Development of New Hot Rolling Process for Thin Strip Rolling

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In addition to the cost savings already provided by the energy saving measures and compact process of the mini mill, the costs are reduced even further by producing thin strips by the hot strip mill alone. The Endless Rolling Technology indispensable to the production of thin strips has been added to the mini mill to create a new hot strip rolling process. As part of this new design, the dynamic PC mill, which can control high crown and alter the cross angle with the line in operation, was introduced to enable flying gauge changes, ensuring an excellent strip shape. To ensure stable cutting and coiling during high-speed rolling, specialized exit equipment such as the high-speed strip shear and the Carrousel coiler have been developed and introduced.

1. Introduction

In recent years, reducing equipment costs and operational costs provided through energy saving measures has become an important theme in the steel manufacturing industry. In the field of new hot strip mills, instead of conventional hot strip mills aimed at mass production, the compact process of the mini mill, in which the hot strip mills are directly connected to the thin slab caster, has rapidly gained popularity since the energy saving gains are possible.

There is a demand to produce the thin strips in hot strip mills. In conventional coils by coil rolling, however, it is difficult to produce thin strips because the head and tail end of each strip are rolled in under non-steady conditions. In order to solve this problem, an endless rolling process using a sheet bar welding machine was developed and applied at the Kawasaki Steel Corporation Chiba Works. In this process, the sheet bar welding machine—located between the roughing mill and the finishing mill—joins the sheet bars together, and it is possible to roll continuously in the finishing mill under stable rolling conditions. As very long sheet bars are rolled, non-steady rolling at the head and tail end of each strip can be largely reduced, leading to stable rolling and uniform strip quality.

This report will not focus on the endless rolling process for conventional tandem hot strip mills, rather it will focus on the mini mill, developed by Mitsubishi Heavy Industries, Ltd. (MHI) to enable the manufacture of thin products with a new hot rolling process. In particular, this report highlights the unique MHI technology essential to the development of this new process.

2. New hot rolling process

2.1 Product specifications

The target specifications of the product is a minimum 1.0 mm thickness, and a production capacity of 1 300 000 tons per year.

2.2 Outline of the new hot rolling process

The layout of the new process is shown in **Fig. 1**. Equipment for the new process line consists mainly of a thin slab continuous caster, a tunnel furnace, two roughing mill stands, an intermediate cooling system, five finishing mill stands, an ultra fast cooling system, a high-speed strip shear and a high-speed Carrousel coiler. The technological keys to thin strip rolling are as follows:

(1) A slab thickness of 70 mm, and a casting speed of 6 m/min. maximum. These figures satisfy both the final strip thickness requirement of 1.0 mm, and the annual production target of 1.3 million tons. The continuous caster can cast 300 m long slabs at one time, and this long slab is equivalent to the endless bar of the sheet bar joining method. For batch rolling, the long slab is cut to the desired length with a pendulum shear installed at the entry of the tunnel furnace.

(2) The length of the tunnel furnace is 310 m, and the furnace can heat slabs up to 300 m in length. The tunnel furnace can heat the slab uniformly so that good strip profiles can be achieved in the rolling mills.

(3) All roughing mills and finishing mills are 4-Hi mills, and the R 2 and F 1—5 mills are equipped with Dynamic Pair Cross Systems which can achieve high crown controllability. The Dynamic Pair Cross System can effect thermal crown control when rolling long slabs, and implement flying

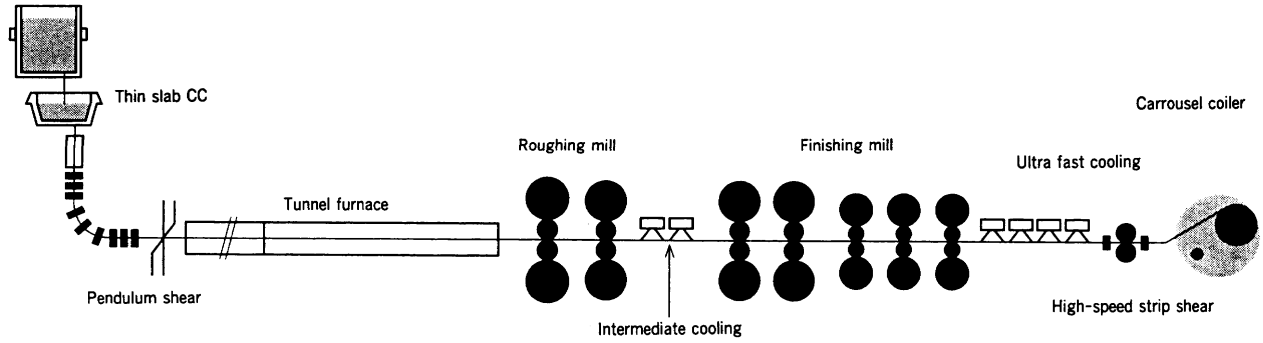

Fig. 1 Layout of the new hot rolling process

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gauge change when processing thin strips. This technology is one of the keys to the new process, and will be explained in more detail in the following section.

(4) The intermediate cooling system cools the rough bar, if necessary, so that the finishing mill delivery temperature is suitable for the product. The ultra fast cooling system is installed on the Run Out Table, and cools the strip rapidly to the target coiling temperature. The length of the cooling system is shorter than that of conventional hot strip mills.

(5) It is necessary to cut the long strips produced from the 300 m long slabs to a suitable length so that the divided strip can be coiled by a high-speed Carrousel coiler. For this purpose, a high-speed strip shear is applied to the line. Because the rolling speed of the process is higher than that of conventional HSM, the shear is specially designed in order to cope with high-speed cutting.

(6) The high-speed Carrousel coiler has two coiling stations with mandrels, so that once divided, the strip can be coiled continuously. With a conventional down coiler, two down coilers are necessary for the process; however, a single high-speed Carrousel coiler is sufficient, contributing energy savings and reduced equipment costs. The advantage of the high-speed Carrousel coiler is not only in its compact structure, it also restrains the uniformity of the product, because it can achieve uniform coiling temperature by keeping the coiling position constant.

3. Key technologies of new hot strip rolling process

3.1 Dynamic PC mill

Rolling mill specifications are as shown in **Table 1**. The No.2 roughing mill and Nos.1—5 finishing mills are equipped with dynamic PC mill technology. PC mills control the strip crown by adjusting the cross of the top and bottom rolls in pairs to change the roll gap geometrically. For ordinary PC mill batch rolling, the finishing mill roll cross angle is preset before rolling, based on an estimate of the required crown control. During rolling, crown control is effected by adjusting the WR (Work Roll) bender according to feed-back from a profile-meter.

For endless rolling, dynamic PC mills effect crown control by changing the roll cross angle while the line is in operation. With its thermal crown control and flying gauge change functions, the dynamic PC mill is a highly effective counter measure against changes in crown profile occurring in mid operation.

3.1.1 Flying gauge change

The long slabs used in the endless rolling process require extra thickness at the strip head and tail to prevent waving and pinching. This is required in batch rolling as well. However, high reduction rolling of the regular portion of the slab between the thick head and tail ends is possible because sufficient tension exists between the finishing mill and the coiler to produce stable rolling conditions. For example, when the final product thickness is 1.0 mm, the strip head portion is rolled to 1.5 mm, and subsequently a flying gauge change from 1.5 mm to 1.0 mm is performed.

In this case rolling force changes sharply so it is not possible to control the strip crown with the bender only. However, to control the crown, the dynamic PC mill is capable of changing the roll cross angle during rolling and is therefore highly effective.

3.1.2 Control of the strip crown as roll thermal crown develops.

With endless rolling, lengthy rolling time means that the rolls expand with heat from the strip. This expansion, which is called thermal crown, greatly influences the control of the strip crown.

It is impossible to obtain the strip crown simply through control of the bender. The Dynamic PC Mill, however, is highly effective in this instance as it allows for changes in the cross angle, and provides tremendous crown control capacity. Accurate prediction of thermal crown is essential in order to give full play to the abilities of the dynamic PC mill.

3.2 High-speed exit equipment

The new hot strip rolling process features continuous rolling, and consequently it is necessary to provide equipment which can cut and coil strip smoothly. The high-speed strip shear makes use of an Oldham's coupling to move the knife drums up and down, cutting the strip by bringing the two knife drums together when the eccentric sleeve is rotated. **Fig. 2** shows an overview of the high-speed strip shear.

The Carrousel coiler has two mandrels as indicated above. Initially, coiling is performed on the Shear side mandrel, and later the mandrel rotates and coiling finishes on the opposite side, 180° away. Preparations for coiling can be performed at the same time as the previous coiling activity finishes, thus enabling continuous rolling.

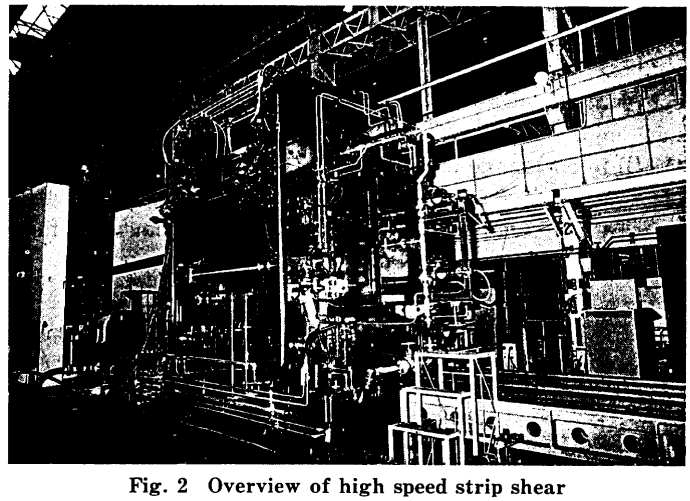

Fig. 2 Overview of high speed strip shear

Table 1 Mill Specifications

Stand		R1	R2	F1	F2	F3	F4	F5
BUR diameter	(mm)	1 450	1 450	1 450	1 450	1 450	1 450	1 450
WR diameter	(mm)	1 050	825	825	825	500	500	500
Motor power	(kW)	4 300	6 300	10 700	11 000	12 000	10 400	7 700
Rolling force	(t)	4 000	4 000	4 000	4 000	3 000	3 000	3 000
PC Max. cross angle	(°)	–	1.5	1.5	1.5	1.5	1.5	1.5

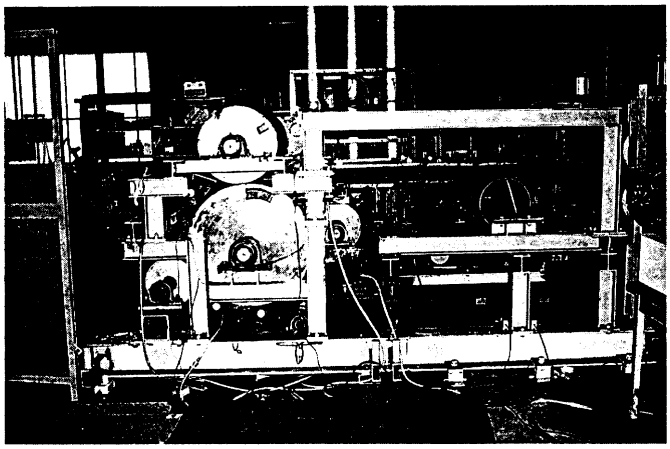

Fig. 3 Overview of coiling test machine

The distance between the leading strip and the trailing strip is slight, so it is important to coil the head of the trailing strip smoothly around the mandrel so as to perform stable coiling. To this end, a test machine (**Fig. 3**) was developed, and the equipment was designed with the optimum arrangement of the circular guides and wrapper rolls. Moreover, the Carrousel coiler has a QOC (Quick Opening Control) system which prevents damage caused by the impact of leading strip head ends with strip coiled later. **Fig. 4** shows an overview of the Carrousel coiler.

4. Conclusion

The mini mill produces energy savings and a compact process in comparison with conventional hot strip mills. The new hot rolling processes has realized endless rolling and the production of thin hot rolled product by using the following technical innovations developed by MHI.

(1) The dynamic PC mill performs flying gauge changes and offers the capability of an accurate control of crown and shape of the strip.

(2) The high-speed strip shear and the Carrousel coiler have been developed to ensure stable cutting and coiling of thin strips under high-speed rolling conditions.

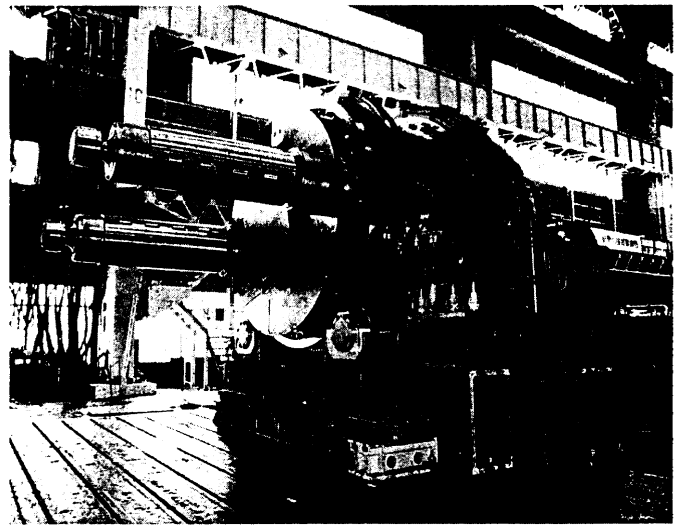

Fig. 4 Overview of Carrousel coiler