THE NEW PLANT FOR SPECIAL STEEL LONG PRODUCTS AT HYUNDAI STEEL COMPANY *

Bruce Kiefer [A]
Luigi Giacomini [B]

Abstract

A new plant for special steel long products was commissioned in recent years at Dangjin, South Korea, for Hyundai Steel. Two multi-line rolling mills can produce yearly 1 million tons of billets, straight and coiled bars, with dimensions from 5.5 to 350 millimeters. The products are used for manufacturing engine and transmission components used by Hyundai Kia Automotive Group. The processed grades include carbon, special alloy, spring, bearing and free-cutting steel.
The first mill rolls blooms into finished large round and square products, as well as into intermediate billets. A 2-high reversing breakdown stand is followed by a finishing and sizing train with CGA stands equipped with an under-load roll parting system for automatic gap control.
The second mill combines lines of small bars, rods and bars-in-coil. Billets are rolled in a continuous rolling mill with original RedRing Series 5 stands. The rod outlet features Morgan No-Twist and Rod Reducing/Sizing mills, Morgan High-Speed Laying Head and Stelmor conveyor.
Advanced sensors and electronics integrate with mechatronic packages, thus equipping the mill for Industry 4.0 applications.
Hyundai can meet the demanding requirements posed by the automotive industry and benefit from optimized conversion costs, the flexibility to meet market changes, achieve high product quality, and reduce floor personnel.

Keywords: Large Bar; Small Bar; Wire Rod; Bar in Coil; Special Steels; Automotive.

[A] *Engineer - Primetals Technologies, Worcester, USA*
[B] *Engineer - Primetals Technologies, Marnate, Italy*

1 INTRODUCTION

Hyundai Steel (referred to as Hyundai) belongs to the Hyundai-Kia Automotive Group and runs several production facilities in South Korea and China. The plant at the Dangjin site produces special steels mainly for the automotive and specialty steel industry. Bars and wire rod products are rolled as primary material for engine and gearbox parts.

For the special steel mill in Dangjin, Primetals Technologies has supplied a continuous bloom casting machine with a yearly capacity of 1.1 million metric tons, a large bar mill (referred to as LBM) and a combined mill for the production of small bars, wire rod and bar-in-coil (referred to as SBWRM).

The four-strand bloom continuous casting machines feed the large bar mill with hot blooms in order to save energy during reheating. The billets produced by the large bar mill, which has a yearly capacity of 1 million metric tons, are input for further rolling to the combined small bar and wire rod mill, which has 0.8 million metric tons of annual capacity. In the future, the large bar combined mills can be upgraded to 1.5 and 1.2 million tons, respectively.

The process equipment supplied for the Dangjin installation complies with the tight requirements imposed by the automotive quality steel users, including controlled metallurgical structure, size tolerance and finished surface quality.

Special mechatronics packages and an integrated automation solution ensure the necessary high product quality throughout the plant.

2 PRODUCTS AND PROCESSING

The steel grades rolled in the Dangjin plant are mainly for automotive use and include carbon, low-alloy, special-alloy, free-cutting, spring and bearing steel.

The LBM mill shares its 1 million ton capacity among some 800,000 tons of billets which serve the SBWRM mill and 200,000 tons of other large bars. The product mix includes 150 mm and 180 mm billets, 80 – 350 mm rounds and 85 – 180 mm finished squares that are 10 – 12 m in length. The starting bloom is 530 x 390 mm with lengths of 3.5 – 8 m, weighing 5.7 – 13 tons. The mill runs at a maximum speed of 1.1 m/s with a maximum production rate of 200 t/h. The produced bars measure 4 – 12 m in length, with bundles weighing 2 – 10 tons.

With an annual capacity of 800,000 tons, the SBWRM produces some 400,000 tons of wire rod, 300,000 of small bars, and 100,000 tons of bars-in-coil. The product mix includes 5.5 – 26 mm wire rod, 16 – 100 mm rounds and 16 – 60 mm bars-in-coil. The starting materials are 150mm and 180 mm billets produced by the LBM; 200 mm billets can also be used. The mill runs at a maximum speed of 110 m/s for wire rod and 18 m/s for bar, with a maximum production rate of 160 t/h. Straight bars are finished-sized by a Kocks block and produced in 4 – 10 m lengths in 1 – 5 ton bundles. Produced coils of wire rod have an inner/outer diameter of 900/1250 mm. The bars-in-coil are finished-sized by a Kocks block and have an inner/outer diameter of 1,000/1,350 mm. Coils from both the wire rod and the bar-in-coil lines weigh 1.7 – 3 tons, and are handled by a common combined vertical/horizontal conveyor system.

3 LBM MILL

Hot blooms, coming from the casting machine, are discharged on the furnace entry roller table by an elevating transfer mechanism. Cold blooms are loaded onto a charging table by overhead cranes with magnets and are delivered to the furnace charge roller table by a transfer mechanism. Weight and length measuring devices are provided.

The Tenova-supplied walking-beam furnace has a nominal capacity of 200 t/h and provides a heating temperature range of 1,050 – 1250 °C. The walking beam design allows for uniform heating and low decarburization, minimizing gas consumption through reduced thermal losses and use of a combustion air recuperator.

In order to improve the product surface quality, the heated blooms are descaled with high-pressure water descaler (250 bar max) before entering the break-down stand. A second high-pressure water descaler is installed to provide further cleaning before the rolling stock enters the continuous train.

The mill train comprises seven stands. The first stand is a reversing break-down stand, while the continuous finishing/sizing train has three rolling stands and three sizing stands, all arranged in horizontal/vertical mode. The rolling stock is free between the break-down stand and the continous train. This arrangement permits the break-down to operate at the desired speeds and minimize temperature loss.

Break-Down Stand

The break-down mill BDM 47" is a two-high housing-type reversing stand (Fig. 1). The rolls have a maximum diameter of 1,200 mm and a barrel length of 2,600 mm. The stand is designed for fully automatic operation and ease of maintenance.

An odd number of passes (maximum thirteen) is rolled at the break-down. A uniform pass sequence prepares the feeds required to roll the whole range of finished sizes and shapes, as per the Single Family rolling concept, with only a few variants for square products and larger rounds.

The top roll vertical position is adjusted by a screw-down system, while the bottom roll vertical position is adjusted by a hydraulic capsule, which also provides the automatic positioning for change operation and a quick-release function in case of jamming.

Wear parts like the screw-down system use special coatings (Nipre®, Nitox®) for extended lifetime and reduced friction. Asymmetrical bending of rolls is compensated by an independent servo-controlled mechanism. Chocks are hydraulically clamped to ensure the rigidity and permit a quick change operation. Rest bars are fitted on chocks.

At both sides of the break-down mill the rolling stock pass change is assisted by heavy-duty lineals with tilting fingers. The lineals also provide a straightening force on the stock between passes.

When the material entering the break-down stand comes from ingot-casting (instead of continuous casting), surface defects may appear during the break-down rolling and need to be removed by a customer-supplied hot scarfing machine located after the break-down.

Before the continuous train, a 1,000 ton hydraulic shear is used to crop the head of the rolling stock. To ensure a smooth cut, the shear is hydraulically balanced, while pressing devices reduce the bar deformation during the cut.

Figure 1 – Break-Down Stand with Bar Lineals

Continuous Finishing/Sizing Train

A device rotates the incoming bar 45° for the square rolling finishing sequence, and a secondary high-pressure device descales the bar.

The finishing rolling train comprises three original RedRing® Series 5 stands, arranged in vertical/horizontal/vertical configuration. The nominal roll diameter is approximately 1,000 mm and the barrel length is 1,200 mm. RedRing (for REDuced RING of stresses or stress path) is a proprietary design presently in its fifth generation, included in more than 7,000 installations by Primetals Technologies.

The finishing sizing train comprises three CGA (Continuous Gap Adjustment) stands arranged in horizontal/vertical/horizontal configuration (Fig. 2). The nominal roll diameter is approximately 850 mm and the barrel length is 1,200 mm.

CGA sizing stands feature a two-roll, multi-groove configuration, designed in response to automotive market requirements of tolerance, quality and flexibility. The hydraulic preload, with a selectable value according to the calculated required load for each size and material, ensures precise size tolerances and surface finish starting with the very first bar. It also serves as an emergency release in case of cobbles and, in combination with the mechanical adjustment, enables the under-load adjustment of gap.

Rolling small lots or with frequent size changes is made feasible by pre-setting the stand offlineand by the short times required for groove or stand change. Free Sizing, that is rolling intermediate sizes only by gap adjustment and within tolerance, is also possible.

Chocks of both RedRing and CGA stands are hydraulically balanced to ease the rolling operation and ensure close tolerance from head to tail. Vertical stands are top-driven, which removes the risk of water or scale contacting the drive group. The stand roll gap is symmetrically adjusted.

The three RedRing stand cartridges are interchangeable among each other, as are the three CGA stand cartridges. A quick-change system assists the finishing/sizing train, allowing stand changes to be done in minutes.

The installation of the continuous finishing/sizing train allows the whole range of sizes and shapes to be rolled using feeds prepared with a uniform pass sequence in the break-down stand, as with the single family rolling concept, with only a few variants required for square products and larger rounds.

Rounds up to a diameter of 220 mm and squares are finished by the CGA sizing train, while larger rounds are finished at the RedRing train. A diamond-square pass design is employed to guarantee the correct shape and edges of square products.

Figure 2 – CGA Sizing Train

Inline Gauge

The finished bar is checked in an inline ProScan gauge (Fig. 3), which measures the bar profile using cameras and lasers. Water cooling and air purging protect the gauge head. ProScan measures the full profile of the final product and indicates any deviation of dimensions, allowing the operator to correct the working parameters in real time.

Recorded measures are stored for each production run and offline analysis enables the identification of corrective actions to be taken, fostering the increase of productivity and improvement of quality.

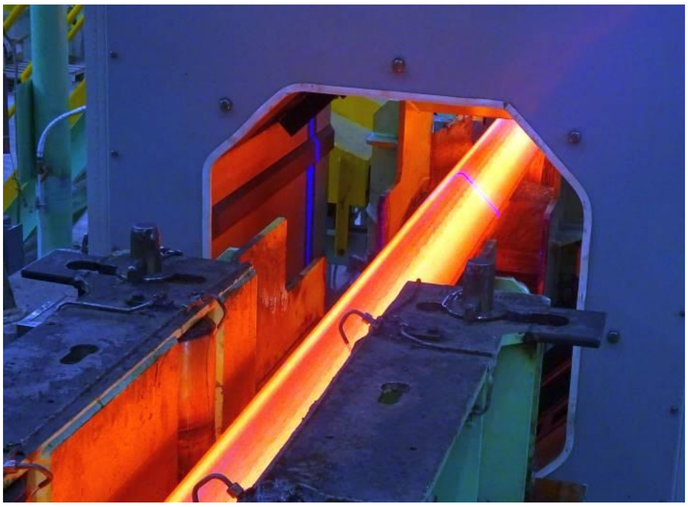

Figure 3 – Inline ProScan Gauge

Dividing
Round bars up to 140 mm are divided by a start-stop flying crank shear with a 270 ton nominal cutting force. The shear also provides front and tail end crop cuts which are collected in a bucket below mill floor level.

A software program optimizes the cut lengths according to the actual bar weight and size, compensating for differences of bloom weight and of crop amounts, while ensuring that only multiples of commercial length are processed by the cut-off station. Short bars which need to be disposed of are either chopped by the shear or moved to a collecting saddle before the cut-off station, depending on the actual length.

Bars are grouped in layers on a chain/car table and transferred to the cut-off station for commercial length cutting. The cut-off station (Fig. 4) comprises two horizontal saws equipped with 1,800 mm diameter metallic disks, which divide bars with the required high-quality cuts. The horizontal cutting travel is provided by a hydraulic cylinder, controlled by a linear transducer and proportional valve. Bar layers under cutting are securely clamped in place at both sides of the disk, which is cooled and cleaned by high-pressure water. The disk is appropriately encased to avoid spilling cooling water onto the bar, and to prevent bar surface damage or undesired hardening effects. Crop cuts of bar ends are collected in a bucket.

The cut-off process is fully automated, including the position/speed recalculation required to compensate for disk wear. All the cutting parameters are controlled by a dedicated mechatronic package. Acoustic and safety protections enclose the area.

Figure 4 – Metallic Disk Cut-Off Machine

Cooling
After the commercial cut, the layers are transferred onto marking grids where each bar is marked at both ends with heat ID and other requested indications. The bars are then moved by cars to the cooling area. Two 12 m cooling beds are provided with walking rakes. Bars are rotated at every walking step to ensure a uniform cooling around the bar section and preserve straightness. The total available bed length is approximately 36 m.

Depending on the final application, customer's prescription, and secondary metallurgy processing in the meltshop, some products may require slow cooling, in order to prevent undesired occurrences such as hydrogen embrittlement. Slow cooling is accomplished in dedicated pits, where the bars are gradually deposited by collecting saddles and remain for the required time.

Bundling

At the end of both cooling beds, bars are grouped in layers and then deposited by shaped retracting fingers onto a collecting cradle, where bundles are gradually prepared with weights varying from 2 to 10 tons. The cradle lowers incrementally, minimizing the drop distance from the fingers to the top of the bundle.

The formed loose bundles are transferred by a horizontal/vertical roller table to the binding station equipped with two wire-tying machines, which apply 3 to 6 ties, according to bundle length and weight, at appropriate distances.

The tied bundles are then weighed by load cells located in the run-out table and automatically tagged with labels including weight and product information. They are finally moved to an unloading table for removal by overhead cranes.

4 SBWRM MILL

Continuous Rolling Train

The continuous rolling train comprises eighteen original RedRing Series 5 stands, arranged in horizontal/vertical configuration. Three sizes of stands are used, with full interchangeability within each size.

Pre-Finishing Mill

A series of two 2-stand 250 Morgan Vee Mini-Blocks is located after a switch that directs the stock to the wire rod outlet (Fig. 5). Preceeded by a 680 mm crop shear, the mini-blocks have a small footprint on the mill floor and are based on the proven Morgan No-Twist Mill technology, with roll housings oriented at 45° to the horizontal, driven by single line shaft. Configured with 250 mm housings, these blocks enable low temperature rolling for enhanced properties in selected products. The relatively long pass life of carbide rolls minimizes downtime for roll changes and increases mill efficiency. The rolls also provide superior surface quality over the life of the groove compared to conventional rolls, thus enhancing surface quality on the finished product.

Figure 5 – Pre-Finishing Mill

Morgan No-Twist® Mill

The modular and versatile design features of the Morgan Vee No-Twist Mill (NTM) allow the mill to be supplied in 4-, 6-, 8- or 10-stand configurations with fixed single pass reductions from 10 to 25%, allowing a wide range of grades to be rolled.

The Vee No-Twist Mill can be configured with 250 mm, 230 mm or 160 mm cantilevered roll housings, depending on the processing requirements and product size range. Due to the unique design of the pinion and bevel gear housings, the roll housings are interchangeable, allowing the mill configuration to be changed to increase the mill's product size range (5.0 mm to 26.0 mm) or enhance the processing requirements, in response to future demands of the world market. For this application, an 8-stand arrangement is installed with 230 mm ultra heavy-duty (UHD) roll housings, providing the optimum configuration for the size range specified as well as reduced roll cost and improved section control.

Morgan Reducing/Sizing Mill

The Morgan Rod Reducing / Sizing Mill (RSM), invented by Morgan in the early 1990's, consists of four stands in a "Vee" type configuration with the first two 250 mm reducing mill stands similar in design to the NTM, while the last two sizing mill stands more like the original 150 Compact Sizing Mill developed in the same era.

Both the reducing and sizing mill units can be independently shifted in and out of the pass line and then transferred off-line or into a roll preparation and maintenance room by transfer car, in order to facilitate quick roll changes (Fig. 6). A patented design incorporating the guide troughs in the cobble guard doors takes the place of the unit when it is shifted out of position.

All service utilities, such as electrical, oil lubrication, water and hydraulic fluids are coupled automatically to the RSM when the mill is traversed into the pass line. The RSM stands are equipped with remote roll parting adjustment under no-load with position feedback for dynamic roll parting adjustment during rolling.

High mill utilization is possible with the RSM through the use of single family rolling, with a single roll pass family, from stand 1 through to the last stand of the NTM, thereby confining roll changes to the RSM only. With the patented single external gear drive, the individual stand reductions can be changed, which allows a single feed section to produce multiple finished product sizes. This, coupled with the transfer car and off-line RSM units, allows for change times between consecutive sizes of 5 minutes or less.

Additionally, the RSM gear drive arrangement provides the sizing mill with a consistent entry section from head to tail, otherwise impossible to obtain with individually driven units due to the high rolling speeds, minimum required inter-unit distances and motor response time.

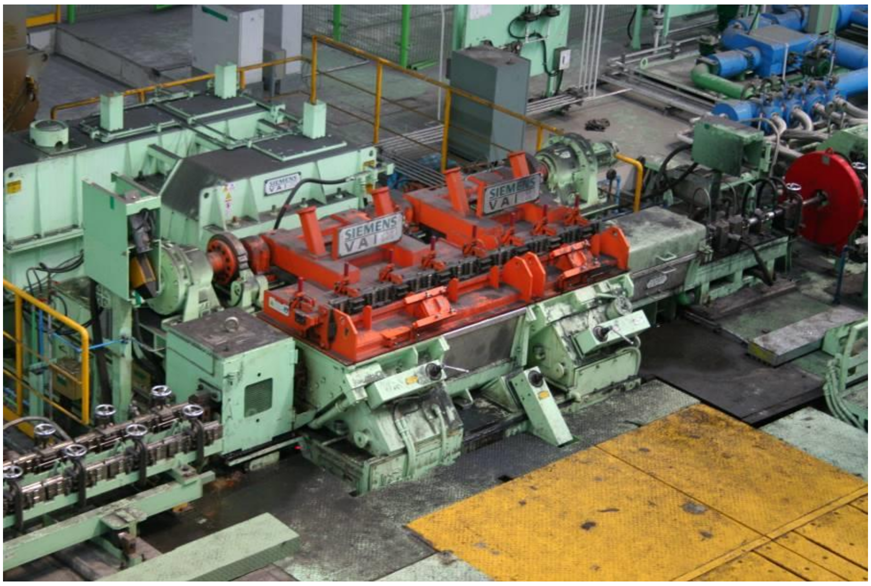

Figure 6 – Morgan Rod Morgan Reducing/Sizing Mill

Water Boxes

Post-finishing block equipment is designed for successful high-speed operations and production of a superior finished product. Alignment of the water boxes and troughs is critical to continuous high-speed operation and the elimination of cobbles. To ensure alignment is maintained, wear-resistant, split-bore, investment-cast stainless steel nozzles and troughs are used throughout the water boxes and equalization trough zones. The water box nozzles use replaceable inserts secured within a reusable body, minimizing the operating costs of the nozzles. Dual-bore equalization troughs allow for quick changes between product size ranges.

The water boxes are located strategically within the rolling line – ahead of the Morgan No-Twist Mill, after the Morgan No-Twist Mill and after the Morgan Reducing/Sizing Mill – to provide controlled temperature rolling throughout the mill in order to meet the processing requirements of many steel grades. In conjunction with a temperature control system, the water boxes provide efficient cooling for consistency of mechanical and metallurgical properties within the coil and from coil to coil.

Pinch Roll and Laying Head

An area of the process line that commonly limits the success of a rod mill is that of the laying head and pinch roll. The ability to roll small size product at high speeds is meaningless if the ring pattern on the cooling conveyor is not consistent and the laying head pipe needs frequent changes. A bad ring pattern can result in failure to achieve the specified tensile uniformities and can require additional personnel at the laying head or reform station to prevent cobbles in each coil. The Morgan Intelligent Pinch roll and the Morgan High Speed Laying Head (Fig.7) were developed to operate at those maximum speeds and have achieved a good reputation for reliable high-speed operation. Numerous mills have upgraded their laying head and pinch roll systems in recent years to increase production, reduce manpower, improve yield and ensure consistent product quality.

Design improvements in the laying head and pipe support have led to even better performance at high speeds, with extremely low vibration levels. Also, a significant advancement in the technology of the laying head pipe, the patented SR Series® pipe, now enables the rolling of many more tons of small diameter products at high speeds – resulting in a dramatic reduction in downtime for pipe changes.

The success of the laying head and pinch roll system is also dependent on the mechatronics package integral to an equipment upgrade. This system provides for consistent coordination of speeds between the units, for repeatable frontend positioning of each coil, fine control of ring diameter and wobble adjustment for large sizes.

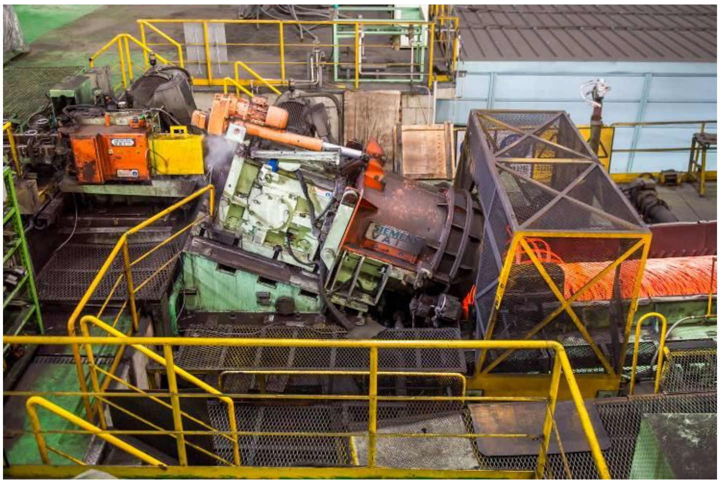

Figure 7 – Morgan Intelligent Pinch Roll and High Speed Laying Head

Morgan Stelmor® Conveyor

The Morgan Stelmor controlled cooling system incorporates a wide range of processing conditions, including both fast and slow or hybrid fast and slow cooling, in a single system to produce a wide spectrum of plain carbon and alloy steel grades. This flexibility, coupled with controlled temperature rolling, allows more grades to be produced in a directly useable condition, thus eliminating or accelerating downstream processes such as recrystallization and solution treatment.

For slow cooling, the Stelmor is equipped with insulated covers which can be closed to retard the cooling rate. Solid conveyor rollers on the conveyor deck are designed to dissipate heat transferred from the rings during slow cooling, thus preventing distortion and reducing maintenance requirements.

Coil Reform

The coil reform station is a critical element of the finishing end of the wire rod mill, collecting the rings from the Morgan Stelmor conveyor, while minimizing cycle time in order to meet production demands. Accurate control of coil plate and nose cone supports insures smooth and continuous coil collection through a mechatronics package. Integral to the reform tub is the ring distributor system, with a specially designed rotating blade to guide the rings as they fall, creating a well-ordered coil package.

Bar-in-Coil Outlet

A switch after the post-Kocks block water boxes and shear directs stock for products from 16.0 – 60.0 mm to a set of pouring reels. A second, high-speed switch located ahead of a rollerized turndown into the pouring reels directs alternating bars within the billet gap into the individual pouring reels, providing sufficient time to transfer the coils from the pouring reel tub. The turndown utilizes three cluster rollers to prevent scratching on the bar. These roller clusters are water cooled and air/oil lubricated for long life and reduced maintenance.

Two pinch rolls are located close to the pouring reels (Fig. 8) for control of tail ends as they enter the reel. All pinch rolls are traversable to allow quick change between the grooves required to cover the complete size range and include hydraulic roll mounting.

The pouring reels are equipped with wear strips on the outer rotating drum to prevent mechanical damage during the formation of the coil. An elevating coil plate assembly incorporated in the reel removes the coil from the tub. A coil transfer mast transports the coils from either of the two pouring reels and positions them directly onto a vertical stem pallet.

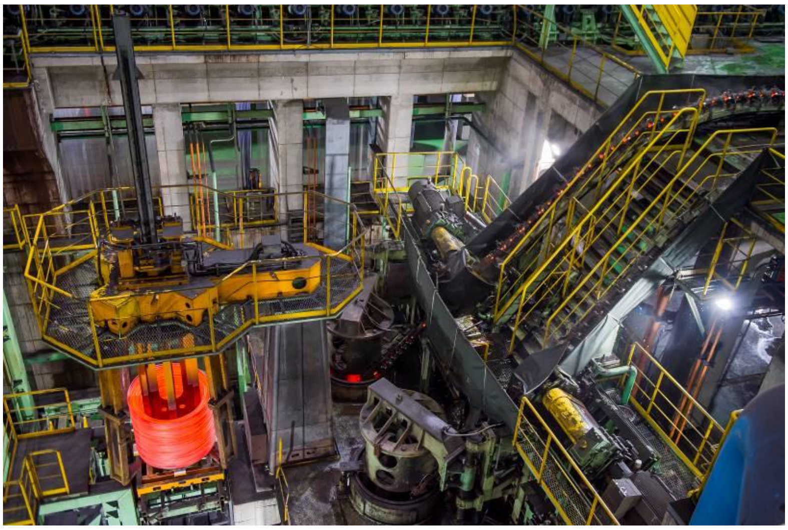

Figure 8 – Pouring Reels

Coil Handling and Compacting

A common vertical pallet coil handling system (Fig. 9) is used to transport both the wire rod and bar-in-coil products through to a horizontal hook system with coil compactors. Bar-in-coil products are taken to either a slow cooling tunnel, air blowing stations, or along the pallet conveyor for natural cooling, with sufficient cooling distance to ensure low coil temperatures prior to trimming and compacting.

All coils move through the common vertical pallet system to coil downenders for trimming and transfer to the hook system, where they are compacted, weighed and then unloaded to a coil storage area.

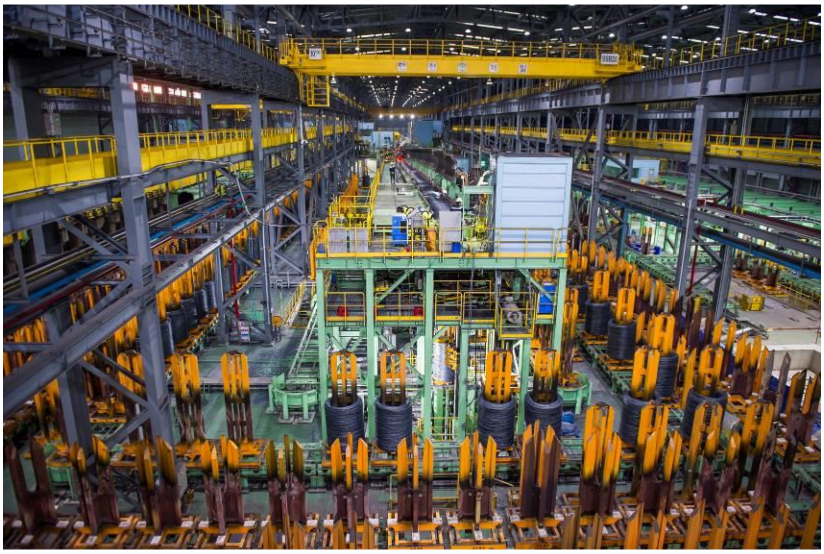

Figure 9 – Vertical Pallet Coil Handling System

5 CONCLUSION

The two LBM and SBWRM mills designed and supplied by Primetals Technologies have been installed at Hyundai Dangjin site, where production has been ramped up as planned. Both mills are now in regular operation, achieving the contracted production rates, and rolling high-quality steel products with precise and uniform dimensional tolerance, excellent surface quality and mechanical properties.

The sound metallurgical properties obtained for all the grades and sizes enable Hyundai to provide yield benefits to the post-rolling processes, such as heat treatments and peeling.

The flexibility of production allows the mills to support short delivery cycles while maintaining a high operating efficiency by minimizing downtimes.

The LBM and SBWRM mills enable Hyundai to provide superior products to Hyundai Kia Automotive and other external customers.

No-Twist, SR Series and Stelmor are registered trademarks of Primetals Technologies USA LLC.
Red Ring, ProScan, CGA are registered trademarks of Primetals Technologies in some countries.