Line speed: 70 mpm to 100 mpm

Required flatness: 0.2% of steepness

Important points with these skinpass mills and tension levelers used for a BAL are to put a shine on the surface of a sheet and to prevent even a slight flaw. For this reason, various methods are devised for the process of passing the material through a polisher and a welding point.

In a hot APL of an annealing and picking line (APL), a tension leveler is installed on the inlet side of pickling so as to have a descaling property as the main object as with hot rolling steel sheet, and in a cold APL, a skinpass mill and a tension leveler are both installed on the outlet side as with the BAL.

In the case of being used off-line, there are the case of single use of a skinpass mill, the case of complex facilities of a skinpass mill and a tension leveler, and the case of single use of a tension leveler. In regard to skinpass mills used for stainless steel, there are generally many cases in which a 2Hi skinpass mill is employed from the reason of placing a premium on a shine of the surface. In this case, since the

diameter of work rolls becomes larger, there is a case in which a required elongation rate of a thin sheet material of AISI430 having yield point elongation is not obtained by one pass. For this reason, there is a line in which a hi-tension skinpass mill is arranged by installing a bridle roll and which enables to obtain the required elongation rate even in the case of a thin sheet material.

Two examples used off-line are presented. An arrangement of a complex facilitiy consisting of a skinpass mill and a tension leveler is shown in Fig. 8. The materials are of APL and BAL materials, and the line specifications are a sheet thickness of 0.3 mm to 3.0 mm, a sheet width of 600 mm to 1600 mm, and the line speed of 250 mpm. The skinpass mill is a hi-tension 2Hi equipped with a bender, and the required steep degree is 0.2% or less. As the method of driving the bridle roll, a mechanical tying driving method, which enables to obtain a high elongation rate accuracy, is employed.

The features of tension levelers used for stainless steel of our company are such that respective work rolls are all driven through a helper drive, and a cleaning liquid is sprayed during leveling. In addition, a looper is provided on both inlet and outlet sides of the line for preventing a stop mark at the mill and leveler.

An example of the arrangement of a single tension leveler is shown in Fig. 9. In recent years, among stainless steel, a demand for the material of thin sheet thickness having ultra-high strength has been expanded due to high-tech thin sheet products. This leveler is one for responding to the material. The typical sheet sizes are 0.1 mm to 0.5 mm in the sheet thickness, 300 mm to 750 mm in the sheet width.

Yield stress: Max. 1800 MPa

Line speed: 100 mpm to 200 mpm

Required flatness: 0.4% or less of steepness

Wave height: 2 mm or less

The features of this line are such that, although the raw sheet have rolling oil adhered on the sheet surface because having been directly transported from a cold rolling machine, the tension leveler has a cleaning function enabling to remove the rolling oil by spraying a cleaning liquid for the purpose of flaw prevention, as well as responding to the 1800 MPa material. For the purpose of leveling of a sai ultra-high

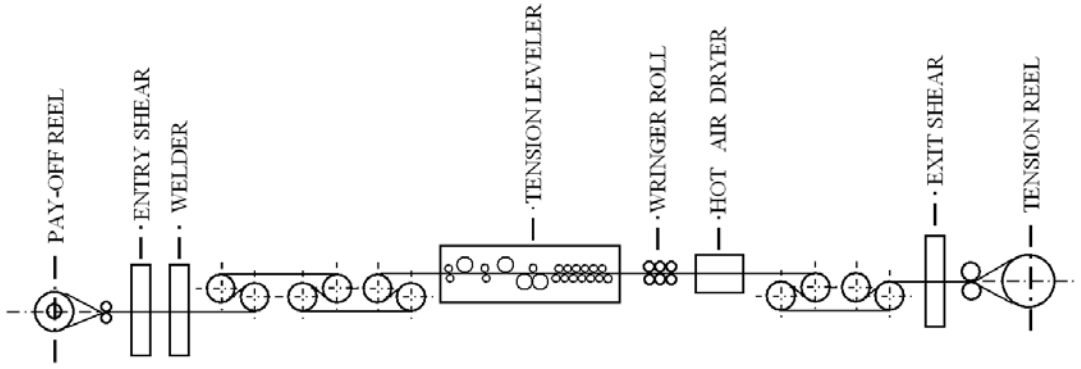

Fig.9 General layout of Extra Full hard Stainless Steel line

strength thin plate material, an extension work roll having the diameter of 16 mm to

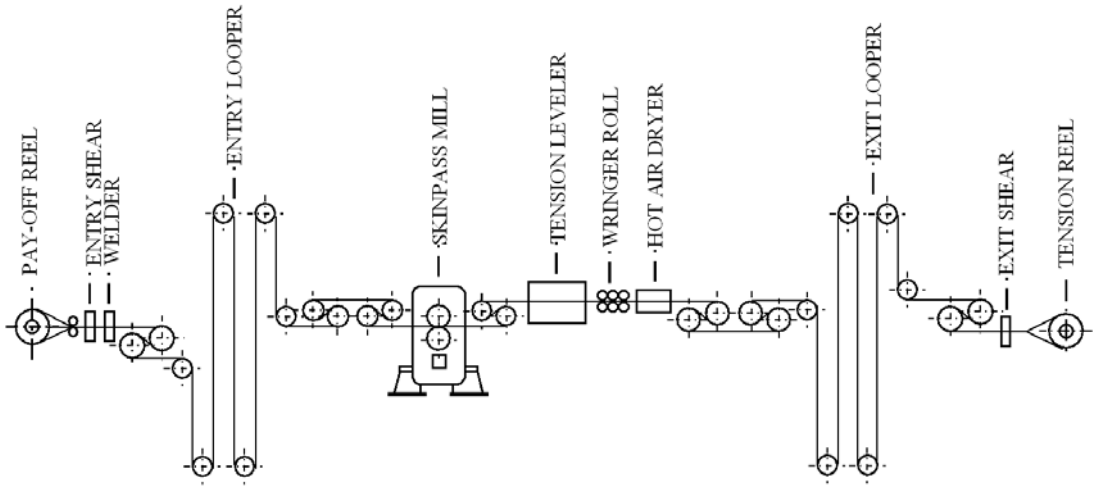

Fig.8 layout of Skinpass and Tension leveler combination for Stainless steel

20 mm is used.

(7) Tension levelers used for aluminum

Aluminum thin sheet are used for a can-end, a can-body, a lithograph sheet, and so on; the typical sheet sizes are 0.2 mm to 0.8 mm in the sheet thickness, 800 mm to 2300 mm in the sheet width, and the durable strength is 80 MPa to 200 MPa. Since a prevention of blank warp is important in terms of the uses of the product, the tension leveler of the type (C) of Fig. 3, which is able to accept a very wide variance in the sheet thickness and satisfies severe requirements, is installed in an oiling line, a CCL and a tension leveling line, and there is even a line, the maximum leveling speed of which reaches 600 mpm.

Required flatness is as follows:

Flatness: 0.2% or less of steepness

Wave height: 0.5 mm/m or less

Longitudinal warp: 50 mm/m or less

Width warp: 10 mm/m or less

The sheet passing speed is appropriately changed depending on the convenience of the process conditions of the line or of the connection with the following coil. Although stable flatness is required from an ultra-low speed range to the maximum speed of the line, an example of variance amounts in the longitudinal warp due to speed changes in the cases of roll types (B) and (C) is shown Fig. 10. In the type (B), a variance of the longitudinal warp of 300 mm arises due to a speed change from the line speed 50 mpm to 450 mpm, and moreover, instability of the warp at the time of acceleration can be distinctly observed even in an identical speed range. On the contrary to this, the variance amount of a warp with the type (C) is 20 mm, that is, a stability higher by the order of 10% as compared to the type (B) can be obtained. Incidentally, in a normal tension leveler used for aluminum thin sheet, spraying of drysol or the like is generally intermittently or continuously implemented during leveling as a measure against a plate flaw, and also there is a case in which the work roll is driven through a helper drive.

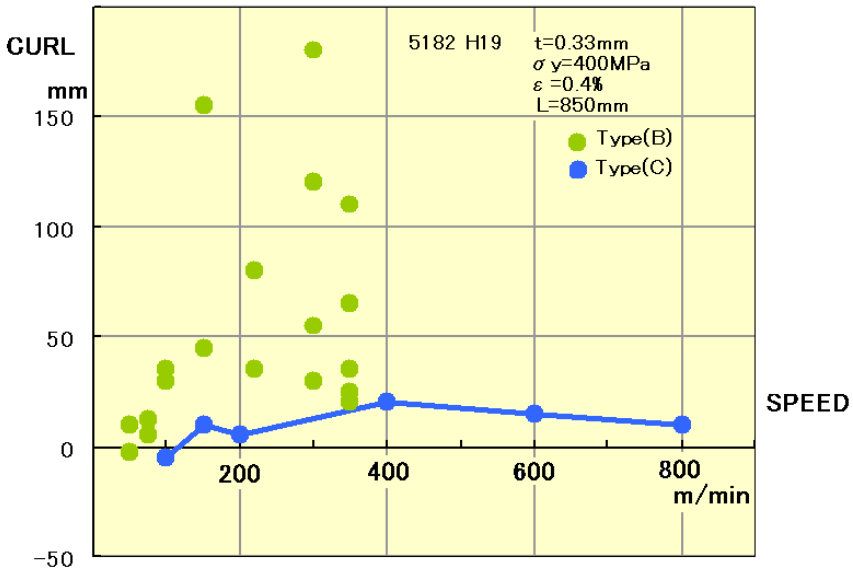

Fig.10 Effect of Leveling speed on Curl roll type (B) and (C)

(8) Tension levelers used for high-tech ultra-thin plates

High-tech products typified by a shadow mask or lead frame material have a thin thickness and severe product requirements. The typical plate sizes are 0.05 mm to 0.3 mm in the sheet thickness, 450 mm to 1067 mm in the plate width. In the case of high-tech products such as a shadow mask material and so on, the flatness after having been subjected to a punching process is important, and one having extremely small residual stress is required. Since high residual stress remains under the conventional condition of high strength, a facility which is allowed to have two functions (shape correction and dispersion of residual stress) at the same time by installing two zones, by which the tension in the line is separated, as shown in Fig. 11 is constructed for the shadow mask. In Fig. 12, an example of variance amounts of the warp before and after edging in a material, which has been tension leveled under low tension, is shown. The object can be attained by carrying out multi-roll leveling under the condition of low tension of an extent which does not extend the material.

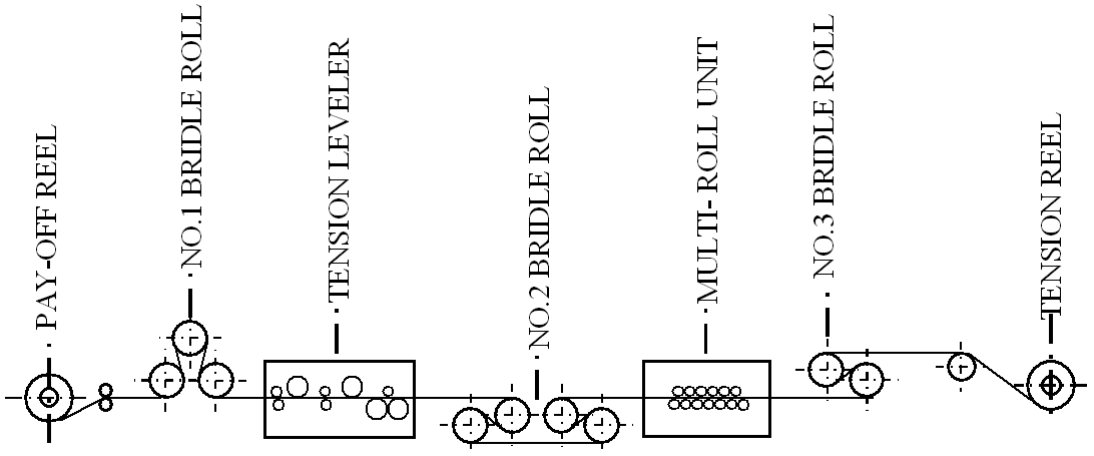

Fig.11 leveling line with two-tension zone for minimizing residual stress

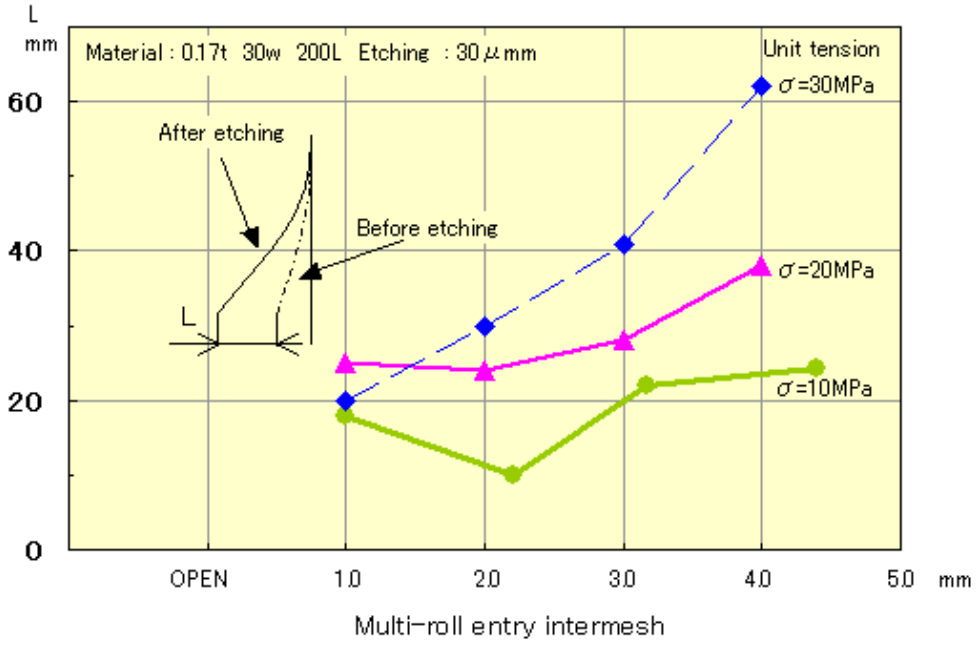

Fig.12 One of evaluation methods for residual stress after tension leveling by type (C)

(9) Tension levelers used for copper alloy

A copper alloy having a superior conductivity has been developed as a lead frame material used for LSIs, and one having strength comparable to the conventional material 42 alloy (Fe·42% Ni) appears. In regard to the required product quality of copper plates used for electronic parts, since the end product becomes a small chip-like one, high level flatness in a stage of the product sheet and also adequate dispersion of residual stress in the plate are required from the points of sheet handling at the step of manufacturing the parts and of preventing a distortion of the parts after being processed. The typical sheet sizes dealt with by a tension leveler used for copper alloy thin plates are 0.1 mm to 0.8 mm in the sheet thickness, 350 mm to 650 mm in the sheet width, and the durable strength is 300 MPa to 800 MPa. In the case of the material used for a lead frame, a value equal to or more than 600 MPa is required as the durable strength.

Flatness: 0.2% or less of steepness

Longitudinal warp: 10 mm/m or less

Width warp: 5 mm/m or less

Warp after edging process: 5 mm or less/ L 60 mm x W 180 mm

In order to respond to these requirements, a tension leveler having the type (C) of Fig. 3 as the roll arrangement is used, and the number of multi rolls is increased as compared with the other tension levelers, particularly because the end product becomes a small chip-like one.

5. Conclusion

Our company has developed and kept the most advanced technology in the world through theoretical formulation and demonstration tests with various materials using a test machine, and also through repeated evaluations of actual equipment delivered from the 1970s. It is also a significant feature that our company is widely involved in tempering and leveling equipment for hot rolling steel sheet, cold rolling steel sheet, stainless steel sheet, aluminum, copper alloy, and so on through these theories and demonstrations to an extent as never seen even in the world.

In this paper, latest technology trends in skinpass mills, tension levelers, and complex equipment consisted of these applied to various production facilities for metal thin sheet are presented. We intend to develop a leveling technology on the cutting-edge in the world also in the future, and to supply leveling equipment responding to a required higher level of performance.

<Reference materials>

1) Kazuto Kaneshige ‘Flatness requirements for metal strip and tension leveler specification’,”15th symposium of the Japan society for Technology of Plasticity”, 1993