

# *Avesta Nyby Bruk*

## *Process-Line Z-High® Mill*

The concept of using a live reduction mill in a stainless annealing and pickling line was developed in the early 1980s. The objective was to take a live pass on annealed and pickled material to develop the surface in order to see if such a coil of strip could be directly cold rolled instead of having to be processed through a surface grinding line. Also to be investigated were the extent to which gauge could be corrected and reduction achieved. 4-High mills and Sendzimir ZS-type mills averaged reductions of 7-8%. However, they had difficulty with shape control, and the material underwent work hardening.

The installation at the Nyby Bruk Works in Avesta, Sweden, utilized the Z-High® Mill, with smaller work rolls, installed at the head of the line, before the annealing operation. The initial goal was to achieve a reduction rate of up to 18%, gauge equalization, and shape control through intermediate-roll shifting and intermediate-roll bending.

### ***Streamlining production of Sweden's stainless***

In 1986, at a time when the world's widest Z-High Mill was being built for the KBR division at Avesta to roll stainless strip up to 84" in width, the entire Swedish stainless steel industry, composed of several different works, was being integrated under the leadership of Avesta, and top management took an active part in technical and economic considerations.

Production of stainless steel strip and sheets was considerably diversified in Sweden, with several works doing the cold rolling operation, while the incoming hot-rolled material was produced at four different plants utilizing completely different types of hot strip mills. These included hot Steckel mills at Fagersta and at

Surahammar and a semicontinuous mill at Domnarfvet. The reversing hot mill at Avesta rolled two-ton sheets subsequently welded into coils, and some slabs were shipped to Germany to be converted at the Kloeckner continuous mill in Bremen.

Consequently, the idea grew to prereducer hot coils at the entry end of an anneal and pickle line by taking a substantial reduction, during which time the gauge could be equalized by using an AGC system, and the shape could be evened out by using axial shifting of intermediate rolls and roll bending. For heavy reductions, a smaller-diameter work roll was needed, and it was felt that the range of 120 to 140 mm was the appropriate solution.

### ***Advantages of the Z-High at the entrance to the A/P line***

Conventional production of cold band required four different operations – raw (hot-rolled) strip annealing, coil preparation, cold rolling, and final annealing – on different lines. These operations required 12 handling motions using overhead cranes or fork lift trucks and called for a great number of operators.

However, having a Z-High Mill at the entrance to the A/P line permits the production of cold-rolled strip on only one line.

The pilot tests carried out by Avesta revealed a number of other advantages.

Energy costs could be saved by eliminating a final anneal, and that heat transfer in the furnace improved due to the strip's more favorable surface/cross-section ratio.

Production could be increased further by descaling the hot strip in the mill stand. This also reduces the cost of pickling and of

preparing and disposing of the pickling liquor.

When carrying out the pilot tests, particular attention was paid to strip surface. The results showed that cold rolling of scaled hot-rolled strip had no deleterious effect on surface quality.

### ***Baseline requirements of an A/P hot mill***

The production of “marketable” cold-rolled strip processed on a hot annealing and pickling line makes the following demands on the in-line mill stand:

Pass reductions of up to 35% on non-annealed hot strip

Thickness and flatness tolerances comparable to those obtained by conventional cold-rolling processes

Such demands can only be met by mills using small-diameter work rolls.

### ***How Nyby Bruk chose their Z-High Mill***

Thus, the Z-High Mill seemed to be the obvious choice for Nyby Bruk's A/P line and, with the experience on the 84” mill obtained at their KBR division, it was decided to proceed with an initial study of mill parameters. As a result of these studies, a ZR 613A-60 section was chosen, but a number of considerations had to be taken into account.

The Z-High mill stand is of the 18-high type. The Z-High has lateral supports that keep the

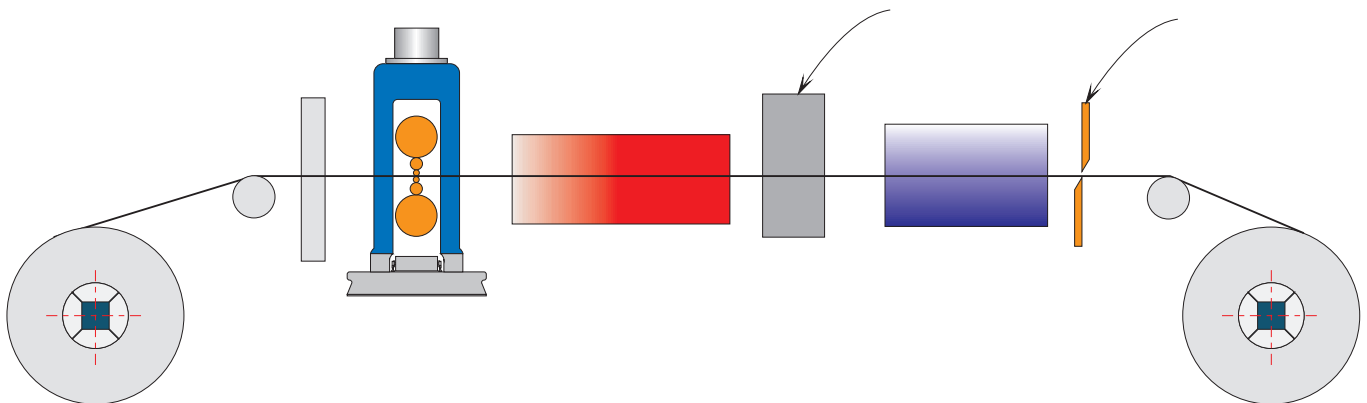
work rolls in the vertical centerline of the mill and absorb the horizontal forces arising from the mill drive and roll torque as well as from strip tensions.

Due to the lateral support of the work rolls in the in-line mill stand, it is possible to select a work roll diameter/barrel length ratio of 1:12; 4-high mill stands only permit a ratio of 1:2 with the work rolls driven, or a ratio of 1:4 with the backup rolls driven. The work roll is backed by lateral small-diameter intermediate rolls, which are supported by two rows of backup bearings on each side, similar to the 20-high mill stand. The backup bearings are mounted in hinged support arms, which are backed by support beams arranged between the mill housings. The beams can be adjusted by wedges to adapt the support to varying roll diameters. Each backup system, including the work roll and the intermediate roll, form a compact unit, frequently referred to as a Z-high cluster or “cassette,” which can be changed in a similar way as the work roll set of a 4-high mill stand. The Z-High work rolls are axially floating between thrust bearings located in the front and the back door, in a similar way as the work rolls of a cluster mill stand. The intermediate rolls in this in-line mill stand are driven.

Unlike carbon steels, which usually undergo little or no work hardening during hot rolling, stainless steel is typically work hardened when it comes from the hot mill, the hardening corresponding to a cold reduction of about 10-20%.

The best place to install a rolling mill at the head end of such a line would be between the uncoiler and the storage loop. At this location, the strip is stopped whenever the welder is in operation.

When the strip is stopped, the mill work rolls



could be simultaneously changed with minimum risk of surface damage to rolls or strip.

Furthermore, the strip can be stopped for an extra few seconds just after the weld passes through the roll bite, allowing time for the mill settings to be adjusted, if necessary. The mill and uncoiler would then be accelerated to refill the storage looper.

Unfortunately, because of severe space limitations in the Nyby plant, it was only possible to install the mill between the storage loop and the furnace. This determined the following requirements for operation of the mill:

The strip must move through the mill at all times. Therefore, it must be possible to open the rolls wide enough to clear the strip.

It must be possible to change all the mill rolls with strip passing through the mill.

When a weld passes through the mill, it must be possible, whenever required, to

open the mill, reset the mill settings, and close the mill during the shortest time interval.

To avoid skidding of work rolls on the strip surface, it is necessary to continue to drive all the mill rolls at the same speed as the strip, whenever the rolls are open.

It must be possible to change both the work rolls and the intermediate rolls (of the Z-High) during passage of a single coil. Such coil is to be selected beforehand. This implies an allowable roll change time of approximately 20 minutes.

### ***Further Reasons for the choice of a Z-High Mill***

The requirement was to roll stainless steel strip (all grades) in the thickness range 1.7-6.5 mm and the width range 800-1600 mm, and to

## **Mill Technical Data**

<b><i>Material</i></b>	<b><i>Stainless Steel</i></b>
<b><i>Strip Width</i></b>	1550 mm maximum
<b><i>Strip Thickness</i></b>	6.0 mm maximum, 1.5 mm minimum
<b><i>Roll Separating Force</i></b>	20000 kN
<b><i>Rolling Speed</i></b>	50 mpm maximum
<b><i>Driven Roll</i></b>	Intermediate Roll
<b><i>Roll Face Width</i></b>	1700 mm
<b><i>Roll Diameters</i></b>	Backup Roll – 1150 mm, Intermediate Roll - 355 mm, Work Roll - 140 mm
<b><i>Strip Tension</i></b>	Entry - 200 kN max., Exit - 400 kN max.
<b><i>Gauge Control</i></b>	In-Gap Control, Feedback Control with additional prepositioning
<b><i>Thickness Tolerance</i></b>	+/- 8 um at thickness less than 1.5 mm
<b><i>Shape Control Actuators</i></b>	Screwdown Tilting, Lateral Shift of IR's Bending of IR's

take as big a reduction as possible in all cases (25% if possible).

In order to keep the capital cost down, a preliminary study was made to see if the existing 200 x 1150 x 1400 Schloeman MKW reversing mill could be used for this application.

A study was prepared to establish the maximum reductions (drafts) that could be obtained with the mill converted to a 4-high mill and also with the mill converted to Z-High operation.

The study revealed the following:

When converted to Z-High operation, the mill was capable of taking approximately 25-60% higher reductions than the 4-high mill (depending upon grade and width).

The reductions were limited by roll separating force for the harder grades and lighter gauges. Otherwise, they were limited by mill drive torque.

It was possible to achieve up to a 20% reduction (depending on width) at 6 mm starting gauge, increasing to the target 25% reduction at 3 mm and below.

Converting the existing MKW mill to a Z-High Mill thus enabled the strip width to be increased from 1250 mm to 1550 mm without the need to replace the most expensive part of the mill: namely, the housings, backup roll chocks, and backup bearings. Furthermore, the reduced work roll diameter of the Z-High mill (120-140 mm) enabled the full target-pass reductions to be achieved at the increased strip width without exceeding the load capacity of the bearings, chocks, or mill housing for most of the strip thickness, width, and alloy range to be rolled.

### Reduction Comparison Chart, 4-high versus Z-High

Entry Gauge: 3.0 mm  
Strip Width: 1050 mm

<b>Z-High Mill: Total No. Passes: 1</b>	<b>3.00 mm to 2.00 mm (33%)</b>
<b>4-High Mill: Total No. Passes: 3</b>	3.00 mm to 2.35 mm (22%)
	2.35 mm to 2.13 mm (9.4%)
	2.13 mm to 2.00 mm (6.1%)

### Performance comparison: Z-High versus 4-High

The Z-High stand is capable of rolling 1,550 mm-wide, non-annealed hot strip from an initial gauge of 3 mm to a final gauge of 2 mm in only one pass. For this deformation of 33%, a 4-high stand with the

same rating would require three passes. The use of 4-high stands on an annealing and pickling line would accordingly necessitate the installation of a tandem mill comprising three 4-high stands.

### The Gauge Control System

The Z-High stand at Nyby Bruk is provided with a sophisticated gauge-control system to achieve close gauge tolerances.

It is also the first one in the world to be equipped with "In-Gap" control, the roll gap being sensed directly beside the strip. In addition to the "In-Gap" control, the gauge-control system includes a feedback control, which will be used to compensate for long-term gauge variations as measured by the exit-thickness gauge and not detected by the "In-Gap" control.

The entry-thickness gauge permits evaluation of the trend of the incoming thickness variation and sends a correction signal to the "In-Gap" control. The gauge-control system also includes a feed-forward control, which can be used if the "In-Gap" control fails. The feed-forward control is used to compare the strip thickness at the stand entry with the reference thickness and to determine the adjustment of the screwdown on the basis of the measured gauge deviation. The adjustment, delayed by the time the strip travels to the roll gap, is transmitted to the cylinder stroke control on the screwdown.

## ***Setting the roll gap contour***

The Avesta Nyby ZR 613A-60 stand is provided with a hydraulic screwdown by short-stroke cylinders and with an electromechanical prepositioning arrangement for compensation of various backup and intermediate roll diameters. The passline is set by a wedge-adjusting mechanism acting on the lower backup bearing chocks. The required back tension is applied to the strip by a two-roll bridle at the entry side and by a four-roll bridle at the exit.

To ensure trouble-free mill operation and good strip flatness, the roll gap contour over the width must be precisely adapted to the strip gauge profile. For setting the roll gap contour, the Z-High stand is provided with a total of four actuators: one for roll tilting, one for bending the intermediate rolls, and two for lateral shift of the intermediate rolls.

## ***Shape control***

Roll tilting is easily achieved by simultaneously changing the screwdown position on the drive side and the operator's side.

Positive and negative bending of the intermediate roll is achieved by a bending arrangement fixed in the mill stand, the so-called "Mae West Blocks," acting on the chocks of the intermediate rolls.

For lateral shift of the intermediate rolls, which may have tapered or parabolic ends, Sendzimir-Sundwig has developed a hydraulic axial adjustment mechanism that permits positioning the intermediate rolls at a high lateral shift rate even with the roll force applied. Lateral shift of the intermediate rolls is actuated by hydraulic cylinders located on the front of the mill.

## ***Closed loop shape control system***

The stand is provided with a shape control system for automatic adjustment of the roll gap profile and hence of the tensile stress distribution in the rolled strip. The shapemeter system used is of the deflector roll type and replaces the normal deflector roll.

## ***Roll oil circulation system***

The in-line mill stand is provided with a rolling oil lubricating and cooling system. The

rows of nozzles supplying the lubricant/coolant to the strip are integrated into the support beams between the mill housings. At the stand entry side, only small amounts of rolling oil are used for roll gap lubrication. The exit side requires larger amounts of rolling oil for strip cooling. Strip cooling is necessary to protect the coating on the exit bridle rolls against excess temperature.

## ***Vacuum wiper system***

A vacuum wiper system is installed at the exit end, consisting of a squeegee roll unit with four rolls. The squeegee roll system is of the cartridge type so as to allow for quick removal towards the operator's side.

## ***Roll change robot and roll storage***

The in-line mill stand has been equipped with a roll-change system that allows both the work rolls and the Z-High roll cassette to be changed during the annealing and pickling process. For roll change, the screwdown is raised with the mill drive rotating, and the passline is lowered by wedge adjustment. During these operations, the work rolls are pressed against the intermediate rolls by the action of hydraulic cylinders so that rotation of the mill drive is not interrupted as the screwdown is raised. The work rolls and the Z-High roll set are changed automatically by means of the roll-change robot.

For the work roll change, the robot moves close to the front side of the mill stand. The long gripper arm of the robot seizes the work roll and withdraws it horizontally from the stand without the roll coming into contact with the strip or with the intermediate roll.

The roll loading carriage travels from the operator's side to a proper position to receive the work roll from the robot. The robot then picks up a new work roll from the roll loading carriage, inserting it into the mill stand in reverse order.

To change the Z-High cassette, a carriage travels from the operator's side close to the stand to receive the heavy Z-High roll cassette, which the robot has withdrawn from the mill stand. Rails mounted inside the stand and in the carriage guide the chock-mounted rollers as the roll cassette is shifted "out of" and "into" the stand. After the robot has inserted the Z-High roll cassette into the stand, the carriage for roll change moves sideways for a new Z-High roll cassette to



be shifted into the stand.

The entire roll change operation, including roll deposition of the roll loading carriage, is program-controlled.

After roll change, the mill stand is closed again. To avoid any slippage between the work roll and the strip, which is still running, the roll surface velocity must be synchronized with the strip speed, as the work rolls come into contact with the strip.

### ***Quick adjustment of the mill at welds***

A built-in computer program allows the mill operator to control the mill's appropriate reaction to welds.

### ***Rapid changing of lateral intermediate roll position***

It is possible to minimize off-gauge material in the coil ends when the mill is not under load by rapidly changing the position of the lateral intermediate rolls.

### ***Strip tracking control***

The strip is tracked to the middle of the line by means of the shape control system and a center-guide unit installed before the entry bridle.

### ***Tension maintenance***

In order to reach the required entry tension of 20 tons, it was sufficient to use a two-roll bridle unit. To reach an exit tension of 40 tons with an oily surface, it was necessary to use a four-roll bridle covered with high-friction material. To minimize the risk of slippage, the cooling oil is removed by a three-roll wiper system.

### ***Automatic flatness control***

The mill is equipped with an automatic flatness control system comprising a shapemeter roll, backup tilting, intermediate roll bending, and intermediate roll shifting. The shape is controlled primarily by intermediate roll bending and backup tilting, but in order to optimize the working points for the intermediate roll lateral position, the intermediate rolls are automatically moved during rolling.

## ***Installation of the mill***

According to the production situation, the installation took place in several carefully planned steps:

The old entry section from 1972 was removed and replaced by a completely new entry section that was installed and put into production after three weeks.

This new entry section had a layout that allowed the mill foundation to be built and the mill to be installed without disturbing production in the line.

The space under the floor of the mill and its bridles was prepared while maintaining production on the line. As the mill was to be located on a rock bed, most of the space had to be created by blasting.

The mill was erected next to the line, without disturbing production.

The bridles and the mill were moved sideways to their final position. This work caused a four-hour line stop. The strip was still passing above floor level in order not to interfere with further installation and trimming of the mill and bridles.

In a subsequent 24-hour stop, the strip line was changed to go through the mill. The work consisted of removing the upper bridle in front of the furnace and moving its gears and motors to the mill entry bridle and finally to put the entry and exit bridles into operation.

Three weeks later, rolling started.

## ***Start-up and operation***

This installation met very different requirements compared to conventional reversing cold rolling mills:

The mill was placed in a continuous line that is highly loaded.

Its annealing and pickling ability was not to be disturbed.

Not all 100% of the material was to be rolled.

As the line was feeding four Sendzimir mills in the Avesta group, it was possible to practice rolling without jeopardizing the final quality of the materials.

A considerable number of new and untested techniques were to be developed.

The mill was located under the floor. The operator neither sees nor hears the mill. He has only to rely upon instruments and TV cameras.

The mill is the first Z-High design with the following features:

Automatic shape control

In-gap thickness gauge system

Mechanized work roll exchange while the strip is running

Mechanized Z-High insert exchange while the strip is running

Mechanized backup roll exchange while the strip is running

Intermediate roll shift during rolling

The installation was complicated by the fact that 1958 mill stands were used.

Despite these circumstances, the mill went into production with very few unexpected difficulties. Trimming and calibration of all the equipment before rolling was complicated, but when rolling started, progress was realized very quickly.

Three days after the first seconds of interrupted rolling, rolling was successful for two hours. The shape control, which is very important for the reduction ability of the mill, operated in automatic mode after two weeks, and thickness goals were achieved.

The possibility of producing annealed materials in the line while preparing the mill for rolling has proved very successful. The majority of the maintenance work on the mill can be made while the line is running.