Some Sources of Variation in the Strength of Hot-Rolled Strip

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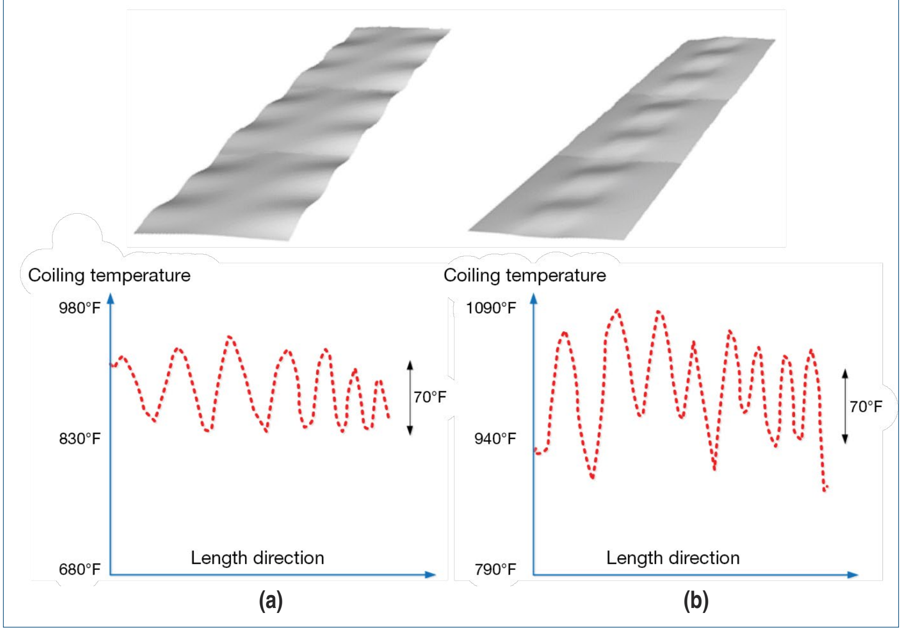
Variation in strength along the length of hot-rolled strip presents the challenge of complying with gauge tolerances at the cold mill. Such strength variation, however, is typically manifested only when cold rolling begins and can lead to strip breaks, especially while rolling advanced high-strength steel (AHSS) grades. Charts of the thickness variation along the length of hot-rolled strip provide no indications of the variable strength. This is because the sources of the variable strength are located further downstream from the finishing stands, i.e., in the laminar cooling section and in the method that the hot-rolled coils are stored in the coil yard.

Maintaining constant coiling temperature is essential for assuring the uniformity of strength of the hot-rolled strip along its length. As industrial studies have shown,[1] flatness of the strip significantly affects the stability of the coiling temperature. Fig. 1 presents results of the measurements of the coiling temperature for the cases of wavy edges and full center. It is worth noting that full center caused a noticeably higher degree of temperature variation compared to the wavy edges.

Usually, true flatness is visible at the head end of the strip, which is rolled without the coiler tension. Once the tension is established, the strip becomes flat. The effect of flatness — full center — is shown in Fig. 2. The head end flatness

Figure 1



Coiling temperature profiles for wavy edges (a) and full center (b), adapted.[1]

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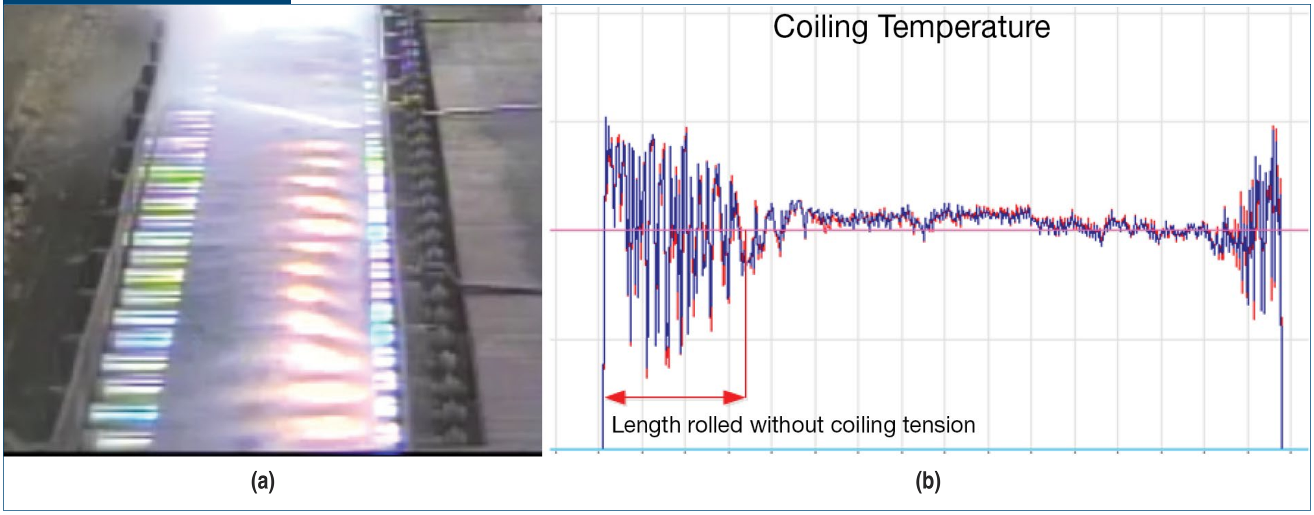
Figure 2



Effect of full center (a) on the coiling temperature (b).

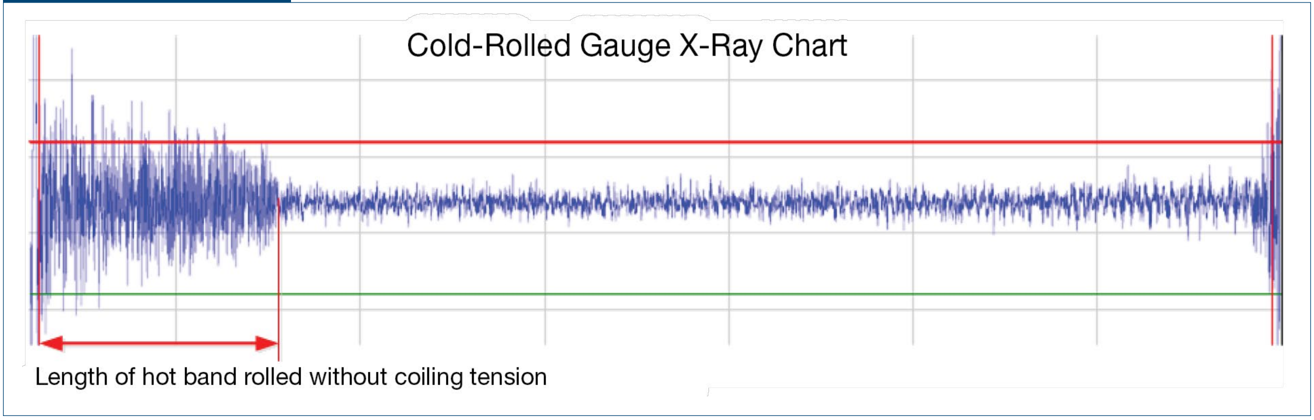
is presented in Fig. 2a. The corresponding coiling temperature demonstrates a high degree of variation (Fig. 2b). As a result, the hot band developed significant variability of strength, which manifested itself during the following cold rolling, as shown in Fig. 3.

It is logical to assume that water carried in the "valleys" of full center, while the strip passes through the laminar cooling section, causes the strip temperature to drop further down compared to the "peaks." Moreover, as the mill practice showed, by improving the head end flatness, variation of the coiling temperature was eliminated, which in turn resulted in stable cold rolling.

The Effect of Coil Storage Arrangement

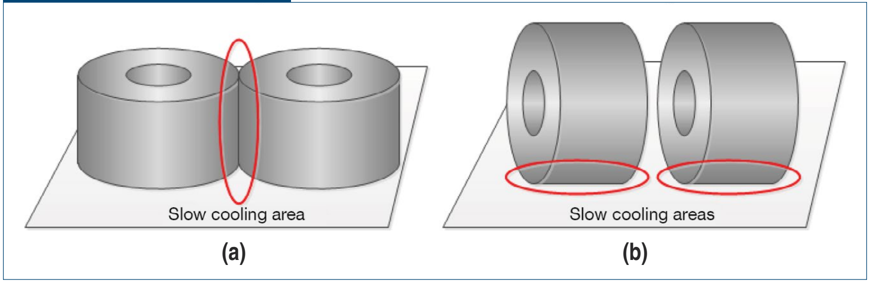
Flatness of the hot band is not the only possible source of strength variability. Equally important is the way the hot-rolled coils are stored in the coil yard. There are two methods of storage widely used in the hot strip mills: eye-vertical and eye-horizontal. Both methods allow storage in a single or two-story stack. The mill's practice shows that some steel grades are very sensitive to the cooling rates during air cooling in the coil yard. Often merely a contact or the close proximity of two coils (Fig. 4a), or a contact with the pavement (Fig. 4b), can noticeably reduce the cooling rate in the affected areas. For example, an investigation[2] showed that storage of two coils as shown in Fig. 4a resulted in a "tornado" gauge variation during the following cold rolling.

Figure 3



Cold-rolled gauge variation caused by the variable strength of the hot band.

Figure 4

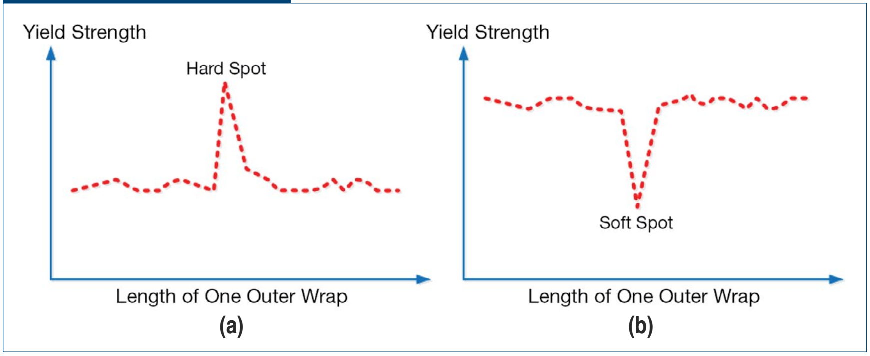


Storage of hot-rolled coils that may cause the yield strength variation.

Slower cooling rates can produce a dual effect, depending on the chemistry of the hot band. In some grades, slow cooling promotes precipitation of interstitial elements, causing precipitation hardening. The measurements of the material hardness along the circumference of one outer wrap show a hard spot located in the area of contact between two coils, as shown in Fig. 5a. Other grades, for example AHSS, can develop a soft spot in the area of slow cooling due to the reduced austenite decomposition to the harder phases, such as bainite and martensite (see Fig. 5b). Nevertheless, both scenarios lead to the same consequences, i.e., to the periodical strength variation along the length of the hot-rolled coil.

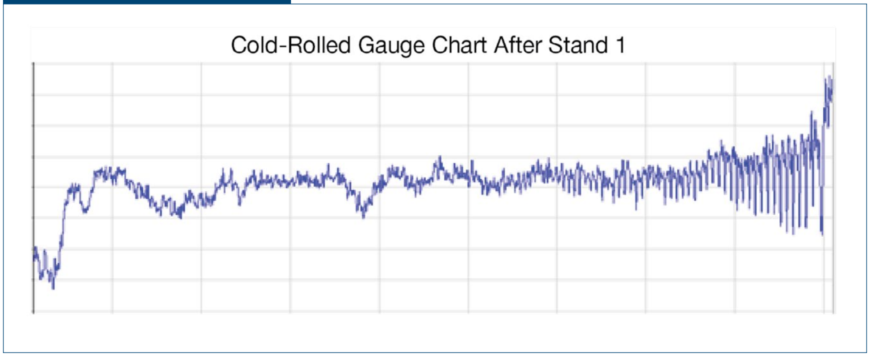
Such periodic variation is not revealed until the strip passes through the roll bite in the first stand of the tandem cold mill, where variable strength will cause deviation of the exit gauge.[3] An example is provided in Fig. 6. An x-ray thickness sensor installed after stand 1 reports the gauge deviation of an exponentially increasing amplitude from approximately two-thirds of the coil length toward the tail. The amplitude of oscillations will significantly increase in the following stands and often can cause the strip break at the tail (Fig. 7) for the same coil as in Fig. 6. The maximum cold-rolled gauge deviation is at the coil tail, which corresponds to the outer diameter (OD) of the hot-rolled coil. This is in agreement with the fact that the maximum effect of slow cooling on the yield strength — either increasing or reducing it — will be at the coil OD, while gradually diminishing toward the coil inner diameter. The findings are in good agreement with other similar investigations.[4]

Figure 5



Yield strength variation over the length of one wrap: a hard spot due to precipitation hardening[2] (a); a soft spot due to smaller volume of bainite and martensite[3,4] (b).

Figure 6



Gauge deviation measured after stand 1.

Conclusions

Variability of strength of the hot-rolled strip along its length can present the challenge of maintaining the cold-rolled gauge within the tolerance range and can seriously jeopardize the stability of cold rolling.

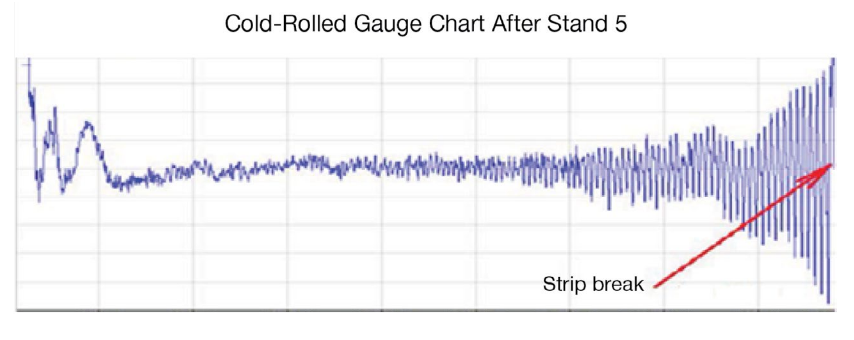
Both an excessive non-flatness at the head end and a method of storage of the hot-rolled coils in the coil yard can noticeably impact the strength of the hot band.

The hot strip mill practice showed that an improved flatness at the head end allowed for the elimination of cold-rolled gauge deviation caused by strength variability.

Slow cooling of the localized areas of the hot-rolled coils during their storage in the coil yard can lead to local hardening or softening, depending on the chemical composition of the particular steel grade.

For grades that are sensitive to the cooling rate during storage in the coil yard, an eye-vertical position avoiding a contact or the close proximity with the neighboring coils may be recommended.

Figure 7



Gauge deviation measured after stand 5.

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Did You Know?

Eneco and ArcelorMittal Unveil Belgium's Largest Solar Roof

The installation of more than 27,000 solar panels on the roof of ArcelorMittal in Ghent has been completed, resulting in the largest solar roof in Belgium. The EUR7.5 million solar roof was installed by Eneco and is its largest project to date. The project will help ArcelorMittal Belgium in become more sustainable as the power generated will be used internally by ArcelorMittal in Ghent. More than 5,000 employees are also given the opportunity to co-invest in the solar panels and benefit from the revenues.

The solar park at ArcelorMittal's site in Ghent consists of 27,104 solar panels for which 157.2 tons of steel was used. The total weight of the installation amounts to 1.5 million kilos. This means that ArcelorMittal now owns the fourth-largest solar park in Belgium and the largest solar roof in Belgium.

The new solar panels will produce 10,000 MWh of energy annually, equal to the energy consumption of 2,900 households. The solar panels, together with the site's (current) 10 wind turbines and the two additionally planned wind turbines, will soon provide approximately 50 MW of renewable power to the Ghent site. The sustainable energy that is generated is used entirely internally to feed the production of ArcelorMittal in Ghent.

With this investment, the company reinforces the implementation of its sustainability strategy. ArcelorMittal Belgium follows the Paris climate agreement. The site's emissions are already 25% lower than in 1990, which is 20% better than what the Paris climate agreement demands. By 2027, ArcelorMittal Belgium aims to produce 43% fewer emissions, with the ambition of being carbon neutral by 2050.