Integrated stainless steel rolling line for China

The unique properties of the Sendzimir Z-High® mill have enabled rolling, annealing, pickling and skin passing to be combined into one continuous line, producing high volume grade 2B stainless steel for the world market.

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The consolidation of the processes of rolling, annealing, pickling and skin passing into one line has always been commercially attractive and is a proven technology for the carbon steel industry. However, for stainless steel, the situation is more problematic, because stainless hot band, unlike carbon steel, is already work hardened to some extent. For this reason, and also because the surface finish on stainless steel is usually more critical, standard practice has always been to anneal and pickle the hot band before cold rolling.

Stainless steel is a high-value product where overall yield is critical. In addition, special reduction rolling technologies are required to address the material's rapid work-hardening characteristics, together with skin passing technologies that deliver the surface finish and temper required by the market.

History of the concept

The concept of directly rolling stainless hot band without annealing was first proposed by Avesta in the late 1980s. At that time Avesta could not produce hot band thin enough for some of its tube-making plants, and it was necessary to cold roll the hot band, usually with a single pass. Avesta's idea was to relocate an existing 4-high mill (Schloemann MKW type) in the annealing and pickling line in its plant at Nyby Bruks, Sweden, at a location just ahead of the annealing furnace. Avesta asked Sendzimir to study the feasibility of this concept, and it was concluded that the desired reductions could be achieved, provided that the 4-high stand was converted to a Z-High.

The reason that the Z-High configuration should be used in this application, rather than 4-high or 6-high stands, is that only relatively small work rolls can achieve the required reductions at sustainable roll force levels, and only relatively large drive rolls can deliver the large torque to achieve such reductions. No other mill type has this combination of characteristics.

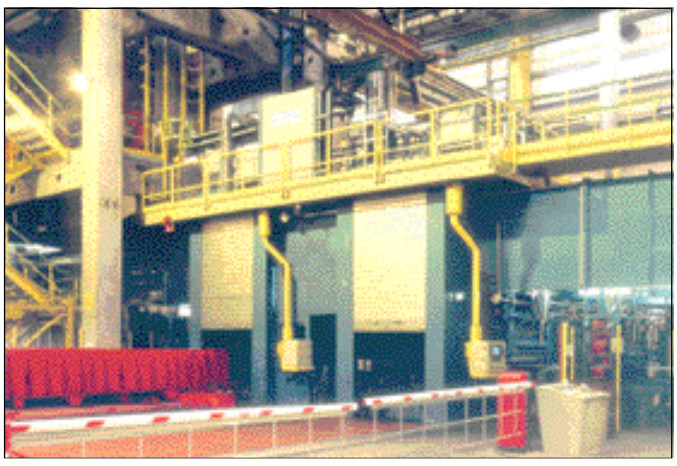
In due course the Z-High was installed and, for the first time on a production basis, hot band was directly cold rolled without prior anneal. The surface finish of the product was quite satisfactory for tubing, chemical vessels, and other products with non-critical surface finish requirements. The Z-High must be operated with high entry and exit tensions, so new entry and exit bridles were installed. In addition, both strip coolant and strip wiping systems were added.

Unlocking the massive production potential of a fully integrated stainless steel rolling and processing line producing 2B quality product from No. 1 hot band requires both maximisation of line-up time and effective integration of all the line's processes. These attributes are even more critical in the case of the relatively slow stainless steel reduction rolling process.

Extension of the concept to rolling surface-critical strip

The Avesta concept gave an excellent return on investment primarily because it increased the capacity of the plant by producing finished product directly from the hot line, eliminating cold rolling. Ugine's engineers realised the concept could be extended to surfacecritical strip by installing more than one Z-High stand in the line. It was thus possible to ship many more products without using the reversing cold mills. (Theoretically, if a sufficient number of Z-High stands are included in the line, no reversing rolling

● **Figure 1**
Ugine Z-High Tandem Mill



would be required.) *Figure 1* shows the Ugine Z-High tandem mill.

Since the average finish gauge shipped from stainless steel plants has been decreasing over the years, a greater quantity of cold rolling is required to produce the same tonnage of final product. In order to optimise the cost/benefit ratio while minimising the capital investment, Ugine decided to limit the number of Z-High stands to two, with space for a third. This decision liberated the capacity of the existing reversing mill stands for the increasingly lighter gauges foreseen in the future.

To achieve the desired results, the concept was also extended to include:

- A pickling section at the entry end to remove all traces of scale before rolling
- An additional looper between the pickling section and the mill stands
- A skin pass mill/tension leveller at the exit end of the line

Integrated stainless steel rolling line for China

The next phase in the development of in-line rolling provided producers the opportunity to become independent of cold rolling. In 2003, VAI UK designed such an integrated stainless steel rolling and processing line for Lianzhong Stainless Steel Company (LSSC) in China. This line achieves both high volume and value-adding potential by maximising the reduction capability of the rolling section while ensuring maintenance of 2B strip surface finish quality and shape without further conventional cold rolling.

For LSSC, the operating mode has been modified from that of Ugine in that annealed and pickled hot band is delivered to the plant, thus eliminating the pickle section and additional looper at the entry end. Furthermore, the number of Z-High stands was increased to three so that lighter finish gauges could be produced.

One key driver in ensuring maximum possible line up-time is coil-to-coil weld integrity. VAI UK included two welding machines, one mash lap and one shear arc, to ensure maximum weld strength for the range of materials and grades to be processed (see *Figure 2a*).

Another driver in ensuring finished product of the highest possible quality is the stability of each process. Specially designed high-tension bridles on the entry and exit sides of the tandem mill work in conjunction with the high-capacity entry and exit loopers to control strip tension and ensure continuity of rolling. The passage of a coil weld through the mill, which often signals a change in strip section, places particular demands on both the accurate setting, as well as the control, of the level of strip tension. Loopers, similar to the mill loopers, are located at the exit of the pickle section and the skin pass mill/tension leveller to ensure stable operating conditions in these sections.

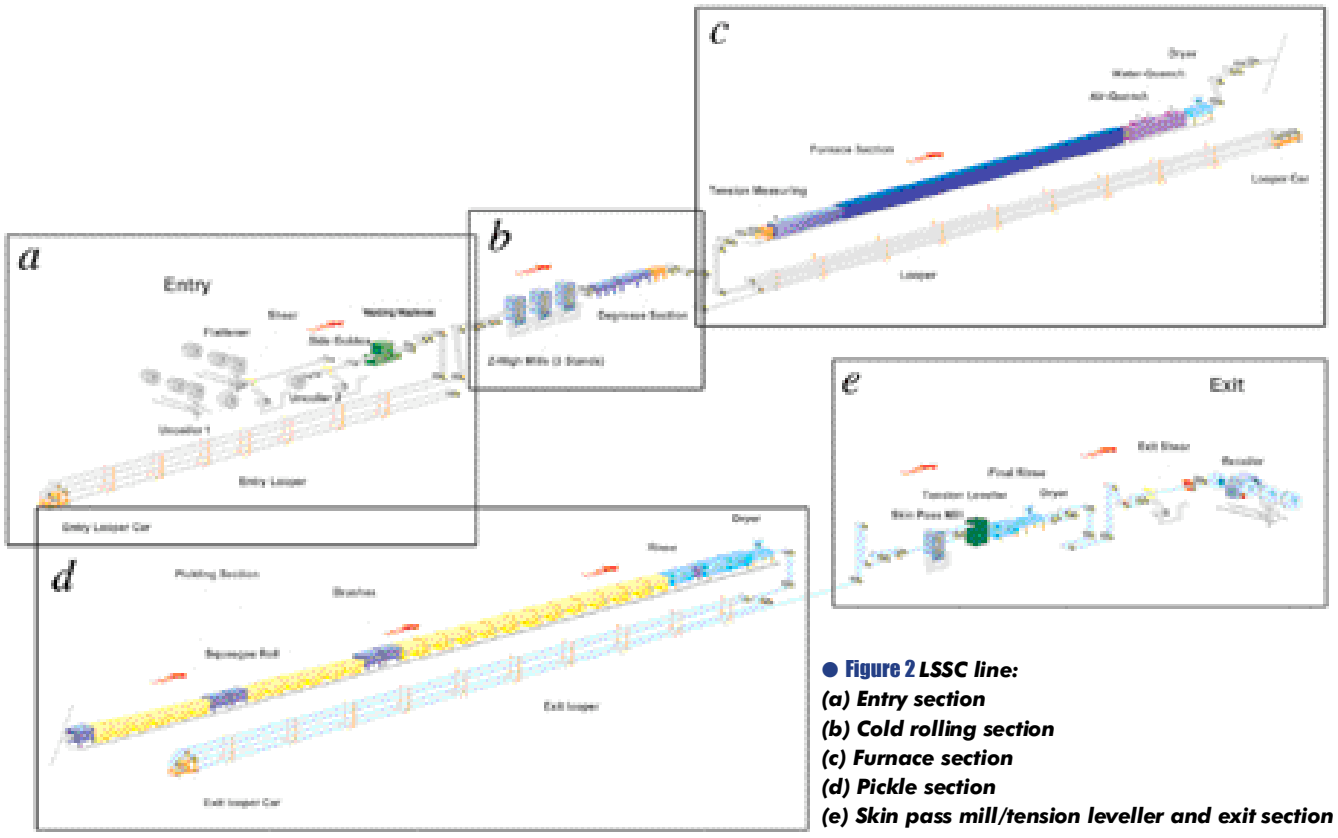
Drawing on VAI's previous experience of supplying integrated stainless steel lines to Ugine and Acesita, the new three-stand tandem Sendzimir Z-High mill concept has extended the previous rolling reduction performance boundaries and VAI has successfully addressed the design problems generated by the significantly differing entry and exit strip thicknesses and speeds.

The key to ensuring maximum reduction capacity lies with the Z-High mill (see Appendix). This concept integrates seamlessly with the VAI mill stand features that are designed specifically to meet the demands of virtually continuous in-line operation. These features, several of which are patented, include special disengagement mechanisms for the first intermediate chocks and axial shift cylinders, automatic lubrication connections, work roll separation devices, and roll change.

Even with stainless steel's rapid work-hardening characteristics, overall reductions of up to 70% are possible with the Sendzimir/VAI three-stand mill design. However, this high reduction capability further exacerbates the normal challenges presented by weld passages through the mill, changes in coil-to-coil strip section, and frequent work roll changes. Each weld passage through the mill falls into one of three categories: rollable welds passed with only a reduction in strip speed, semi-rollable welds passed with a reduction in roll load and speed, and un-rollable welds passed with a reduction in speed and open mill gap. The category to be used is automatically selected and depends on changes in material composition, grade, width, and thickness. Un-rollable welds present the greatest control challenges, and in order to increase yield, each stand is opened and closed sequentially as the weld passes through. This method greatly reduces the unrolled material length but requires very careful control of tension, speed, and load as each mill stand opens and closes. The mill's automatic set-up and operation further ensures high production.

Automatic gauge and shape control, combined with the Z-High mill's features of intermediate roll bending and shifting, quickly re-set each stand whenever a coil-to-coil change includes a significant section change.

The other key mill function requiring close control is that of roll change. VAI's patented work roll change ensures that both work rolls in each stand are changed automatically within 2.5 minutes and, if necessary, on all three stands simultaneously. Roll change, when required, is initiated by the arrival of the weld at the final stand, while the mill exit looper ensures continuous operation downstream. To maintain strip surface finish, the stand 3 work rolls are changed with approximately three times the frequency



● **Figure 2** ***LSSC line:***
(a) Entry section
(b) Cold rolling section
(c) Furnace section
(d) Pickle section
(e) Skin pass mill/tension leveller and exit section

of stand 1, with stand 2 rolls being changed at approximately twice the frequency of stand 1. VAI provided special change devices for handling both the work rolls and the Z-High inserts in and out of each mill stand, and for transportation to and from the roll shop. Ensuring continuity of roll supply to the mill is a critical sub-process.

High-quality strip surface finish demands the effective removal of mineral rolling oil from the strip. The VAI-designed mill exit wipers, combined with a specially designed degrease section located after the tandem mill (see *Figure 2b*), prepares the material for annealing and pickling. In the degrease section, use is made of alkali cleaning, rinsing, and drying.

Proven annealing section technologies of waste gas preheating are provided, with specially designed air and water cooling to ensure the maintenance of strip shape (see *Figure 2c*). In addition, pickle section technologies of electrolytic and mixed acid pickling with double brush scrubbers, high turbulence line tanks provide optimum pickling at speeds up to 125m/min, with brush and spray rinsing to ensure strip cleanliness (see *Figure 2d*).

As with the tandem mill, the VAI-design skin pass mill is provided with automatic elongation control. In order to cope with coil-to-coil material section changes, the mill has specially designed high-capacity roll bending so that roll camber can be adjusted quickly and automatically from coil to coil. Special strip brushes and roll polishers ensure the best possible surface finish. The high-speed work roll change is designed to ensure continuity of operation. Optimum strip shape and finish is attained by the VAI wet tension leveller, which is also provided with a rapid opening function for weld passage (see *Figure 2e*).

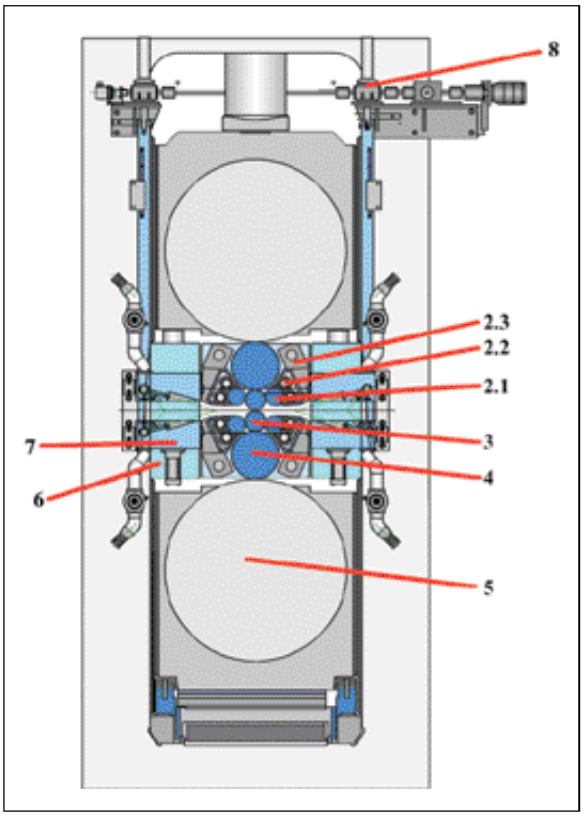
Finally, a highly sophisticated line speed control system integrates the rolling and processing operations, which are fully optimised to address the different requirements of each processed product.

Summary

This integration process successfully combines the high-reduction rolling capability of the Sendzimir Z-High mill with leading-edge annealing, pickling, and skin passing processes of VAI design to establish a new benchmark in the high volume production of 2B quality stainless steel to the world's market.

Appendix Description of the Sendzimir Z-High mill (see *Figure 3*).

1. 6-high mill having side supported work rolls.
2. The side support assemblies, mounted at both entry



● **Figure 3** ***Description of the Sendzimir Z-High mill***

and exit sides of the work rolls, each consist of the following:

2.1 A side support roll, chock mounted in a cluster arm.

2.2 Two rows of side support bearings, each row mounted on a stationary shaft, each shaft being mounted in, and supported by saddles formed in the cluster arm.

2.3 A cluster arm, pivot mounted on and between front and back intermediate roll chocks.

3. The work rolls have no chocks, but float freely in the mill. These rolls are axially located by work roll thrust bearings, mounted in front and back doors.

4. The intermediate rolls are mounted in chocks, and can be axially shifted within the chocks, using hydraulic cylinders, which are mounted in fixed locations on the drive side of the mill. The intermediate rolls can also be bent 'crown-in' and 'crown-out' using hydraulic roll bending cylinders, which are mounted in stationary 'Mae West' blocks (housing blocks). Intermediate rolls are driven.

5. **Back-up roll assemblies**

These rolls and their chocks are identical to 4-high mill backup roll assemblies. Back-up rolls are non-driven.

6. **Mae West blocks (housing blocks)**

Similar in principle to blocks used on 4-high and 6-high mills, these are used to provide transverse location of intermediate chocks and rolls, and, by means of keeper slots, to provide axial location of intermediate roll chocks. These blocks are bolted and keyed solidly to the mill housing.

They are also used (a) to provide backup roll balance by means of hydraulic cylinders (b) to provide a solid mounting base for the side support beams (c) to provide a mounting base for front and back door hinges and latches. They are also used as a mounting base for spindle support clamps and axial shift cylinders, and for mounting roll removal rails.

7. **Side support beams**

There are four of these beams, mounted between front and back Mae West blocks, at upper left, upper right, lower left and lower right. They are used to transmit the transverse forces on the cluster arm assemblies (caused by torque transmission from intermediate roll to work roll) back to the mill housings.

The side support beams are also used to mount the spray nozzles used for roll and strip cooling. Zone sprays can be used but are not usually needed. Also horizontal preload cylinders are usually mounted in the beams.

8. **Beam adjustment drives**

The beam positions can be individually adjusted for each of the four beams by a horizontal motorised screw/nut adjusting system to compensate for roll wear.

9. **Front and back doors**

These are small hinged and latched devices which incorporate work roll thrust bearings. They are also used to deliver lubricating oil to intermediate roll bearings and side support bearings.

Preload cylinders

These cylinders act horizontally in the transverse direction, and one of these is mounted in each of the exit side support beams.

Their function is primarily to ensure that the exit side support roll and bearings are lightly loaded against the work roll, and thus not liable to surface degradation caused by scuffing.

Z-High® is a Sendzimir registered trademark

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