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VCR 롤이 판평판도에 미치는 영향

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Effects of Varying Contact back-up Roll on the strip flatness in four high mill

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ABSTRACT

VCR is a back-up roll with a special contour which leads to the length of the contact line between back-up roll and work roll becomes self adjustable in accordance with the width of the strip. The simulation of a finite element model and the on-line test at production mill demonstrate that the VCR roll may keep the crown of the roll gap relatively stable, and at same time, permit the rolling pressure to be adjusted over a wider range, and increase the effect of work roll bending on the roll gap. The VCR rolls have been successfully used at the first stands of two largest cold rolling mills in China, and on-line test has been done at a wide hot strip finishing train. The use of VCR roll has created favorable conditions for subsequent rolling passes and the achievement of better flatness quality.

Key words: strip flatness control, strip shape, strip rolling, back-up roll, varying contact.

Flatness is one of the most important criteria in determining the quality of strip. Steel consumers prefer strip of high-precision flatness. Poor shape, such as wavy edges or center buckles, will lead to operational difficulties in rolling itself and in subsequent processing. Control of the flatness of strip has been one of the most important developments in rolling mill technology in recent years.

In China, the two largest cold strip rolling mills are located in the cities of Wuhan and Shanghai. Both of them are five-stand, one is 1700mm cold tandem mill in Wuhan Iron and Steel Company (WISCO), and the other is 2030mm continuous cold tandem mill in Shanghai Baoshan Iron and Steel Complex (SBS). In practical operation, the two mills have difficulties with bad strip shape.

From 1987 to present, a varying contact length back-up roll (VCR) for the purpose of flatness control has been developed at the WISCO cold mill, and then applied to the SBS cold mills. As a new approach, a series of on-line tests have been done at 1700mm hot mill in WISCO in 1997. The use of VCR roll enables better control over strip flatness. Furthermore, they have helped to reduce operational difficulties and raise mill productivity.

1. Principle of the VCR roll

In a conventional four-high mill, the length of the contact line between the work roll and the back-up roll is longer than the width of the strip rolled. The bending action on the work roll exerted by the distributed contact pressure at the overhung sections tends to increase the crowning of the roll gap and caused the roll gap crown to vary with the

rolling pressure fluctuation. Both effects are undesirable in terms of flatness control, because an increased roll gap crown contributes to the occurrence of a wavy shape or implicit residual compressive stresses at the strip edges, and a variable gap crown restricts the possibilities for adjustment of rolling pressure, which is necessary as the operational condition fluctuates. An ideal roll gap should be capable of maintaining its crown relatively stable at an optimum value for high-quality flatness and, at the same time, permit the rolling pressure to be adjusted over a sufficiently wide range to deal with variations in rolling conditions or feedstock.

The stability of a roll gap can be evaluated by the gap stiffness values S, which is defined as the ratio of the rolling pressure fluctuation ΔQ to the correspondingly induced change of the roll gap crown ΔCw across a given strip width, that is:

$$S = \Delta Q / \Delta Cw$$

In order to strengthen the roll gap stiffness, every effort has to be made to eliminate the undesirable overhung sections of the contact zone between the work and the back-up rolls beyond the width of the strip rolled. One simple way is to undercut both overhung portions of the back-up roll. Thus, the length of the contact line between the rolls is identical to the width of the rolled strip. This type of back-up roll is known as a stepped back-up roll. However, when a wider strip is rolled or a strip travels with some offset, the roll gap will result in an impermissible negative crowning. Therefore, this option is only applicable for mills that produce strip of a constant width. Another way is to shift the work roll transversely in order to eliminate overhung section. This solution is also relatively simple in concept, but installation of roll shifting is expensive and time consuming, especially in the case of modification of an existing mill.

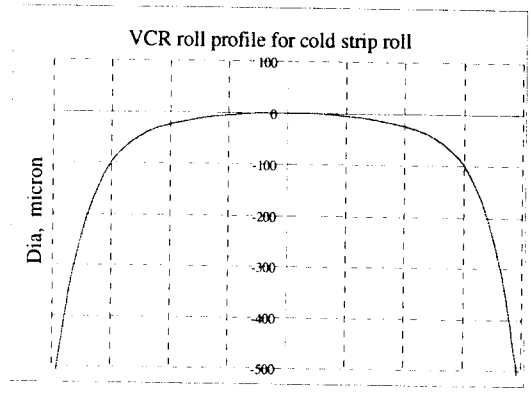

Figure 1. Design contour of VCR roll

The concept of the VCR back-up roll is derived from the stepped roll mentioned above. A curved contour for the back-up roll, as shown in Figure 1, was designed so that the length of the contact line between the rolls becomes self-adjustable in accordance with the width of the strip rolled. Under all circumstances, the contact length between the rolls is not exactly equal to the width of the strip, but is fairly close to it. This effect helps to provide the VCR roll system with increased roll-gap stiffness. At the same time, the curved contour enlarges the area of roll-gap adjustment by work roll bending.

The contour design of VCR roll was based on the finite element approach of elasticity and a series of on-line tests at WISCO and SBS.

During the on-line tests at the two production mills, all five stands were brought to a standstill and the top rolls were lifted to leave the roll gaps open. Samples of strip having a length extending from the entry of the first stand to the exit of fifth stand were cut to obtain the profiles of the exit strip from each stand, which described the geometry and the crown of each roll gap. A total

of 101 samples were obtained from different coils, with a total length of about 3km, to provide sufficient data verify roll contour design and determine roll gap characteristics.

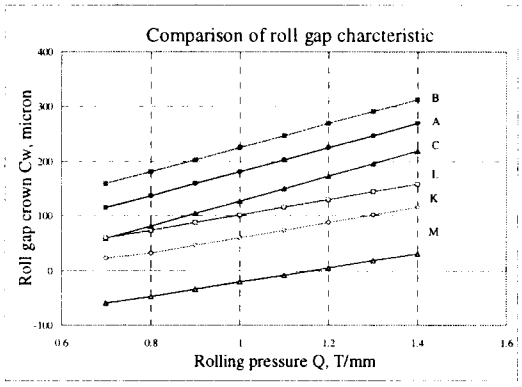

Figure 2. Comparison of roll gap characteristic of VCR roll and conventional back-up roll
(A,B,C - conventional roll; K,L,M - VCR roll)

2. Roll gap characteristic

The roll gap characteristic is defined as the functional relationship between the rolling pressure Q and the roll gap crown Cw across a specific strip width B. From the computer simulations and the on-line test data, the roll gap characteristics can be expressed to a satisfactory approximation by family of parallel straight lines in a Cw-Q coordinate plan, as shown in Figure 2. The family consisting of the lines A, B and C is for a conventional back-up roll, and the family consisting of the lines K, L and M is for a VCR design. In each family, there are three lines for the work roll bending force applied, Jw, and the pattern of the rolling pressure distribution across the strip width, Ps. The latter parameter is defined as:

$$Ps = Qc / Qav$$

where Qc is the rolling pressure at the center of the strip width, and Qav the average pressure across the strip width. For line A or K, Jw=0 and Ps=1.0; for line B or L, Jw=0 and Ps=1.1; and for line C and M, Jw=100 percent and Ps=1.0.

In Figure 2, the area between the lines A and B represents a possible zone of uncertainty of the pattern of the rolling pressure distribution, and that between the lines A and C, the zone of roll bending force is adjusted from zero to its maximum. The same is true of the areas between the lines K and L and between the lines K and M. From this plot, the following conclusions may be drawn:

a) By the use of a VCR back-up roll, the roll gap crown can be reduced to a more optimum level for flatness control. And at the same time the roll gap stiffness is strengthened - these characteristics of the VCR roll open the way to attaining a more unrestrained adjustment of the rolling pressure for dealing with complicated situations or fluctuation of the feedstock conditions.

b) The area of roll gap adjustment by bending the work roll can be enlarged by the use of a VCR back-up roll, and

c) Consequently, it is most suitable to use the VCR back-up toll at the first stand of a cold tandem mill where a wider range of either rolling pressure or roll gap adjustment is required for maintaining smooth throughput of the incoming stock and creating favorable conditions for flatness control in the subsequent stands.

3. The performance of VCR rolls

Operational experience of VCR rolls in the cold rolling mills of WISCO and SBS has enable us to draw the following conclusions with respect to performance.

The VCR roll enables a higher rolling pressure at the first stand and a more uniform distribution of

loads among the five stands. The rolling forces from first to fifth stand are now: 1, 1, 0.9, 0.9, and 0.9 compared with 1, 1.25, 1.1, 1.1 and 0.9 before VCR application.

The VCR roll ensures smoother passage of strip through the first stand and prevents offset or breakaway, Furthermore, it promotes mill adaptability to product varieties, as well as the ability to handle varying feedstock, and most importantly, it contributes to improved mill productivity.

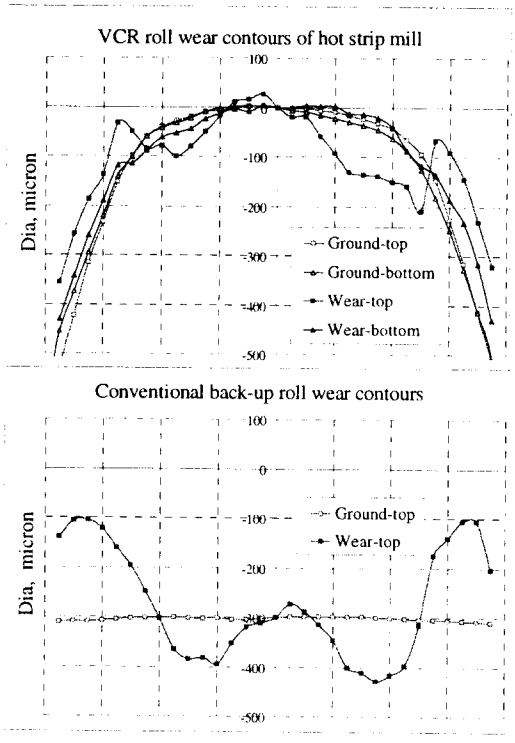

Figure 3. Comparison of wear contours of VCR rolls and conventional back-up rolls for stand F3 of 1700mm hot strip finishing train

The VCR roll can maintain its contour through a complete campaign in a similar shape to that originally ground without the formation of a concave section at the center of the roll in cold rolling mill. The tonnage of strip rolled by the VCR roll in one campaign is 35-40 percent greater than when using conventional rolls and has reached a level of 80 - 100kt, equivalent to a length of 3500-4400km. The similar results have been achieved from the on-line tests for stand F3 of 1700mm hot strip finishing train in WISCO as shown in Figure 3. Generally the local wear of back-up roll in hot mill is greater than cold mill. The local wear on the center portion of back-up roll may alter the distribution of pressure between back-up roll and work roll and increase the strip crown.

Table 1. Distribution of strip flatness after the use of VCR back-up rolls

Range of Flatness in I-units	Accumulated strip length	
	Meters	%
<=5	37444.5	76.84
>5-10	6498.2	13.34
>10-15	2663.5	5.47
>15	2123.9	4.36
Total	48730.1	100

Finally, the standard of strip flatness has improved considerably. In the sampling operations, 27 coils or 48.73km of finished strip from the SBS mill, whose fifth stand is equipped with a continuously variable crown(CVC) system for automated flatness control, were examined by measuring flatness in I-units using a computerized laser system and the results are shown in Table 1.