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Renewal of Pouring Reels of Bar Mill Plant

Shohhei SAKIYAMA* Kouichi HASEGAWA

Abstract

The formation of special steel bars and wire rods by cold forging is increasing, and as a consequence, users of these products require an increasingly higher surface quality. With respect to bars in coil, in particular, it is necessary to decrease the banding marks resulting from the scratching of rings in a coil during banding. To improve the coil appearance and decrease surface defects in consideration of the situation, the pouring reels and the main control system of the coiling line at the Bar Mill Plant of Muroran Works, the facilities of which have aged considerably, were renewed in 2014, producing satisfactory results.

1. Introduction

The Bar Mill Plant of Muroran Works of Nippon Steel & Sumitomo Metal Corporation began operation in 1974 as a plant specialized in special steel bars. The equipment of its bar-in-coil line was relocated from the Wire-rod Mill of the same works in 1988, and the plant has produced both straight bars and bars in coil ever since (see **Fig. 1**). The coiling line has aged through many years of operation, with the pouring reels sitting at 45 years since installation and the main control system for the line sitting at 28 years. Moreover, customer requests for higher coil quality have increased significantly. In consideration of the above, the pouring reels, their drive motors and the main control system of the coiling line were replaced with new ones in April 2014, aiming at enhancing the coil packing quality, an essential quality item of the product, reducing surface defects arising from coil banding and improving the productivity and work environment. This article presents the details of the revamping work.

2. Outline of Pouring Reels

Figure 2 shows how a bar is coiled by a pouring reel. After passing through the finishing mills, the bar goes through the guiding line equipped with pinch roll stands and then is led to one of the pouring reels, where it is wound into a coil. After the bar is wound to the tail end, the coil is discharged from the reel, loaded onto the coil transfer line, and then undergoes conditioning, which consists of end cutting, inspection and banding. Finished bars in the coil are either

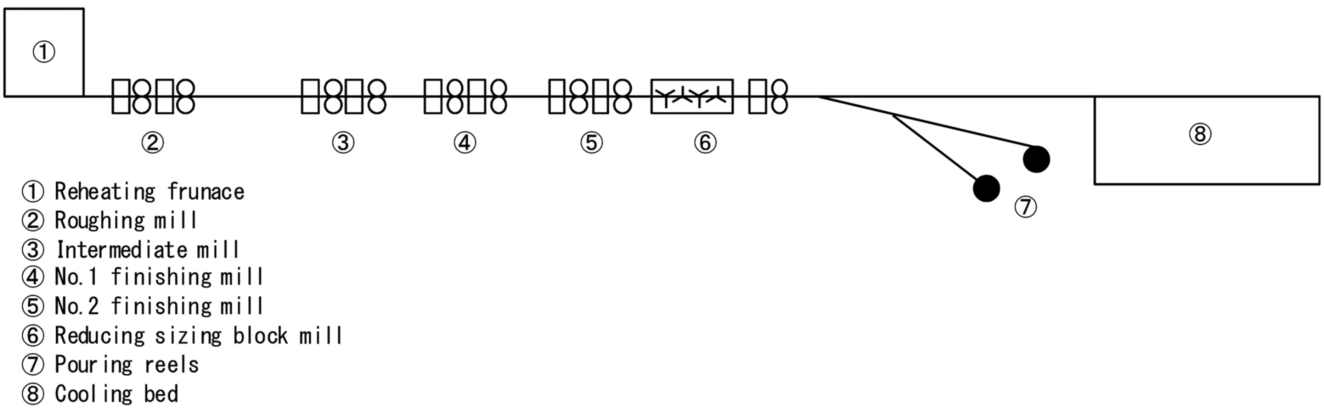

Fig. 1 Layout of Muroran Works bar mill plant

* Bar & Wire Rod Rolling Technical Dept., Bar & Wire Rod Rolling Div., Muroran Works
12 Nakamachi, Muroran City, Hokkaido, 050-8550

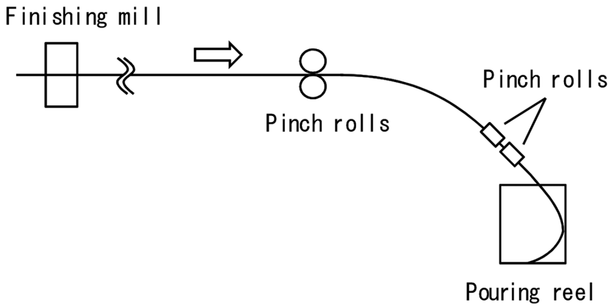

Fig. 2 Layout of coiler line

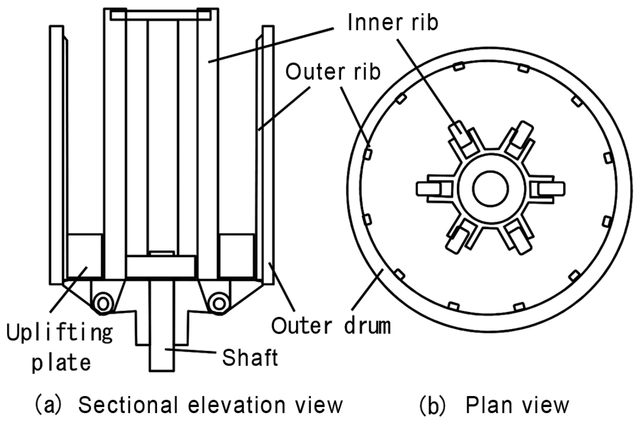

Fig. 3 Pouring reel before renewal

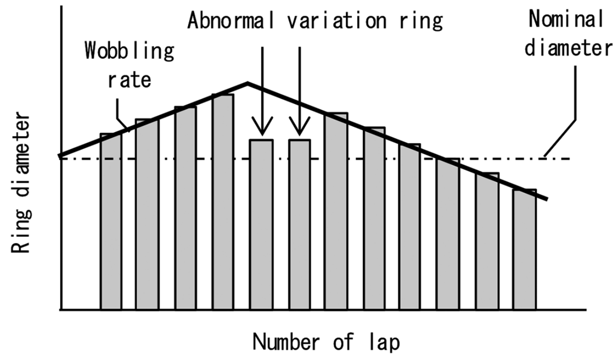

Fig. 4 Measurement results of the ring diameter

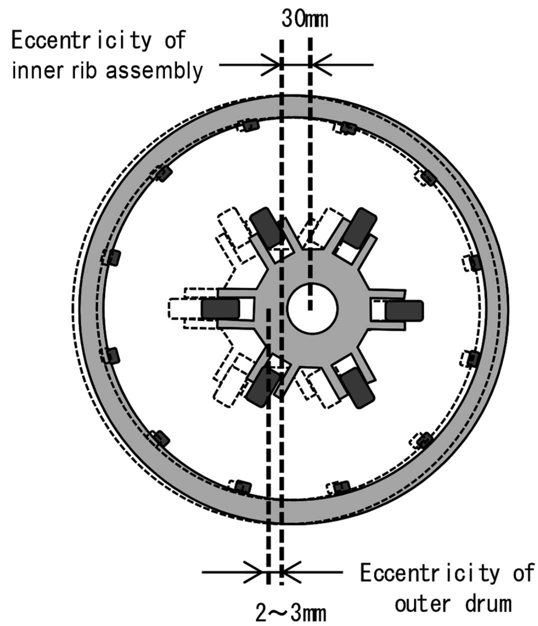

Fig. 5 Measured eccentricity of reel

shipped to users or sent to further treatment processes such as annealing.

Figure 3 schematically shows the pouring reel before the renewal. Vertical members, called ribs or sometimes pins, were provided to hold the coil from the inside and the outside at equal intervals. Whereas the outer ribs were mounted movably in the radial direction to produce coils of two different outer diameters, the inner ribs were fixed at their lower ends to the bottom of the drum, and tied to each other horizontally at the top ends. The bottom plate of the space in which the coil is wound is vertically movable so that, before receiving an incoming bar, it is set at the best position calculated from the weight of the coil to prevent the tail end of the bar from protruding outside the reel.

3. Problems of Old Facilities

The problems of the pouring reels before the revamp are explained below. There were various problems due to different reasons: some arose owing to the aging of the equipment, and others became obvious as a result of the capacity increase, change in the operation regime, etc. of the mill.

3.1 Banding marks

User requirements for higher product surface quality have grown stricter year by year, and regarding bars in coil, measures were sought to minimize surface defects, especially banding marks, which tended to be deep. They resulted from the scratching of rings with each other within one coil during banding after coiling. They were mostly in the form of grooves running roughly at right angles to the rolling direction, the grooves form in both of the scratching rings, and since the marks are formed mostly when cold, the groove surfaces have a metallic luster in different degrees depending on the temperature of banding. Past experience has shown that banding marks tended to occur more with loose coils since the rings moved more easily during banding.

Investigations into the cause of banding marks confirmed that they occurred more often at specific positions as explained below. To increase the packing density of coils, the reel rotation speed is changed during the coiling of a bar so as to evenly distribute the rings from the inner to outer sides of the coil; this speed control is called wobbling control (see **Fig. 4**). When the diameters of the rings in which banding marks occurred were measured, however, more than half of them were found to occur in rings with irregular diameters not conforming to the wobbling control. Figure 4 shows a case where the diameters of some rings are smaller than intended by the wobbling control. Note that abnormal rings are either smaller or larger in diameter, and the banding marks were confirmed to occur in both cases.

We presumed that the cause of the abnormal ring diameter was the decentering of the reel due to deformation of the ribs and their support structures, and investigated the decentering during rotation. **Figure 5** shows the investigation result: the eccentricity of the inner rib assembly was as large as 30 mm at worst, which supposedly led to the steel being wound at a speed not intended by the wobbling control, and caused temporary fluctuation of the ring diameter, which then adversely affected the diameters of subsequent rings. The decentering was found to result from thermal deformation of the ribs proper and the wear of their support structure. The parts fixing the ribs were replaced with new ones to correct the decentering, but the situation did not improve significantly. From this, we concluded that it was necessary to review the entire reel structure to improve the structural strength and replace them with new ones.

Another cause of the irregular change of ring diameter was that the drive motors of the reels sometimes failed to run at the rated speed for high-speed coiling of small-diameter products. This was because, even when large acceleration and deceleration were required for wobbling control, the motor speed could not surpass a certain rotation owing to the upper limit of the motor current. Thus, it was necessary to increase the motor capacity as well at the renewal.

3.2 Rib marks and rib polishing

During coiling using the old pouring reel, the ribs contacted the hot product and their surfaces were roughened by seizure at high temperature. When a coil was wound to the end and lifted up from inside the reel, the coil scratched the ribs and because of the rough rib surfaces, oval depressions having a rough surface, or rib marks, formed at the bar surface on the outer side of the coil. **Figure 6** shows the change in the surface temperature of the outer rib surfaces during continuous operation. Since the old reels did not have any measures to cool the ribs, the rib surface temperature often exceeded 250°C after coiling roughly 30 bars, and in this temperature range, the surface roughening advanced and the depth of rib marks tended to increase. For this reason, after coiling a product lot of 500 t, the mill line operation was temporarily stopped, the reels were cooled with water spray from above, and then after the machine became sufficiently cool, operators went down to the reel inside to polish the rib surfaces. This, besides being unpleasant work in a hot environment, greatly decreased the productivity of the mill line, and for many years effective measures to dispense with the stoppage were investigated.

3.3 Tail overflow

At the end of coiling of a bar, the tail end sometimes fails to be wound to inside the reel and protrudes upwards; this is called tail overflow or pig-tailing. It tended to occur more at the coiling of small-diameter bars at low temperature. This was because the coil height of a small-diameter product tended to be large, and in addition, in coiling at low temperature, the bending stiffness of the steel increased, lowering the packing density of the coil, which led to further increase in the coil height; the coil height sometimes exceeded the reel depth before winding up a bar to the tail end. Before the revamp, there were no other countermeasures than to set an upper limit to the coil weight of small-diameter bars, but this lowered the yield of the product more than that of others. It was desirable, therefore, to increase the depth of the reels and remove the upper limit of the coil weight.

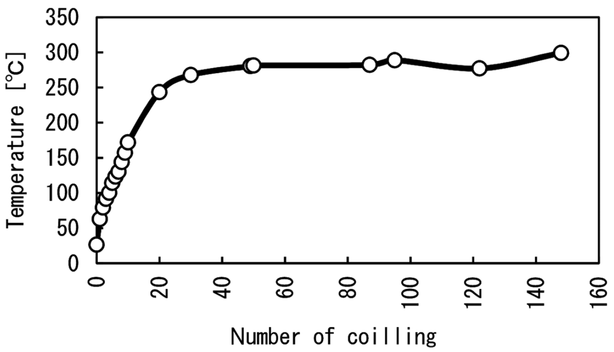

Fig. 6 Change of rib surface temperature

3.4 Machine aging

In addition to the product quality problems described above, the very machines of the reel were seriously aged; the bearings and gears of the reduction units, which were the causes of the reel decentering, were near the end of their service lives, as was the insulation of the drive motors. Moreover, the main control system that regulated the operation of the coiling line was so old that there was little room for partial improvements; the circuit boards were no longer manufactured, and its software capacity was insufficient. It therefore had to be renewed as a matter of urgency.

4. Outlines of Renewal

To solve the problems described in the previous Section 3, the pouring reels, their drive motors and the main control system were replaced with new ones. The pouring reels were ordered from Danieli Morgardshammer in appreciation of the rich supply of references of this type of machine worldwide including Japan. **Figure 7** shows a vertical sectional view and a plan view of the reel after the renewal, and **Table 1** its main specifications. The features of the new machines are explained below.

4.1 Change from rib type to drum type

To solve the problem of the decentering of the ribs permanently, the machine structure was changed from the rib type to the drum type, which is more robust and less prone to the decentering by aging than the rib type, although it is more expensive. Another advantage of the drum type is that the bar is held by the inner surface of

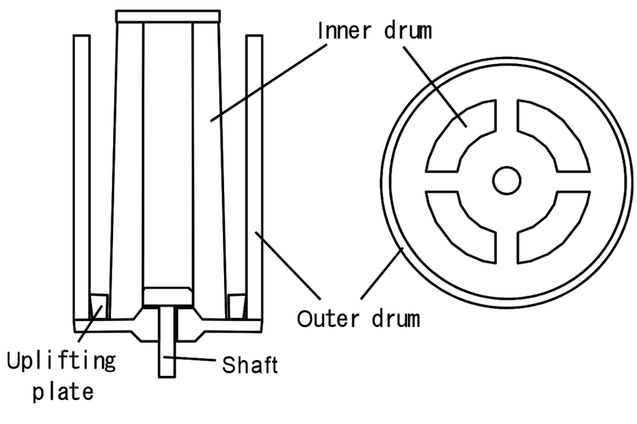

Fig. 7 New pouring reel

Table 1 Main specifications of pouring reel

	Before renewal	After renewal
Type	Rib type	Drum type (no ribs)
Outer diameter	1400/1270 mm	1350 mm
Inner diameter	1010 mm	1000 mm
Height	1800 mm	2300 mm
Motor capacity	400 kW	600 kW
Manufacturer	Hitachi Zosen (Kobelco)	Morgardshammar (Danieli)

the outer drum rather than at points by the outer ribs, and surface defects are less likely to occur. On the other hand, to produce coils of large and small diameters, which was possible with the rib type reels, with the drum type it is necessary to change the drum, and this did not seem viable considering the operators' work load and the line stop required for the drum change. Since the majority of the coils were of the larger outer diameter type before the revamp, the coil diameter was unified to the larger through consultation with clients, and selection of the drum type was enabled. The drum diameter of the new reels was set slightly smaller than the larger outer diameter before the renewal, and by reducing the coil thickness (the difference between the inner and outer diameters), increase in the packing density was envisaged.

4.2 Introduction of reel cooling

To prevent the recurrence of seizure marks like the rib marks before the revamp, measures for cooling the outer and inner drums were newly introduced. The outer drum was designed to be cooled with water spray from outside, and the inner drum to consist of sections of water tanks so that they were cooled by the vaporization of the water. Thanks to these measures, it became possible to keep the reel portions in contact with the product cooled during coiling operation.

4.3 Improvement of wobbling control

To increase the coil packing density, the reel rotation speed was changed during coiling (wobbling control), but before the renewal, the pattern of the acceleration and deceleration could be controlled in the form of triangular waves, only the amplitude and cycle were changeable, and for this reason, delicate wobbling control was impossible. To increase the coil density, the wobbling control function was improved during the replacement of the main control system. Trapezoidal and other waveforms were enabled in addition to the triangular waves, and changing wobbling conditions according to the size and steel grade of the product became practicable. It also became possible to individually set, in addition to the amplitude and cycle, the rates of acceleration and deceleration, the time of constant speed after each acceleration and deceleration. Furthermore, to prevent the head end of bars from sticking in the reel bottom plate or striking it too strongly, a head-up control has been introduced, whereby the reel rotation is accelerated when the head end of a bar comes into the reel.

4.4 Increase in reel depth

Overflow of coil tails was a problem before the renewal. Moreover, since the diameter of the outer drum was decreased slightly, the coil height would inevitably be larger than before. In consideration of this, the reel depth has been increased from 1800 to 2300 mm.

4.5 Increases in motor capacity and speed

As described earlier, there were cases where the drive motors could not run as fast as required owing to the current limit. Besides this problem, it was necessary in the capacity and rotation design of the new reel drive system to solve another problem of the motors being used mostly above the rated current. In consideration of the load conditions of the old motors and the moment of inertia of the new reels, the capacity of the drive motors was increased from 400 to 600 kW.

4.6 Other improvements

At the renewal of the main control system, it was replaced with one composed of programmable logic controllers (PLCs) of the most advanced type used in the steel industry, and at the same time, an on-line data collection and processing system was incorporated to enable storage and analysis of control data. By this, it has become possible to prevent machine problems from recurring and decreasing product quality problems by tracing back operation data to identify their causes.

5. Effects of Reel Renewal

5.1 Decrease of banding marks

When coil packing density is low, rings move easily in the coil during banding, increasing the risk of banding marks. In consideration of this, the improvement effects of the revamping were evaluated using unit coil height (mm/t, coil height after banding divided by coil weight) as an indicator of the coil packing density. As a typical example, **Figs. 8** and **9** compare the unit coil heights of bars in the coil of JIS S10C, 19 mm in diameter, before and after the renewal. After the revamp, the unit coil height decreased roughly by 9 %, on average, realizing an improvement in the coil packing density. Similar results were obtained with products of other sizes. In addition, the eccentricity of reel rotation has been suppressed and the occurrence of abnormal ring diameters deviating from the wobbling control decreased thanks to the renewal of the reels.

Since the above looked promising for decreasing the banding marks of coils, we examined the actual banding marks off line along the entire lengths of S10C bars in a coil, 19 mm in diameter, produced before and after the revamp. **Figure 10** shows the result: the occurrence of banding marks decreased by 80% after the revamp, realizing the positive effect of increased coil packing density. The increase in the coil packing density proved effective also at improving coil appearance. Thus, the revamp of the bar-in-coil line has produced significant improvements in surface defects and coil appearance, important quality items of bars in coil.

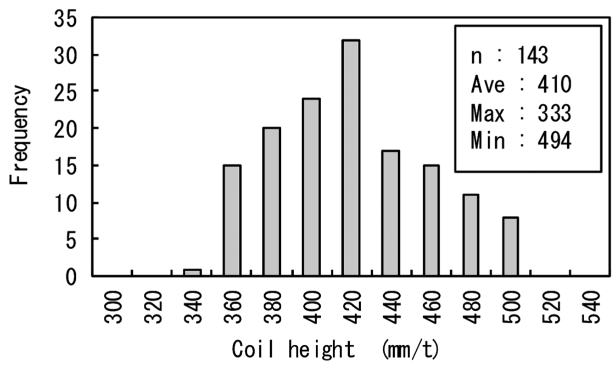

Fig. 8 Coil height before renewal (19 mm dia. S10C)

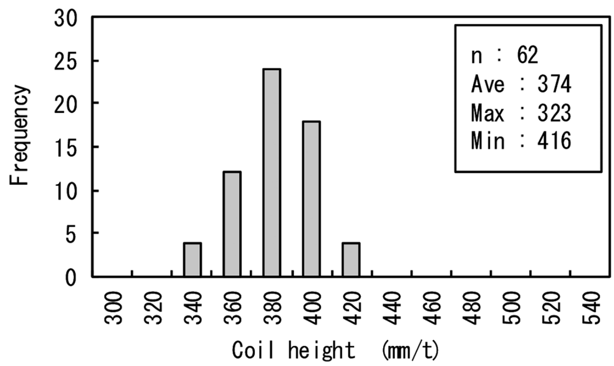

Fig. 9 Coil height after renewal (19 mm dia. S10C)

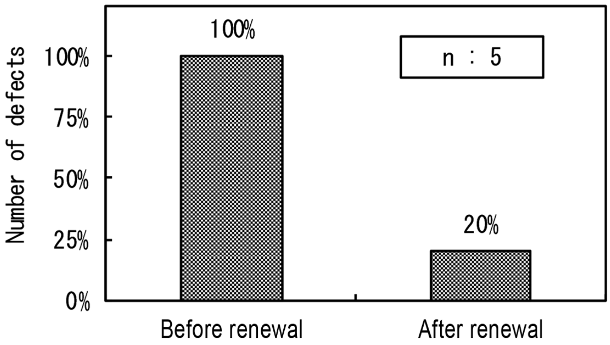

Fig. 10 Number of defects by banding (19 mm dia. S10C)

5.2 Other effects

Since the introduction of the water cooling of the outer and inner drums of the reels, the drum surface temperature during coiling has been controlled to 200°C or lower, and the surface roughening due to burning has ceased to occur. As a result, the mill stop after rolling at a prescribed tonnage has become unnecessary, the productivity has increased, and the operators have been freed from exhausting rib polishing work. Since the reel depth was increased, the tail overflow at low-temperature coiling has decreased, and as a consequence, the upper limit to the unit weight of the billets has been removed, creating an increase in production yield.

6. Conclusion

As a result of the renewal of the pouring reels and the main control system of the bar-in-coil line, the problems regarding essential product quality items such as banding marks, rib marks and poor coil appearance have been solved, and in addition, productivity, operators' work conditions and production yield have been improved. The new facilities have been operating satisfactorily since the completion of the renewal in May 2014.


Shohhei SAKIYAMA
Bar & Wire Rod Rolling Technical Dept.
Bar & Wire Rod Rolling Div.
Muroran Works
12 Nakamachi, Muroran City, Hokkaido, 050-8550


Kouichi HASEGAWA
Manager
Bar & Wire Rod Rolling Technical Dept.
Bar & Wire Rod Rolling Div.
Muroran Works