Development of the Z-High® Design

The first cluster mills with small-diameter work rolls came on the market in the early 1930s. They were initially used to roll low-carbon steel and very special materials in narrow widths. It was only in 1950 that the industry fully recognized the suitability of the Sendzimir cluster mill for rolling stainless steel.

In the 1970s, strip width increased from 36" up to 50" and thereafter to 64". Superimposed on this development was the use of silicon steels in 800mm widths for oriented-grain, and wider for non-oriented. Today, 1250mm-wide cluster mills are rolling silicon steels. Cluster mills with roll diameters of 6mm to 100mm are also used for non-ferrous metals, including brass, copper, bronze, Monel, Inconel, invar, covar, titanium and its alloys, and alloyed steels, as well as, medium and high-carbon steels.

In total, some 500 Sendzimir-style cluster mills are now in operation throughout the world. They have a definite share of the metals rolling market, and their use is going to increase for rolling hard alloys to thinner gauges and in wider widths, with Europe and Japan leading in the development, use, and application of powerful cluster mills (mills with 6000 to 9000 HP mill motors).

In the 1970s, with the oil shortage and the consequent need to promote fuel economy for automobiles, American cars had to be downsized and made more efficient. It became evident that the way to do this was by reducing weight by using stronger steels in thinner gauges. The bumpers, frame, door posts, rocker panels, and outside metal of new cars, if not substituted by plastic or aluminum, have been reduced in thickness.

Thinner, stronger steels had to be of better quality. Low-alloy steels with a higher carbon content and other alloying elements were tried. HSLA steels were developed and are widely used today. Steels with strengths of 90,000 psi have been incorporated by Fruehauf Corporation of Milan, Michigan, in the construction of frames for their trailer trucks. Similar adjustments have been made in the passenger car industry.

The harder alloy steels required conversion of existing installations. In order to process higher-strength steels, the equipment used for making flat products had to be upgraded.

To that end, Sendzimir worked for nearly two decades to use the technology acquired through development of the cluster mill in order to improve the design and performance of classical mills such as the 4-High.

One of the advantages of the cluster mill was axial displacement of the intermediate rolls, which permitted control of the shape of the strip edge. The intermediate rolls on cluster mills were ground at one end into a cone or a parabola. By moving the rolls towards the center of the mill, less pressure was applied to the edges, and the edges became tighter. By moving the rolls "out", more pressure was applied to the edges, and the edges were overrolled.

This principle was applied to the 4-High mill by making the work rolls of the 4-High mill axially displaceable. This adjustment had one defect: the work rolls of the 4-High mill became more complicated. They had to be ground with a shape and had to have a substantially longer body. Had we stopped there, the work roll cost per ton rolled would have increased.

We brought some of these ideas to Japan, where the engineers of Sendzimir Japan brought them to a higher technical level. There was also development of straight 4-High mills without any lateral support and with work rolls on the central line but approximately one-sixth the diameter of the back-up roll. These mills are limited by the problem of lateral bending.

Since a significant amount of capital has already been invested in the infrastructure of the steel industry, the logical approach to the problem was to revamp and upgrade existing equipment. Consequently, Sendzimir went to work to develop a design using small-diameter work rolls that would fit into existing mills and give those mills the ability to take bigger reductions on harder materials. Simultaneously, by allowing for shape control through axial displacement of the intermediate rolls, these mills could produce better flatness. In short, better surface and better gauge accuracy became keywords of what would become the Z-High®.

Conversion of a standard 4-High mill into a Z-High® involved installation of lateral beam supports, a mechanism for axially displacing the intermediate rolls, and doors for holding the thrust bearings of the work rolls.

The Classical 60 Series 18-roll Z-High® Mill

The 4-High mill's work rolls are spread vertically apart in order to accommodate the Z-High® mill's small-diameter work rolls, whose diameter can vary in the ratio of approximately 1 to 2. These work rolls have no necks and no bearings. They are free to float axially and are restrained in their axial movement by thrust bearings located in the doors of the mill. They are laterally supported by an intermediate set of slightly smaller diameter rolls, each of which, in turn, is nestled by two shafts containing bearings. There are no saddles on these shafts. Any force vector generated by the work roll is transmitted to the backing beam, which is attached to the housing.

Since the main rolls are in the vertical line of the mill, statically there should be no side force component at all if we are on a perfect dead center. However, once rolling torque is imparted to the rolls, this torque will generate a lateral force on the work rolls that will have to be absorbed by the bearings and thence by the side frame housings. This side force, in normal operation, is a small fraction of the vertical roll separating force. It is important that, whenever the roll diameters are changed, the realignment of the mill is always made to its vertical line. It is also important that the entire cluster be firmly closed together so that all components rotate and there is no misalignment, or skewing, which could generate chatter.

It should be obvious that the sense of rotation of the main mill motor will have to be reversed. This is actually the only electrical correction that has to be made. Winder motor speed ranges and winder tensions can remain the same.

For displacing the intermediate rolls axially, there are several concepts. The amount of axial adjustment depends upon the width of the mill, but for a 40" wide mill, approximately 8" might be the correct movement.

Inasmuch as a smaller-diameter work roll will not retain its finish for as long as a big-diameter 4-High work roll, the small roll can be changed in a matter of approximately 60 seconds. No special jigs or fixtures are required, even though an automatic work roll change mechanism could be provided.

This is the same technology as is used on Sendzimir cluster mills. Moreover, the small-diameter work rolls can be made of through-hardened steel and can withstand regrinding down to their minimum diameter without losing their hardness or basic metallurgical characteristics.

All of what has been said above has referred to the revamp of existing mills into Z-High® mills, or the construction of new 4-High/Z-High® combinations. However, should we design a pure (nonconvertible) Z-High® mill right from the beginning, we would make such a mill considerably smaller in size. Assuming that each pass would take the same amount of reduction as an equivalent 4-High, the Z-High® would nevertheless have the ability to continue making passes and reducing the metal beyond the point at which roll flattening on a standard 4-High would prohibit further reduction. On the Z-High®, due to smaller-diameter work rolls, the roll separating force is smaller. Consequently, the diameter of the backing roll and its bearings can be substantially reduced in size. With smaller-diameter back-up rolls, the housing can be scaled down in weight to approximately half the size of an equivalent 4-High housing. In effect, we would then produce a rolling mill that could be substantially lighter and less expensive while being more efficient.

Waterbury Rolling Mills, Waterbury, CT

The first Z-High® mill contract was signed in 1979 for retrofitting a Ruesch 4-High mill located at Waterbury Rolling Mills (WRM) in Connecticut. The WRM plant produces more-difficult non-ferrous alloys by melting, continuously casting, scalping, hot rolling, pickling, and, finally, cold rolling nickel-silver and phosphor-bronze. In the 4-High configuration, the work rolls were 3.50 to 4.25" in diameter, and the back-up rolls were 13.5" in diameter. The strip width rolled was 14" maximum, which meant that for a number of applications the mill was too narrow.

Sendzimir outfitted the Ruesch WRM mill with a ZR 64-16 retrofit. The work roll diameter was reduced to 1.6", and the intermediate roll was set at 3.08". Hand-operated axial displacement was incorporated.

Sendzimir was the primary contractual party, and the manufacture was performed by Ruesch. The Z-High® retrofit started operation on January 3, 1980, and it was immediately evident that the mill could take a heavier total reduction. Moreover, with axial displacement of the intermediate rolls, the shape of the strip was considerably improved, even though the tension on the winders remained the same. The only electrical adjustment was reversing the leads to the main mill motor in order to change the sense of rotation.

The WRM 4-High mill had an electromechanical screwdown without any automatic gauge control, and the strip gauge was measured by two Pratt and Whitney contact micrometers. After the retrofit, the operator of the mill immediately noticed that, even without touching his screwdown button, the variation of the gauge was very substantially reduced and could be kept within 0.0003". Moreover, due to the facility of changing work rolls, it was possible to substantially improve the surface of the finished strip.

Approximately a month after start-up, the Z-High® ran out of its initial set of four work rolls. The mill was reconverted to a 4-High for approximately two weeks. As soon as spare Z-High® work rolls arrived, the Z-High® was reinstalled.

Kamani Metals, India

The second Z-High® was ordered by Kamani Metals and Alloys of Bombay, India, for installation in their Bangalore plant. The Kamani Z-High® was also a retrofit unit into an existing 4-High mill, but it was somewhat bigger and of the ZR 65-15 type. The mill was to roll carbon steels. The work roll diameter was 2.25" nominal, the intermediate roll diameter 5.25" and the back-up roll 19.7".

In the case of the Kamani mill, Sendzimir supplied certain critical components from the United States but otherwise delivered drawings for manufacture by Kamani in India.

Hamilton Precision Metals, Lancaster, PA

The third Z-High® was also of the ZR 65-16 type, but this time for Hamilton Precision Metals in Lancaster, Pennsylvania. This new 4-High/Z-High® mill was built entirely by Ruesch, with Sendzimir providing the Z-High® design. This mill was meant for the rolling of stainless and other alloys. Maximum strip width was 16" and the mill motor 250hp. Since Hamilton’s was a brand new mill, the winder tension was increased to 16,000 lbs. The mill was shipped in November 1981.

Tokushu Kinzoku Kogyo, Japan

The fourth Z-High® was ordered by Tokushu Kinzoku Kogyo (TKK), near Tokyo, Japan. TKK is a reroller of high-carbon steels, including steel used in making tape measures, of which they export 60% to the United States. They have a total of 18 rolling mills, some of which are 4-Highs, others 5-Highs and even 7-Highs. Most of the TKK mills were designed in their own plant and built in their own works.

The Z-High® retrofit was of the ZR 64-13 type. The mill was to roll stainless and high-carbon steels. The minimum gauge was 0.1mm (0.0025"), and the mill motor was 220kW.

The design of this mill was done entirely by Sendzimir Japan (SEJA), using drawings established by T. Sendzimir, Inc., in Waterbury. SEJAL was responsible not only for design, but also for ordering the materials and managing construction of the unit. Start-up took place in May 1981, and some three months later, TKK was so pleased by this operation that they ordered three more conversions: Two of those were for existing mills and one for a new mill yet to be built.

Arrowhead Metals, Toronto, Ontario

The fifth order was a tandem mill for brass and copper. The order was obtained by Ruesch, and the two stands were of a 4-High/Z-High® combination of the ZR 64-15 type. The minimum thickness to be achieved was 0.0015", and the maximum speed of the mill, on the finishing passes, was to reach 3000 fpm.

Universal Cyclops, Coshocton, OH

The number 6 unit was ordered by Universal Cyclops for the Coshocton, Ohio, plant and was the biggest Z-High® retrofit to be contracted up to that point – a ZR 67BB-30. This mill was to roll stainless steel at a maximum top speed; in the 4-High mode, it would seldom exceed 300 fpm.

The ZR 67-30 insert had work rolls of 3.25", intermediate rolls of 7.3", and back-up rolls of 28" nominal diameter. Soon after the order was placed, Universal Cyclops also placed an order for an adequate supply of rolls, and the mill started operation during the summer of 1981.

Takasago Tekko Kogyo, Japan

In Japan, stainless steel manufacturer Takasago Tekko Kogyo (TTK) also placed a retrofit order with SEJAL for a ZR 64-15 module to roll stainless steel. That unit was built in Japan and started operation soon after the No. 1 mill at TKK was made operational.

Today, the number of Z-High® mills continues to grow, with new applications being developed. Arcelor now has two Z-High® mills in tandem at Ugine, in France, as well as at J&L Midland, in Pennsylvania. The keypoint of the in-line processing of stainless steel, the tandem configuration is designed to take total reductions of up to 60%. In the future, the Z-High® is expected to play a major role in the continuous casting of thin strip, where its unique abilities will contribute the high value added attributes of good strip shape and surface quality.