A continuous, stretch leveling skinpass line, designed specifically to meet the high-quality demands for galvanized products, consists of mechanically coupled entry and exit bridle tensioners, a nonmotorized skinpass mill and leveler separated by an independently motorized intermediate bridle that provides exact control of strip elongation. The skinpass mill features small diameter work rolls to enhance surface quality, continuously variable work roll crown adjustment and ultrafast work roll changing.

Tension leveling and skinpassing in a galvanizing line

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DEMAND for galvanized sheet that meets the increasingly severe requirements of the ultimate users for particular characteristics and quality has become intense. This demand, coming at a time when the majority of the steel industry's products are finding fewer outlets, has occurred due to the introduction of higher quality galvanized sheet with varied coatings and precise mechanical and surface characteristics. These products have outlets in the building, domestic appliance, metallic furniture and automobile industries. New products, with more added value, are becoming available on the market for new applications where, in the past, it was necessary to paint after forming.

To obtain high-quality products, galvanizing lines require new additional equipment and automatic control systems. One essential element of these lines is a skinpass/leveler section.

The skinpass/leveler section of a galvanizing line is designed to provide the sheet, in conjunction with a zinc bath, with its final characteristics of resistance, pliability, flatness and surface condition. The principle adopted more than 30 years ago consists of passing the strip through a rolling mill and roller leveler under high tension.

Many different solutions have been employed to apply a high, continuous tension to the strip using two groups of bridle rolls. The oldest and simplest method employs rigid gearing between the bridle rolls. With this method, the tension in the strip between the bridle rolls can be increased by a fixed amount. In addition, the strip can be elongated by a set amount by providing an adjustable differential between the two groups of bridle rolls. Later developments utilized electric or hydraulic drives that allowed better control of intermittent slipping.

The rolling mill, in general, was a classical nonmotorized duo type. However, the user of this type of mill was faced with many problems that were associated primarily with the diameter of the work roll which, together with the chocks and drive spindles, took substantial time to change. This led some plants to use two 2-h mills to insure that one set of clean rolls was always available.

The leveler, itself, has two or three clusters of flexing rolls that, under the effect of the tension imposed on the strip, subject the strip to a plastic deformation and bring all the metal fibers to the same length, thus, making the strip flat.

The combination of a mill and leveler represents an assembly of two very different machines whose role is essential in obtaining a good product. This condition can only be fulfilled if precise and different tensions are imposed on the strip on either side of these two units.

Steel sheet passing through a skinpass mill imposes both tension and compression on the metal. These effects modify the mechanical characteristics of the metal and provide a particular desired surface. At the same time that the yield point is changed by light cold rolling, the required surface texture of the sheet can be produced by employing a roll with an appropriate surface finish. For a given product, these properties necessitate the appropriate control of the rolling mill's operating parameters: roll separating force (RSF); strip tension; and roll crown.

The entry and exit tensions of the skinpass mill are, therefore, an integral part of the process in obtaining the required product characteristics. For a nonmotorized mill of the Redex-Sendzimir type, the tension at the exit side corresponds, for a current galvanizing line, to a stress of approximately 7000 to 28,000 psi. The stress at the entry side is approximately 20% lower regardless of product thickness.

The entry and exit tensions at the leveler are associated with the diameters of the flexing rollers which, in turn, are a function of the thickness of the strip to be flattened. The combined effect of the tension/flexion causes the section of the metal to be worked in the plastic zone, thus, inducing elongation. Based on a theoretical analysis of this phenomenon, the elongation that has to be applied to the strip at entry and exit of the leveler can be calculated. Generally, the necessary entry and exit tensions are slightly different for thin sheets and greatly different for thick sheets.

The differences in tension between entry and exit, called losses in the leveler, increase with thickness. The stress at the entry side is, on occasions, only 10% of the stress at the exit side.

It is, therefore, necessary for a given elongation, that the stress at the entry side can be rapidly reduced as the sheet thickness increases, while for skinpassing, the stress at the exit should be reasonably constant. These two contradictory conditions demand a method of achieving different tensions at the exit of skinpass mill and entry to the leveler.

The skinpass entry and leveler exit tension is determined by the outer groups of tensioning bridles. The intermediate tensions can be controlled in two ways:

- Motorizing the skinpass mill such that the energy introduced is used to allow variations and reductions in the exit tension. (This solution has many practical difficulties.)
- Isolating the skinpass mill and leveler by an intermediate motorized bridle designed to reabsorb the desired difference in tension between the two machines.

The latter solution has both numerous operating advantages as well as a cost advantage with respect to the skinpass

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equipment. This arrangement has been selected for a specially developed nonmotorized skinpass mill for galvanizing lines.

Redex continuous stretch leveling skinpass line

This development has the advantage of bringing together the necessary conditions for producing a quality product.

The main features of the line are the drive system and location of the tensioning bridles and the Redex-Sendzimir skinpass mill.

The general layout of the line is shown in Fig. 1. It consists of:

- A 4-roll entry bridle tensioner.
- Skinpass rolling mill.
- Intermediate tensioning bridle.
- Leveler with two or three sets of flexion rollers.
- A 4-roll exit bridle tensioner.

Motorization of the two outer tensioning bridles — The outer tensioning bridles (Fig. 1) are driven via mechanical differentials by a single motor. Precise control provides a wide range of strip elongations between the two bridles. This elongation, representing the total elongation of the strip between these two sets of bridles, is produced by a working tension which, in turn, is obtained by a difference in speed between the two groups. It is, therefore, a machine capable of imposing elongations required for a particular product and is independent of the product cross section.

The increase in tension as the strip passes through entry bridle rolls is obtained by the progressive increase in tangential roll speed which is identical to that of the strip. There is no possibility for slip between the strip and bridle rolls. The decrease in tension through the exit bridle rolls takes place in a similar manner.

In each of the bridle units, the torque is distributed so as to achieve optimum tension.

Tension progression depends on the friction coefficient of the roll surface and angle of contact with the strip. The distribution of torque and speed (compensation of elongation during the initial tensioning phase) is made automatically by the differentials. The Redex differential system obviates any necessity for control of speed or torque at each of the tensioning rolls by complex electronics.

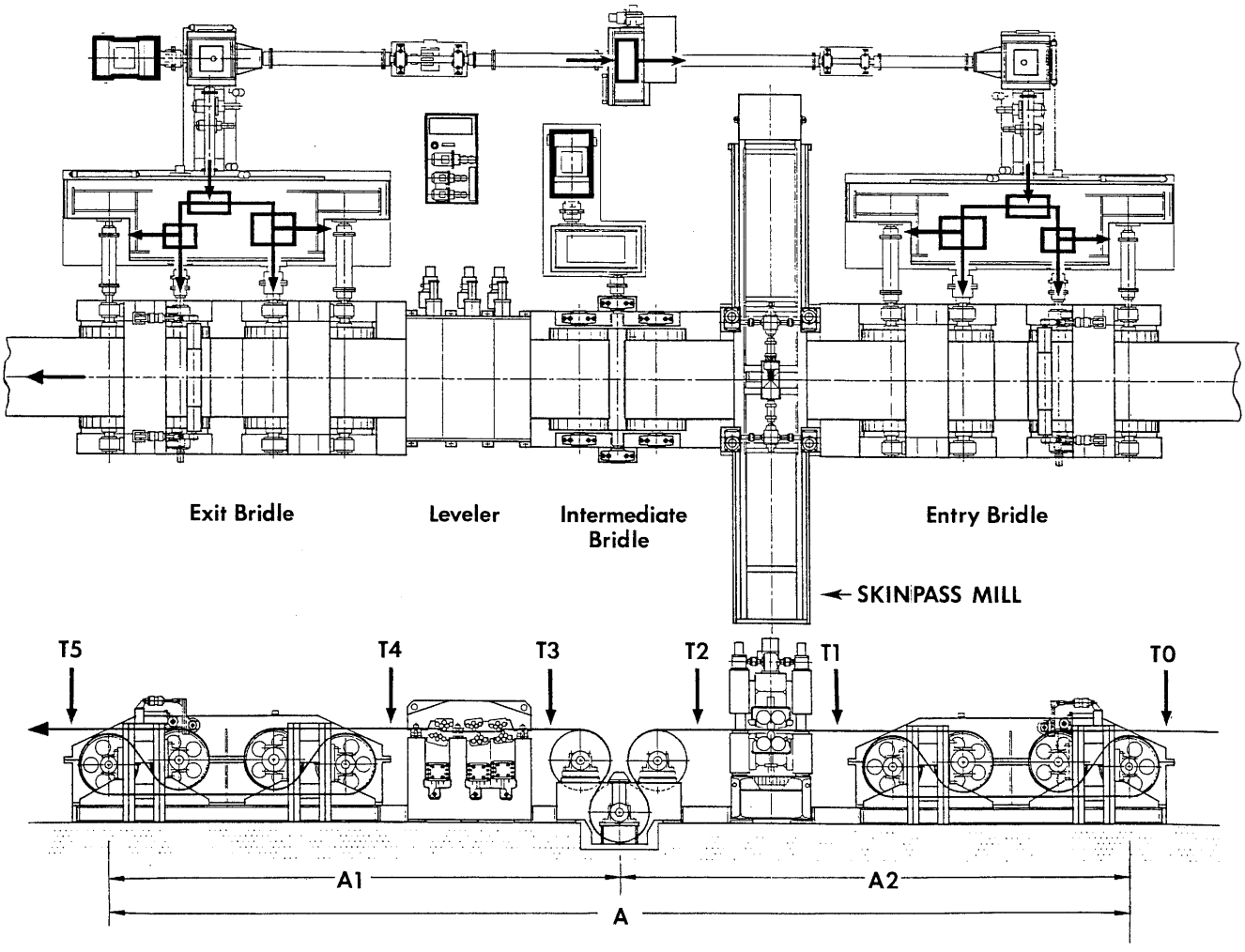
The required torque is automatically distributed on each roll, by differentials, in the optimum proportion determined at the machine design stage. Consequently, unexpected slippage cannot take place between strip and rolls as any increase in tension is automatically distributed between the four rolls.

With regard to speed, this is also shared through a kinematic differential chain. Each roll has the same linear speed as the strip in contact with that roll, such that the average of the sum of the speeds of each one is proportional to the speed of the main motor.

The difference in speed between the entry and exit is also obtained by a differential that creates a small difference in speed between these two groups of bridle rolls. It is this difference in speed that induces the required tension in the strip. A small, automatically controlled variator is used to produce this small speed difference (between 0 and 3%) that corresponds to the elongation imposed on the strip.

The assembly constitutes a closed-loop system driven by a single motor. This arrangement gives major advantages in

Fig. 1 — Redex continuous stretch leveling, skinpass line.



the simplicity of electrical equipment, ease of adjustment and maintenance together with low energy consumption.

The system, therefore, has the following advantages:

- No slipping of the strip on the surface of the bridle rolls.
- The possible use of covered rolls having a high coefficient of friction without risk of wear.
- Accommodate rolls with different diameters not exactly equal.
- No regulation sensors.
- Schedule changes are easily made by the operator.
- Wide range of (product) mechanical characteristics.
- Strip elongation precision of 0.01%.
- Elongation precision maintained during acceleration and deceleration of the machine.
- Tension maintained at zero speed.

Motorization and role of intermediate tensioning bridle

The braking and driving bridles impose a controllable total elongation on the strip. In practice, it is desirable to have a precise elongation at the leveler and a separate precise elongation at the skinpass mill; the total elongation being the sum of the two.

The tension characteristics of the line are also illustrated in Fig. 1. The leveler entry tension, T3, and skinpass mill output exit tension, T2, are a result of the elongation selected and may be different in certain cases.

The elongation at the leveler A1, being fixed, corresponds to the total elongation imposed by the two principal tensioning bridles before the skinpass mill is brought into service. The energy from the intermediate tensioning bridle will permit, when bringing the mill into service, the progressive attainment of the tension T2, while the total elongation increases to the value A1 + A2. Thus, the desired elongation at the skinpass mill is obtained without affecting that selected for the leveler.

The drive to the intermediate tensioning bridle is by a torque-controlled d-c motor. Its absorbed power does not affect the total elongation which remains the same as that imposed by the mechanical system between the two principal tensioning bridles at entry and exit. Conversely, incorrect regulation of this motor alters A1 and A2, their sum remaining constant.

The torque-controlled intermediate bridle permits control of the tensions between the skinpass mill and leveler in a system that remains within the imposed elongation.

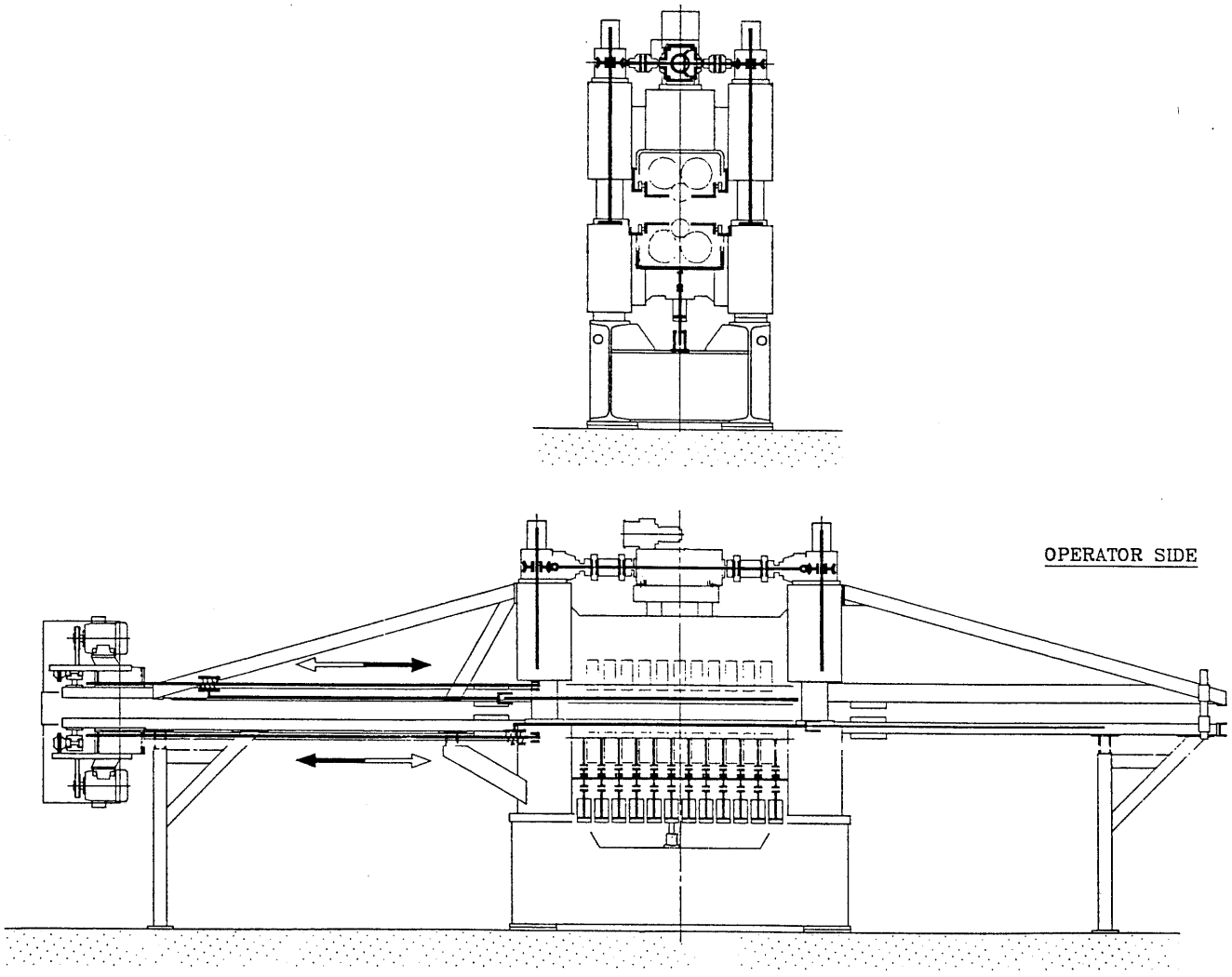
Redex-Sendzimir skinpass mill

A 2-h skinpass mill is generally used in combination with a leveler. This combination has various disadvantages:

- Prolonged roll change time. (Crane is required.)
- Only one crown is available in the mill at a time.
- Necessary to drive work rolls.
- Heavy weight of chocks.

If the strip surface is not satisfactory, the line must be stopped for a long period of time to change rolls.

Fig. 2 — Skinpass mill for galvanizing and painting lines.



Sendzimir and Redex have developed a new skinpass mill that is especially appropriate for galvanizing lines. Strip surface control is improved and the roll surface texture is transferred to the strip.

The mill is the 1-2 type (Sendzimir ZS05-50), Fig. 2. The housing is split into top and bottom halves or beams with the top beam raised by hydraulic actuation. The mill is comprised of two work rolls, each of which is supported by two backup shafts containing bearings, mounted between saddles. The bearings, in turn, are attached to each beam. The floating-type 142-mm (5.6-in.) dia work rolls are not driven. They are supported along their entire length by 10 to 15 bearings, depending on the maximum width of strip to be processed.

Four mills of this type were built in the 1960's. Three were supplied to the French group, La Galvanization. Two of these mills were installed in the galvanizing line. The third mill was set up as a separate skinpass unit for aluminized strip, where more than one skinpass was necessary. The latter mill was of the crocodile-type housing construction. A fourth mill was installed inside a 2-h mill housing at Fabrique de Fer de Maubeuge, France, on a high production galvanizing and painting line. This mill was followed by a Wean triple-head leveling unit. Tension on this installation was 30 tonnes.

The small diameter work rolls on these mills adequately transfer the roll surface texture onto the strip. Moreover, they were successfully used several years ago on a scale-breaker installed at the Midwest Div. of National Steel ahead of the sulfuric acid pickling line. Studies made by IRSID do not show any sensible variation of roughness imprint as a function of roll diameter. The only important factor is the work roll pressure. A standard parameter of $\frac{1}{3}$ depth of transformation would apply in this case.

The principal design features of the skinpass mill are illustrated in Fig. 2 and summarized in Table I. An actual installation together with an entry and intermediate bridle unit is shown in Fig. 3.

The lower beam includes a set of 10 to 15 hydraulic jacks connected to the lower saddles that allow each jack to apply a separate pressure which is adjustable from the operator's panel. The hydraulic jacks are connected to a set of solenoid valves. Thus, the operator is able to apply a variable pressure transversely across the width of the strip. This feature provides the same effect as a continuous variable crown adjustment. Sensors are provided to control the resulting effects. A monitor on the operator's panel indicates the crown setting of the mill.

An ultrafast roll change device is located on both sides of the mill, front and back. This device includes guiding rails for two holding cars for the work rolls and end thrust bearings. Both sets of work rolls and thrust bearings are pushed simultaneously inside the rolling mill in opposite directions, one from the back side and one from the front.

TABLE I Principal characteristics of Redex-Sendzimir skinpass mill for galvanizing and painting lines

Mill type	ZH 2.9
Strip thickness	0.15 to 3 mm
Mill speed	0 to 180 metres/min
Roll separating force	110 tonnes
Roll dimensions	
Work roll dia	142 mm (max.) 124 mm (min.)
Backup roll dia	225 mm
Screwdown mechanism	
Upper beam speed	
Up (fast)	12.1 mm/s
Down (slow)	0.48 mm/s
Motor	25 kw
Work roll change time	20 s

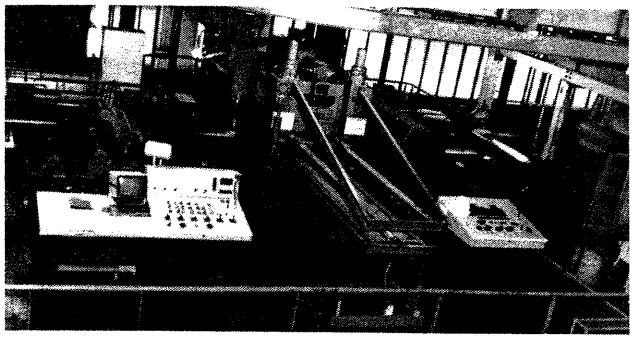


Fig. 3 — Skinpass mill together with 4-roll entry bridle (right) and 4-roll intermediate bridle (left) units.

Two sets of roll holding cars are provided. One set is inside the mill with the set of work rolls in operation. The other set is on each side of the rolling mill with a new work roll standing by.

The simultaneous work roll changing mechanisms also include an additional drive for a small longitudinal adjustment of the work rolls to obtain bright strip surface and to prolong roll surface life. Two small cranes are provided in front and behind the housing for roll transfer.

Main advantages of the Redex-Sendzimir skinpass rolling mill are:

- Small work rolls giving better quality surface.
- Work roll changing is possible by the line operator.
- Continuously variable work roll crown is quickly adjustable during line operation with corresponding read out.
- Small grinding machine for parallel grinding of the work roll only.
- Comparatively small rolling mill housing or insert retrofit made to an existing 2-h mill.
- Only small cranes necessary for roll changing.

The leveling machine used in this type of installation consists of two clusters of two nonmotorized working rollers. The first cluster, the flexion rollers, in conjunction with the strip tension, imposes a deformation on the strip to elongate the metal fibers by plastic deformation. The second cluster, known as antidish, corrects any transverse deformation caused by the first cluster. The two rollers of the flexion cluster have diameters appropriate to the range of sheet thicknesses processed.

Summary

In modern galvanizing lines, it is necessary to use a special purpose skinpass mill in tandem with a tension leveler to achieve perfectly flat sheet having precise mechanical and surface characteristics demanded by current market conditions. A Redex continuous stretch leveling, skinpass line provides this capability.

The line consists of a mechanically coupled 4-roll entry and exit bridle tensioner, a nonmotorized skinpass mill and leveler separated by an independently motorized intermediate tensioning bridle unit. The intermediate bridle controls the tension between the skinpass mill and leveler to provide optimum processing condition for flattening and, at the same time, insures that the overall required elongation is maintained. Strip elongation is controlled with a precision of 0.01%.

The nonmotorized skinpass mill features small work rolls to enhance surface quality with the transfer of appropriate roll surface texture to the strip, continuously variable work roll crown adjustment and ultrafast work roll changing.

The nonmotorized leveler consists of two roll clusters with the second cluster correcting any transverse deformation caused by the first set.