NEW DEVELOPMENTS IN BAR AND ROD MILL TECHNOLOGY[1]

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SUMMARY
Developments in bar and rod mill equipment and mill layout designs continue to provide rolling mill operators with new ways to improve productivity and product quality. Advanced rolling equipment such as the Reducing/Sizing Mill, now being applied to both rod and bar mill configurations, enables significant improvements in mill utilization, while simultaneously enhancing the size tolerance of the finished product and providing the capability to do thermo mechanical rolling for metallurgical advantages. Other developments in the rolling line, such as high speed guides, new water box cooling nozzles, high speed shears and intelligent pinch rolls and new laying head features provide additional operational improvements. Handling of the finished rod products after rolling through to shipping has also benefited from equipment developments, such as ring distributors, coil handling systems and coil compactors. For bar mills, new cooling bed designs, along with stackers, bundlers and tiers provide for reliable operations with improvements in productivity.

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INTRODUCTION

Since 1888, Morgan Construction Company has brought most of the technological innovations to the modern bar and rod mill industry. These innovations have enabled rolling mills to produce countless millions of tons over the years and continue to provide solutions that can be intelligently applied to new and existing mills to benefit operations and product quality.

The Morgan mill equipment and process developments that have helped progress the state-of-the-art in rolling mill technology include:

No Housing Stands
No Twist Mills
Mini Blocks
Reducing Sizing Mills
Compact Sizing Mills
High Speed Trimming Shears
High Speed Guides
Process Monitoring Guides
Powered Roll Parting
Axial Roll Mounting
Slit Rolling
High Efficiency Water Box Nozzles
Traversing Water Boxes
High Speed Laying Heads
Stelmor Controlled Cooling Conveyors
Mist Cooling
Reforming with Ring Distributors
Coil Handling via Hooks and Pallets
Coil Compactors
Bar Handling
Bar Cooling Beds
Thermomechanical Rolling
Temperature Control
Tension Control
Vibration Monitoring of Equipment
Process Monitoring and Control

Several areas that have received much attention in recent years are explained in more detail below.

NO HOUSING STANDS AND BREAKDOWN MILLS

The successful development of No Housing Stands has had a significant impact on new rolling mill installations and in the modernization of both single and multi-strand mills. This style of stand can provide a higher quality product at a lower cost than traditional closed-top stands. No Housing Stands contain fewer parts and thus require less maintenance, resulting in less down time in the mill. Down time is also reduced because virtually all adjustments can be made on line. Hydraulic screwdowns provide symmetrical roll parting adjustments around the pass line, so there is no need to adjust shims or presets at the roll shop. Pass alignment and groove adjustments are made using a hydraulically driven screwjack, while an encoder and position sensors provide feedback to the operator.

No Housing Stands are more compact and provide a greater degree of stiffness than conventional closed top stands, with hydraulic balancing around the screw posts to help ensure maximum rigidity. Because the load is distributed over a wide are, the stress on bearing elements is also reduced, resulting in a choice of smaller bearings or longer bearing life. An example of the No Housing Stands is shown in Figure 1.

The advent of the breakdown mill has allowed existing single or multi-strand mills to economically increase their billet size without negatively impacting the mill operation during the construction phase. The installation of a breakdown mill ahead of the existing rolling mill line provides significant cost savings to the upstream processes, plus provides the rod mill with operating and quality advantages. Some of the main advantages are:

- Increasing the billet size to the range of 160 to 200 mm square, thus allowing the steel plant to reduce the number of billet sizes being produced by the casting or primary rolling facilities, since the rod mill typically utilizes the smallest billet size in the steel plant. Consolidation of billet sizes reduces storage needs and increases the utilization of the upstream billet producing processes.
- The ease of continuously casting a large cross section at high tonnage rates, since existing casters can be easily modified to increase output with the larger section.
- The possibility of deleting primary rolling equipment, such as blooming and billet mills, with consequent improvement in yield.
- The improvement of product quality from the cast section, due to the increased number of elongations to produce the finished size, which minimizes segregation, porosity, and inclusions.
- The ability to produce larger coil weights, with improvement in product yield.
- The ability to roll small sizes from large billets.

For example, at one customer site with a two-strand rod mill, the installation of a breakdown mill resulted in a significant increase in yield. When rolling ingot-based billets, the yield from ingot to wire rod was 83%, compared to continuously cast billets rolled in a breakdown mill through an existing rod mill, where the yield is 97.7%.

Figure 1 – Morgan Breakdown Mill Stands

The addition of a breakdown mill usually requires a new furnace to accommodate the larger billet and, perhaps, an increased rolling rate. A new furnace design permits decreased decarburization levels and reduced scale losses. It is preferred that descaling takes place at a speed much higher than the entry speed of the breakdown mill to minimize temperature loss. Therefore, the descaler should be located at a sufficient distance from the first stand to allow a “free bar”. The breakdown mill can consist of 2, 3, 4, 5 or 6 stands, depending upon the starting billet size, the required entry section into existing stand #1, and the preferred pass design.

The new reheat furnace, the breakdown mill stands, and the crop and cobble shear can all be installed and commissioned (hot and cold) without interruption of the existing mill operation. Demolition of the old reheat furnace and the installation of the insulated roller tables can be carried out in as little as two weeks. Recent Morgan mills to install breakdown mills in modernization schemes are: Belgo Mineira

No. 1 Mill - Brazil, Rocky Mountain (CF&I), Pueblo - USA, Charter-Cleveland, Cleveland - USA and Ivaco, L'Orignal - Canada.

MINI-BLOCKS FOR NEW AND EXISTING MILLS

The Morgan mini-block was designed as an answer to one of the frequently problem facing rolling mill owners of how to improve quality and boost productivity without incurring substantial new equipment costs and lengthy installation times. Using many features of the highly successful Vee No-Twist Mill, Morgan developed the Vee Mini-Block to be available in two-, four-, six- or eight-stand units.

Most often used in the two-stand configuration, the mini-block has a small footprint, making it ideal for mill retrofits, either upstream or downstream of an existing finishing mill. In position as a pre-finishing mill, these mini-blocks reduce the size and improve the tolerance of the stock entering the finishing block, thereby permitting the production of smaller diameters than previously possible with greater precision on the finished product. As post-finishing blocks, the mini-block increases finishing speed, therefore increasing the production rate and allows rolling of smaller diameters than previously possible with the existing equipment. In numerous installations, mini-blocks have increased productivity by as much as 50%, while adding capabilities for thermomechanical rolling on critical products.

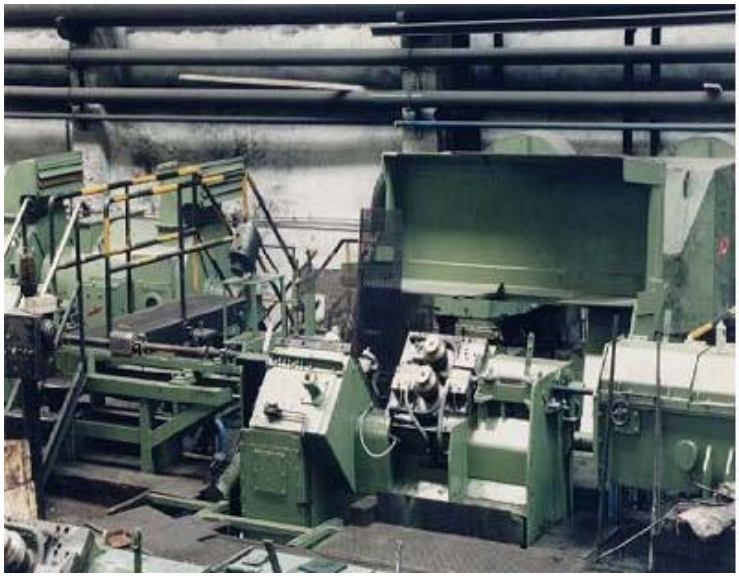

Figure 2 – Vee Mini Block

An example of a post-finishing mill mini-block is shown in Figure 2. There are now more than 35 rolling mill strands throughout the world with Morgan mini-blocks.

REDUCING/SIZING MILL TECHNOLOGY

Since the first Reducing/Sizing Mill (RSM) was introduced in 1995, approximately forty (40) units have been installed worldwide, mostly as part of major mill modernizations but some in new mill installations. The justifications for the installation of the RSM in these mills are as varied as are the benefits provided by this technology[2, 3].

For most rod mills, the RSM has provided significant increases in productivity, especially on small diameter product where the maximum finishing speeds were previously limited to less than 70m/s. Installing the RSM after an existing 10-stand NTM and rolling 7.0mm in the last stand to feed the RSM can increase the finishing speed for 5.5mm from 65m/s to near 100m/s, as was the case, for example, at Global Steel Wire in Spain. For mills producing a large percentage of 5.5mm products, the addition of the RSM can result in a significant increase in annual

output. In addition, improvements have been realized following the introduction of the single family rolling method inherent with the application of the RSM technology.

The single family rolling method allows a single roll groove to be used in each stand from the first stand in the roughing mill to the last stand in the NTM to produce the complete product size range through the RSM. This not only simplifies the mill setup, but also improves yield through reduced number of cobbles and elimination of trial bars as well as significantly reducing the roll and guide inventory.

REDUCING/SIZING MILL TECHNOLOGY FOR BAR MILLS

The rod reducing/sizing mill technology has now been incorporated into bar mills. The Bar RSM consists of four straddle-mounted stands in a horizontal/vertical configuration, with two reducing, followed by two sizing stands mounted in independently traversing cradles. Figure 3 shows an overview of the arrangement concept.

The Bar RSM, like the rod unit provides mills with the capability for producing precision tolerance product, as low as +/- 0.12 mm with 60% ovality, single family rolling and enhances mechanical properties through normalized and thermomechanical rolling.

With the reducing mill stands driven by individual motors and the sizing stands coupled through a multi-ratio external gear drive, the Bar RSM provides both increased flexibility and stable rolling conditions over the complete size range. Most importantly for bar producers, the Bar RSM is capable of not only producing rounds, but squares, hexagons, flats and rebar products as well, a feature that is not fully offered by other types of sizing mills. The ability to produce these common bar mill shapes through the same sizing mill equipment, with reduced setups compared to conventional rolling further enhances the mills flexibility and utilization resulting in reduced downtime and operator costs and increased production. These units provide a high-tech, low cost sizing solution for the bar mill industry.

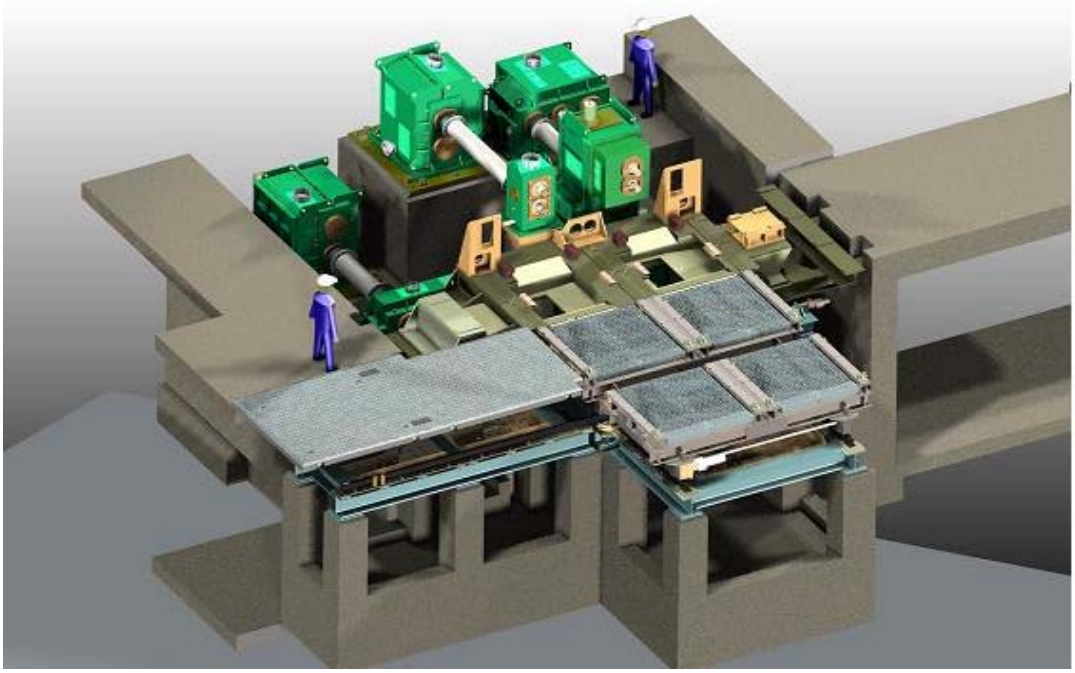

Figure 3 – The Morgan Bar RSM arrangement

ROLLING OF REINFORCING BAR AND ROD

Along with the ever-increasing demand for reinforcing bar in developing countries, there has been continuing pressure to increase productivity on these and other products. Limits of existing mill layouts and equipment capacity usually dictate that new technology be implemented to meet those demands. Morgan had responded to that need with advances in rolling mill equipment to enable increases in rolling rates and quality on these products.

In addition to the application of the No Housing Stands discussed above, Morgan has successfully extended the Vee No-Twist Mill technology so popular in rod mills to that of finishing blocks for bar mills. The use of a block mill for the finishing stands has many well know advantages, such as

- Short stand center distances, to help with section control on front tail ends.
- Elimination of need for loopers between stands.
- No-twist rolling and consistent stand alignment reduces cobble rate.
- Roll changes faster than conventional stands

Several Japanese mills have implemented the Morgan Vee mills over the past ten years, making large quantities of small diameter rebar products in their two strand mills (see Figure 4). In all cases, the dimensional tolerances of the products have been improved, yield and utilization have increases and the cobble rate has significantly decreased. In Japan, it is essential to maintain the lowest possible weight (i.e., kg/m) for each size, since the product is sold by the length. Using the Morgan block and rolling mill, a negative tolerance can easily be attained. An additional benefit of the Vee Block is that the number of personnel in the mill have been reduced, since fewer adjustments during rolling are needed. Improvements have also been realized in roll utilization through the use of the carbide rings on cantilever stands of the block mills.

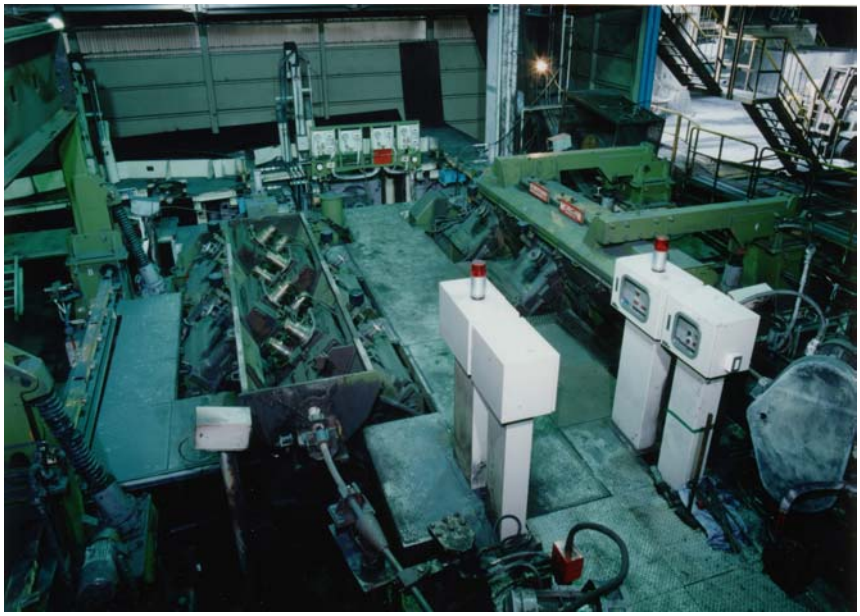

Figure 4 – Vee No-Twist Blocks in a Two-Strand Bar Mill

From the processing standpoint, it well known that many mills are producing quenched and tempered rebar as a construction product, which has advantages of improved properties with reduced alloying. Plain, low carbon, fully-weldable, ribbed reinforcement rod and bar can be rolled and thermomechanically treated in-line by the Morgan HYQST (High Yield Quenched and Self-Temper) Process.

The chemical composition required for HYQST product is a lower carbon equivalent which is weldable, and meets the standard elongation and bend test requirements for many specifications. There are many regional specifications around the world for patterned reinforcing bar and the HYQST process can be used to manufacture bars which comply with many of these specifications. This allows manufacturers worldwide many options and opportunities to meet even the most demanding certification requirements.

High yield strength in these products is attained by a combination of fine grain size and a self-tempered martensitic surface zone. The usual principle of manufacture is to rapidly cool the surface below the martensite start temperature with the core also being reduced to near critical temperature. As the bar moves rapidly from the cooling medium the remaining heat in the core dissipates to the surface, resulting in the surface martensite layer and due to the sharp temperature gradient the surface is rapidly heated and the core lowered in temperature to an equilibrium temperature suitable for tempering.

An alternative approach now possible with the high load capability of the Reducing Sizing Mill technology is to finish roll these products at low temperatures. The thermomechanical rolling has the effect of refining the austenitic grain structure, creating a final microstructure that adds strength and toughness. Combining this with a limited amount of quenching after rolling can result in properties as least as good as conventional quenched and tempered product. This process has additional advantages of less tendency for cobbles after the finishing block due to increased stiffness of the stock and reduction in amount of water required for the quenching part of the process. Thus, higher rolling rates would be possible, which is particularly advantageous for small sizes. Trial rollings have shown that the thermomechanical rolling approach is feasable.

Figure 5 – Powered Slitter

SLIT ROLLING TECHNOLOGY

One of the latest developments in this area has been that of slit rolling technology. Morgan has successfully implemented several slitting operations in recent years, including the use of slitting guides at Sheffield Steel in the USA, at Barra Mansa in Brazil, and shortly a greenfield-site mill in Taiwan. Also, a powered slitter (see Figure 5) has been developed and installed in mills in Japan, Brazil and most recently in India.

To aid in the advancement of the Multi Slit Rolling technology Morgan has formed a Partnership with Badische Stahl Engineering (BSE), in Kehl, Germany.

The contract in Taiwan is the first since the inception of this Partnership. Working closely with the BSW rolling mill, the Multi Slit rolling process has been developed and optimized..

MORGAN GUIDES

As the speeds of wire rod mills increases, the development of proper guiding equipment must accompany these increases to achieve the outputs demanded by the world market. As the expectations for maximum rolling speeds approaches 120m/s Morgan Guides have set the high standards for roller guide life for long rolling campaigns of precision wire rod. The X-clamp mounting system has provided unsurpassed component life and product quality for the full range of wire rod products.

With the recent trends of the market, driven by the expansion of developing countries worldwide, the production of construction materials has shown increasing demands. As mentioned above, the growth of the market for reinforcing bars has led to a Morgan Partnership with BSE, with the guiding equipment playing an important role in the long-term productivity of the multi-slit rolled products.

Over 100 years of Company history, the Guide products cover a large number of installations rolling many combinations of long-products. Together with over 30 guide references on non-Morgan mill equipment the last 10 years, Morgan Guides continues to expand with the market.

WATER BOXES AND HIGH EFFICIENCY COOLING NOZZLES

Maintaining a high level of mill utilization with minimum personnel, while supporting a multiple cycle rolling schedule, requires not only the need for fast roll and pass changes, but also requires quick changing of auxiliary equipment as well. Morgan's split bore cooling nozzle design allows operators to quickly and easily open a nozzle for inspection or cleaning and to remove cobbles. To avoid the necessity of changing the bore of the nozzle line for a new product size, multiple lines of different bore nozzles can be arranged in a traversing box, thus creating large reductions in manpower and mill downtime. A new design of split cooling nozzle has recently been developed and is now being offered for new mill installations and as replacements for existing nozzles. The new design has a higher cooling efficiency, using less water than previous designs and therefore reducing the load on the contact water system. The high efficiency design can be used for plain products as well as ribbed, including HYQST quenched and tempered products.

LAYING HEAD DEVELOPMENTS

The ability to roll small size product at high speed, i.e., above 100m/s, is meaningless if the ring pattern on the Stelmor® cooling conveyor does not allow the specified tensile uniformities to be achieved, or requires additional personnel at the laying head or reform station to rearrange and trim the head and tail ends. Morgan has developed a high speed laying head, capable of operating at speeds up to 150m/s, without distortion of head or tail end rings, thus allowing mills to increase production, reduce manpower, improve yield, and ensure consistent product quality. As rolling speeds increase, there is a tendency for the tail end of small diameter products to accelerate as it leaves the laying head. This typically produces a relatively large ring, causing problems with the coil package on the conveyor and at the reform tub. A tail end control device, consisting of a 360 degree trough located after the pipe end, was developed and patented by Morgan. When the rod tries to

accelerate out of the pipe, it is contained in the trough, forcing the formation of a ring in a shape that can fall into the reform tube without manual intervention.

COIL COMPACTING

Morgan compactor systems have been designed to be versatile and reliable. They are available in vertical or horizontal configurations, using either wire or strap binding. Easily coupled with an overhead hook system or a vertical pallet system, the Morgan compactor can be integrated into existing mills or supplied with a new mill installation. The binding heads of the Morgan compactor produce a consistent and reliable high-strength knot for improved shipping and handling of the coil. Some of the key features of these compactors include the capability of handling coils with a maximum 1400mm outer diameter and 750mm inner diameter, the possibility of using binding wire in diameters from 6mm to 8mm as-rolled, with cycle times for compacting and tying in the range of 30 to 35 seconds, depending on the weight of the coil. An example of a horizontal compactor system is shown in Figure 6.

Figure 6 – Morgan Horizontal Compactor

BAR COOLING BEDS AND HANDLING EQUIPMENT

In bar mills or bar/rod mills with a bar mill outlet - the rolled product is processed in straight lengths for subsequent cooling, collecting in batches for cutting into order lengths and forming bundles of finished products – rounds, rebars, squares and/or section products. In recent years, Morgan has been active in developing and implementing tailor-made solutions for new and existing mill set-ups. The equipment designed and supplied by Morgan include:

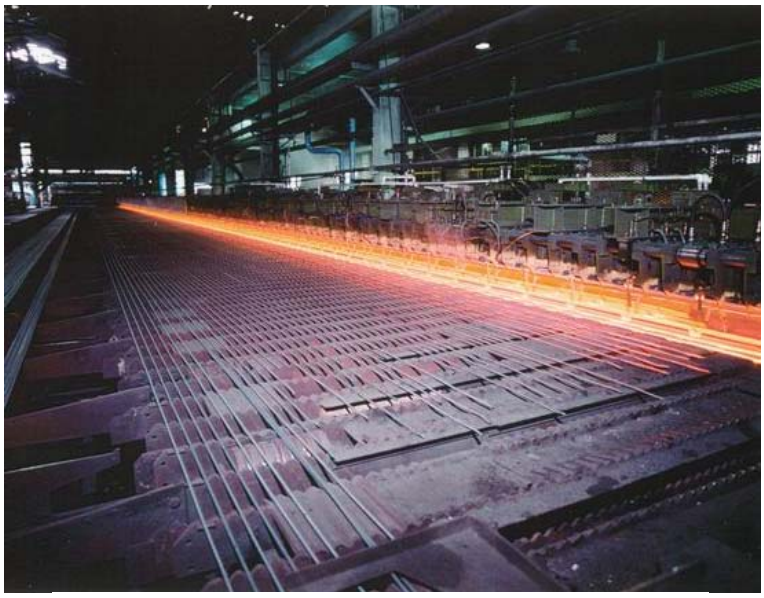

Figure 7 - Morgan High Speed Cooling Bed

- the run-in and run-out roller tables to/from the cooling bed,
- cooling bed proper,
- cold shear for cutting order lengths, gauge heads,

- bundling stations for rounds/rebars/squares/flats,
- stacking stations for squares/flats/angles/channels/beams,
- wire tying machines,
- strapping machines and
- manual, semi-automatic/automatic handling of bundles/stacks through roller tables and unloading stations

Figure 7 shows an example of a high speed cooling bed.

CONCLUSIONS

Rolling mill equipment and process improvements by Morgan during the last decade have enabled many mills to undergo successful modernizations. Significant increases in rolling speed, production rate, mill efficiency and product quality have been realized with these modernizations. Morgan now has many rod mills operating with rolling speeds in the range of 100m/s to 115m/s on a regular basis. Many mills that have implemented Reducing/Sizing Mills and other new technology have increased mill speeds, utilization and improved dimensional and metallurgical properties with resulting dramatic effects on mill profitability.

REFERENCES

1. Shore, S. M., “Developments for High-Speed Rod Mills,” Iron & Steel Institute of Japan, Nov. 2001.

2. Shore, S. M., Dyck, J. and Shore, T. M., “New rod rolling technology for improved mill utilization and product quality”, MPT International, Aug. 1995.

3. Vincent. J. C. and Kiefer, B. V., Improvements in Thermomechanical Processing for High-Speed Rod and Bar Rolling with Reducing Sizing Mills,” AISE Steel Technology, Feb. 2003.

4. Kiefer, B. V., Vincent, J. C. and Varo, R. A., “Thermomechanical Process Improvements in High Speed Rod and Bar Rolling with Reducing Sizing Mills,” Proceedings, International Conference on Thermomechanical Processing: Mechanics, Microstructure & Control, Sheffield, England, June 2002.

5. Hentschel, L. et al, “BSW/BSE Multi-Slit Rolling Technology: The Efficient Way to Increase the Productivity in Bar Mills,” STEEL 2000 – International Rolling Conference, Beijing, China, 7 – 11 May 2000.

6. Vincent, J. C. and Kiefer, B. V., “Modernization of Stelmor Conveyor Systems for Expanded Process Capability and Improved Product Quality,” Proceedings, Wire and Cable Technical Symposium – Interwire 2003, Atlanta, GA, May 2003.

7. Ichida, Y. et al, “Overview of the New Finishing Block Mill and Coil Handling Line at the No. 7 Wire Rod Mill”, R&D Kobe Steel Engineering Reports, Vol. 50, No. 1, Apr. 2000.