HIGH PERFORMANCE HOT STRIP MILL - INTRODUCTION OF TECHNOLOGIES APPLIED TO THE NEW NO.2 HOT STRIP MILL AT USIMINAS IN CUBATAO[1]

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Abstract
To meet the current demand of steel manufacturers for high reduction mill capability for high strength steel and thinner strip production, improved strip crown and shape control capability for various strip grades including silicon steel, easy maintenance and stable operation for high productivity, Mitsubishi-Hitachi Metal Machinery Inc., (MH) has developed unique technologies. One of the most modern mills operating in Brazil is the No.2 Hot Strip Mill at Usiminas Cubatao. MH supplied some of the advanced technologies for this Hot Strip Mill. One of the advanced technologies applied at the Usiminas No.2 Hot Strip Mill is the advanced pair cross mill. The number of parts in the advanced pair cross mill mechanism has been reduced to less than 25% of those of the 1st generation pair cross mills. In addition, a mill stabilizer system is combined with the pair cross mill to reduce mill vibration. The mill stabilizer device improves high reduction rolling and also contributes to stable threading and easy maintenance of the housing window. In this paper, MH introduces the newest high performance Hot Strip Mill.
Keywords: Hot rolling; Pair cross mill; Mill Stabilizer; High strength steel.

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1 INTRODUCTION

Several steel grades are produced at the No.2 Hot Strip Mill at Usiminas Cubatao. In addition to conventional steel grades such as low carbon steels, high carbon steels, and steels for cold rolling, the production of special steels such as line pipe steel, DP, TRIP, HSLA, IF, and Si steel is increasing. With more of these steel grades being produced, the range of the target strip crowns becomes wider. The target strip crowns for cold rolling steel tend to be higher, while the target strip crowns for Si steel tend to be lower. In recent hot rolling mills, the requirements for greater strip crown control capability are becoming more demanding.
Rolling speeds are becoming faster to increase productivity and reduce temperature loss. At the same time, rolling force capacity and reduction in strip thickness are increasing to produce high strength steel and thinner strip. It is known that higher rolling speed, larger rolling force, and higher reduction in thickness amplify mill vibration.(1) Large mill vibration not only causes reduced life time of the mechanical parts, but also reduces the operational stability and manufacturing efficiency of the mill. As a result, a mill stabilizing function to reduce mill vibration is required to produce high strength steel and thinner strip at higher rolling speeds.
The pair cross mill with mill stabilizer device has been developed to achieve these requirements of higher strip crown control capability and stabilization of mill vibration. This system is mostly installed on the upstream stands of the finishing mill. The mill stabilizer device consists of hydraulic cylinders with orifices that act as a damping system(2,3) and eliminate the clearances between the roll chocks and housing, thereby reducing the thrust forces along the axial direction of the mill rolls. This function reduces the differential rolling forces between drive side and operator side. As a result, strip steering stability is improved. Mill stabilizer devices have been increasingly installed on downstream finishing mill stands to improve pinching trouble caused by strip steering and reduce maintenance requirements of clearances between roll chocks and housing. The mill stabilizer can be applied for any type of mill. This includes conventional mills as well as work roll shifting mills, whether newly-built or revamped.
One of the most modern mills operating in Brazil is the No.2 Hot Strip Mill at Usiminas Cubatao. MH supplied some of the advanced technologies for this Hot Strip Mill, including the pair cross mill stands and mill stabilizer devices. In this paper, MH introduces the newest high performance Hot Strip Mill.

2 NEW NO.2 HOT STRIP MILL IN USIMINAS CUBATAO

The No.2 Hot Strip Mill at USIMINAS Cubatao (Figure 1) started operation in 2012. To cover the wide range in production sizes and steel grades, many modern technologies are applied. MH was involved in this project as a mechanical equipment supplier and has supplied the following equipment:

- Furnace Entry and Delivery Tables and related equipment;
- Roughing Mill area equipment;
- Finishing Mill area equipment;
- Down Coiler area equipment;
- Coil Conveyor area equipment.

In addition to the above main line equipment, MH also supplied auxiliary equipment such as roll shop equipment, water treatment system, compressed air plant, cranes, VAC, fire detection and extinguishing system, etc.

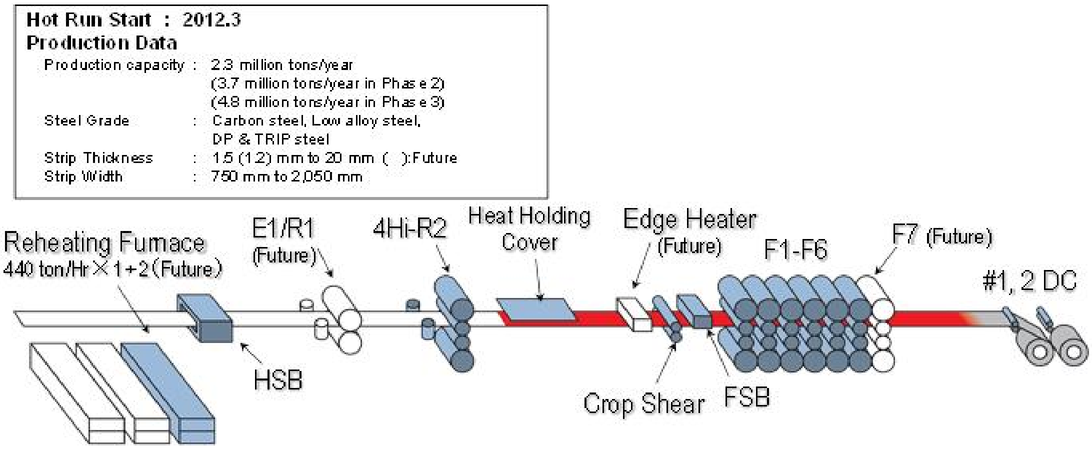

Figure 1. Layout of No.2 Hot Strip Mill in Usiminas Cubatao.

The production capacity of the mill is 2.3 million tons per year in the initial phase, with a maximum of 4.8 million tons per year in future expansion. The product mix includes low, middle and high carbon steel, API pipe steel (up to X80), DP, TRIP, HSLA, IF steel and Si steel. The hot run tests and performance tests were successfully completed within 6 months after hot run start. During these tests, low carbon steel of 1.5mm thickness, API X70 of 6mm to 19mm thickness, HSLA of 2.0mm thickness with a tensile strength of 590 MPa, DP, IF, as well as Si steel have been successfully produced.
The features of the main equipment in the production line are described hereinafter.

2.1 Roughing Mill with Attached Vertical Edger

A four-high reversing roughing mill (R2) is provided in roughing mill area (Figure 2). The roughing mill is equipped with the screw down system mounted on the top of the mill housing for high speed, motor driven roll gap adjustment between each rolling pass. Hydraulic gap control cylinders are located on the bottom of the housing for fine levelling, zeroing calibration, and proper pass line adjustment. One attached vertical edger (E2) is provided at the entry of the roughing mill. The edger is equipped with long stroke hydraulic Automatic Width Control (AWC) cylinders, without a screw system, for high accuracy of width control and easy maintenance.

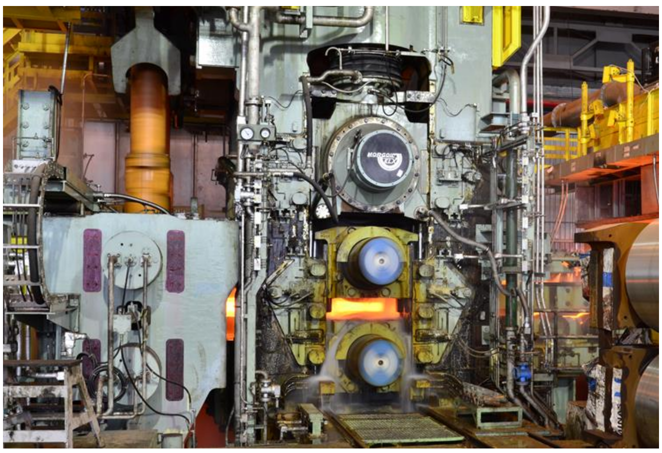

Figure 2. Roughing mill with attached vertical edger.

2.2 Differential Speed Rotary Crop Shear

The differential speed rotary crop shear (Figure 3) is installed in front of the finishing mills to cut off uneven parts of the transfer bar on head and tail ends. The differential speed rotary crop shear is a unique technology developed by MH. The drum diameters are different on top and bottom, resulting in different circumferential speeds. The top knife passes the bottom knife during the crop cut and the gap between top and bottom knives is transitionally changed from negative to zero to positive. This function extends the knife changing cycle, increases the allowance for knife gap, and shortens the cut length of the crop.

Figure 3. Differential speed rotary crop shear.

2.3 Finishing Mills

The finishing mill consists of six four-high mill stands, F1 to F6, in a tandem configuration (Figure 4). Hydraulic AGC cylinders are provided on all finishing mill stands for work roll gap adjustment and automatic gauge control (AGC). Pair cross mills with mill stabilizer devices are included in stands F1 to F4. Together with heavy duty positive work roll bending, the system reduces mill vibration and allows for excellent strip crown and flatness control, and high reduction in thickness. The pair cross mill and mill stabilizer device is described in more detail below. Stands F5 and F6 are equipped with work roll shifting, a technology first developed by MH[5] and consequently spread throughout the world. The work roll shifting allows for an extension of the rolling campaign and of same width rolling through the cyclic shifting method. The work rolls are shifted cyclically to prevent stepped wear and local wear of the rolls, as shown in Figure 5. Heavy duty positive and negative work roll bending systems are also provided for stands F5 and F6 for fine flatness control. These stands are also outfitted with mill stabilizer devices to improve pinching trouble caused by strip steering and reduce maintenance requirements of clearance between roll chock and housing.

Hydraulic cylinder operated loopers are located at each interstand for mass flow control for each stand and better speed regulation. A rolling oil system is furnished at the entry side of each stand to improve roll wear, roll surface defects, and electrical power consumption.

Figure 4. Finishing Mill Stands F1 to F6.

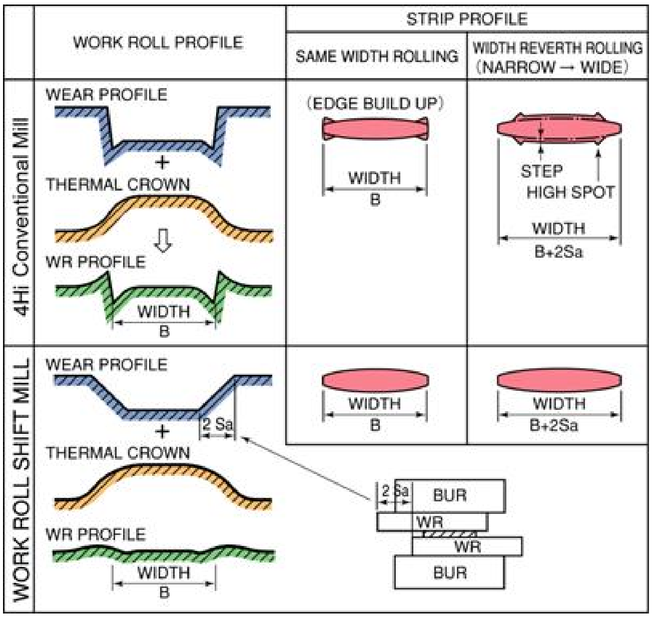

Figure 5. Wear and thermal crown dispersion by cyclic shift method.

2.4 Strip Cooling System

A laminar flow system on top and bottom, incorporating a line-side head tank system, is provided between finishing mill delivery side and the down coiler (Figure 6). The cooling zone length and flow rates are designed for both the production of general carbon steels as well as DP and TRIP steels. The cooling zone is divided into 15 cooling banks, which consist of intensive cooling banks for faster cooling before and after the air cooling zone during DP and TRIP steel rolling, normal cooling banks for regular cooling and fine cooling banks for fine temperature control.

Figure 6. Strip cooling system.

2.5 Down Coiler

Two down coilers are provided. The coiler frames are fixed on the foundation to ensure excellent coil profiles. 3 unit roll type hydraulic down coilers with quick opening control (QOC) are capable of properly coiling thicker strip of high strength steel. The mandrel (Figure 7) is a link and wedge type with step-less expansion. The QOC with step-less expanding mandrel improves top end marks and loose coils. Since the sliding surfaces on the wedges inside the mandrel are positioned close to the mandrel center, no internal water cooling is required. A plug-in type connection between the mandrel and the rotary cylinder is provided for quick mandrel changes. The mandrel can be removed from the down coiler without disassembling the mandrel drive unit.

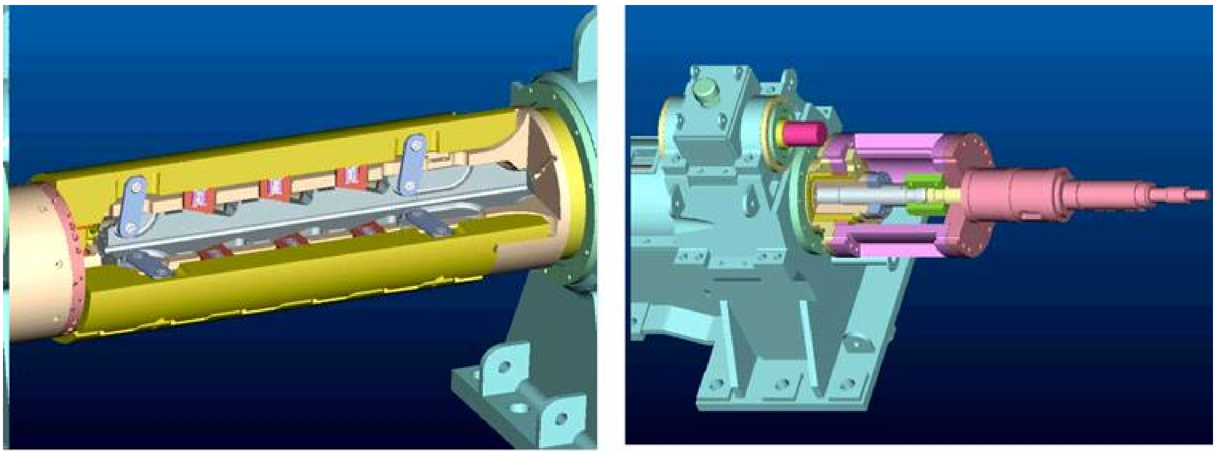

Figure 7. Link and wedge and step-less expanding type of mandrel.

3 PAIR CROSS MILL WITH MILL STABILISER DEVICE

3.1 3rd Generation Pair Cross Mill

The pair cross mill[4] was developed in the 1980's for superior strip crown and flatness control capability. Since then, MH has enhanced the pair cross mill. The latest design of the pair cross mill is now in its 3rd generation. In addition to the superior strip crown and flatness control capability of the 1st generation pair cross mill, the 3rd generation pair cross mill has the following advantages:

- Simpler mechanism for easy maintenance;
- Higher reduction in thickness with stabilization of mill vibration by mill stabilizer device.

Figure 8 shows the outline of 1st generation and 3rd generation pair cross mill for comparison.

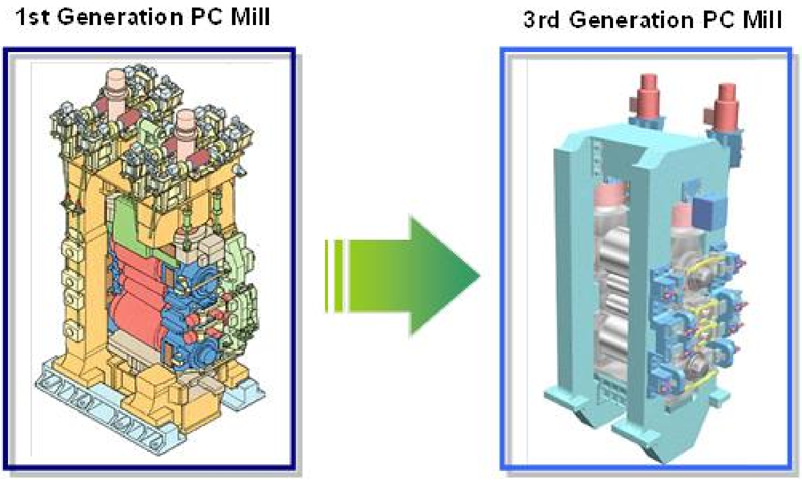

Figure 8. Comparision of 1st and 3rd generation pair cross mill.

The number of parts in the pair cross mechanism of the 3rd generation has been reduced to less than 25% of those of the 1st generation. The cross mechanisms are installed on the bottom delivery of the operator side and top delivery of the drive side.

3.2 Mill Stabilizer Device

The mill stabilizer devices are installed on the entry side of the housing posts. The mill stabilizer devices, which consist of hydraulic cylinders, push the work roll and back up roll chocks against the delivery side housing posts and eliminate the clearance between roll chocks and mill housing (Figure 9).

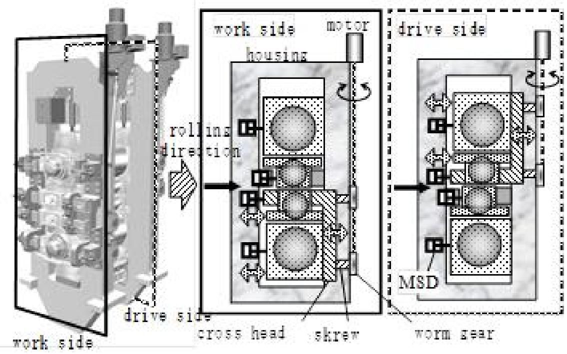

Figure 9. Pair cross mill with mill stabilizer device.

The mill stabilizer devices function in place of the entry housing liners, and eliminate clearance during operation, but can be retracted to allow necessary clearance between roll chocks and housings during roll changes. Therefore, the maintenance of entry side housing liner and the housing window gaps between entry and delivery side housing liners is not required. This feature will reduce the maintenance requirements for the housing liners to approximately one-third of those of a conventional mill.

As mention above, it is known that faster rolling speeds, larger rolling forces and higher reductions in thickness amplify mill vibration. The phenomenon of mill vibration in hot rolling consists of the upper and lower work rolls vibrating in opposite directions of each other, mainly in the horizontal direction. The mill stabilizer device is installed between the roll chock and housing, increasing the dynamic rigidity of the mill housing in the horizontal direction and therefore reducing mill vibration. The hydraulic cylinders of the mill stabilizer device are provided with orifices. The orifices create a damping effect on the stabilization of mill vibration and further increase the dynamic rigidity. Figure 10 shows the measured results of mill vibration at Kwanyang works in POSCO. The accelerations are measured by accelerators on the work roll chocks in the rolling and thickness direction. After the strip comes into the mill, mill vibration suddenly starts. The acceleration in the rolling direction is much larger than that in the thickness direction. When the Mill Stabilizer Device is ON, the acceleration in the rolling direction is reduced to approximately half of that with the Mill Stabilizer Device OFF.

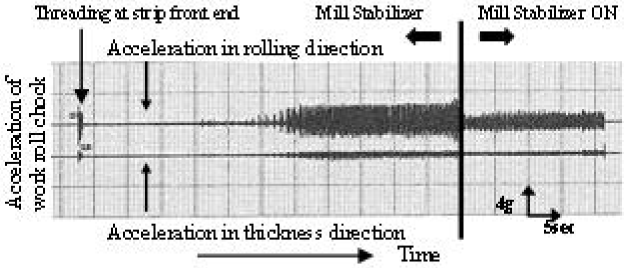

Figure 10. Measured acceleration of work roll chock.

4 CONCLUSIONS

The requirements for higher strip crown control capability with high reduction in thickness are increasing to cover the widening production range in sizes and steel grades. To meet these demands, the pair cross mill with mill stabilizer device has been developed. The pair cross mill with mill stabilizer device (i.e. 3^{rd} generation pair cross mill) can achieve the required high strip crown control capability and higher reduction in thickness with stabilization of mill vibration and reduced maintenance. The No. 2 Hot Strip Mill at USIMINAS Cubatao has been equipped with these and other advanced technologies to meet market demands. More than 50 mill stands with pair cross and mill stabilizer devices have been supplied worldwide.

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