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Coil breaks in low carbon steels

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Abstract. This paper represents the metallurgical and mechanical background of the so-called coil break formation in low carbon steels. Coil breaks are narrow, shiny or matt bands on the surface of steel strips. These bands are considered as very rough surface defects, because they will appear on the surface of the end product and make difficulties during further processing.

Keywords: coil break, stretcher lines, discontinuous yielding

1 Introduction

Low carbon steels in hot rolled as well as in cold rolled and annealed state are frequently used for cold forming applications. The surface quality of the final product is depend on the surface quality and yielding characteristics (deformation mechanism) of the raw material [1,2]. Low carbon steel grades usually consist of elements in w.t. %: 0.02…0.05 C, 0.15…0.3 Mn, ~ 0.01 Si, 0.03-0.06 Al, 0.004…0.006 N, 0.015…0.02 Cr, 0.01…0.03 Cu, and low amount of Ti, Mo, Ni, Nb [3-5]. Fig. 1 shows the production sequence of low carbon steels in conventional hot strip mills. The raw material for producing a low carbon steel strip is the continuously cast slab. This is a 220 mm thick, 1 m wide and 6-8 m long pre-product, which is reheated to 1200-1270 °C in order to make possible the further plastic deformation. The slab is hot rolled in the austenite region, firstly in the roughing mill (usually it is a reversing mill) after that in the finishing mill consisting 6-8 tandem rolls. The finishing temperature of hot rolling is ranging between 840 and 900 °C, depends on the steel chemistry and sheet thickness. After the strip left the last finishing stand, it is cooled down using water jets to the so-called coiling temperature. The strip is coiled using an appropriate equipment and

transferred to the store. Here it cools very slowly, approx. 2-3 days later its temperature reaches ~60 °C.

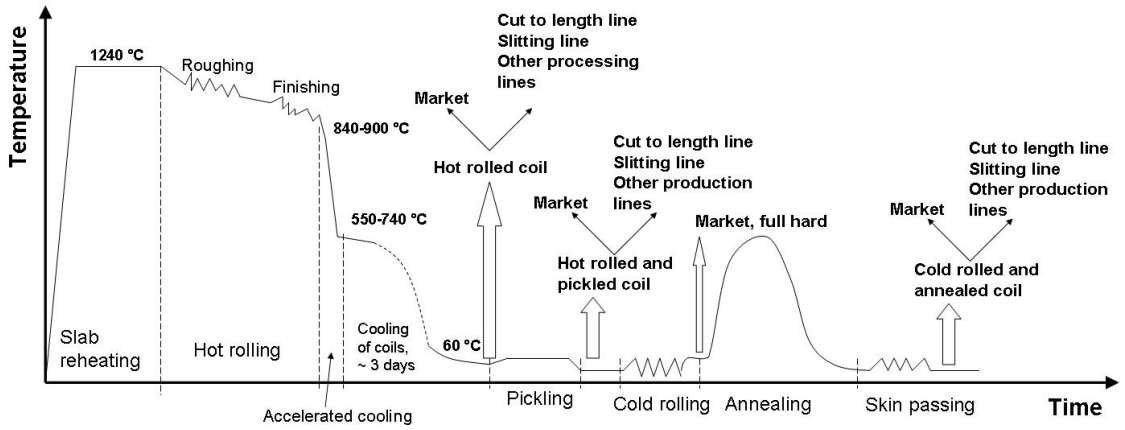


Fig. 1. General production sequence of low carbon steels in conventional hot rolling mills.

Now, the hot rolled coil can be sold in form of coil or can be cut to rectangular blank. The surface of it is covered by scrap, which limits the application purpose. In order to remove the scrap, pickling is necessary. During pickling, the strip is conveyed through hydrochloric acid baths to remove all of the rust and scrap. Recently, hot rolled and pickled coils are much more preferable than cold rolled and annealed strips,because of their lower price.

2 Coil breaks, as surface defects

Coil breaks are irregularly changing, elastically and plastically deformed bands on the surface of low carbon steel strips. As it was demonstrated in the introduction, the steel goes through a lot of technological processes. The first situation, when coil breaks can be observed is the entry end of any production lines, which start the processing with decoiling. During decoiling, uncontrolled bending of the strip can occur leading to the formation of coil breaks. These deformation lines become more visible after pickling. Typical coil breaks (stretcher lines) are shown in Fig. 2.

Fig. 2. Coil breaks in low carbon steel sheet.

The intensity of coil breaks can be quite different. Usually, 4 or 5 grades are differentiated according to the visual appearance of the surface defect [3] (Fig. 2 shows grade 4 coil breaks). Coil breaks can appear randomly along the strip, so, generally there are not usual locations along the strip where coil breaks appear more frequently than in other locations. However, in many cases, coil breaks often appear at the ends of the strip and they are usually more frequent on one side of the strip. Their intensity, location and presence can change also along the strip length. It should be noted, that it is very difficult to characterise the intensity and amount of coil breaks on a steel strip, because the strip moves quickly and therefore the visual inspection is unreliable (or even impossible).In a lot of steel plants, high-speed cameras record the surfaces (top and bottom) of the strip and an appropriate software analyses the surface defects. It requires high computational capacity (in every 3-5 minutes a large amount of data is generated), high-speed processors and intelligent softwares to recognise these (and at the same time other) surface defects.

3 Metallurgical and mechanical background of coil break formation

Coil breaks can appear only on steels, which exhibit discontinuous yielding phenomenon. Discontinuous yielding occurs, when the movement of dislocations is inhibited by interstitial impurities (Cottrell-atmosphere). The stress required for moving the dislocations is lower than tear them from the locking impurities. Therefore, the elastic deformation treansfers to plastic deformation with a local stress maximum, not only in case of tension, but in compression or bending as well. A tipical tensile test diagram of a steel exhibiting discontinuous yielding is shown in Fig. 3.

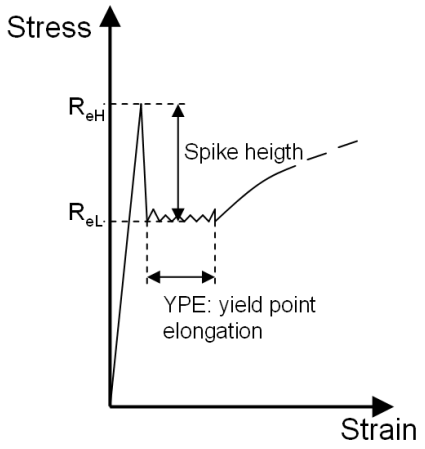
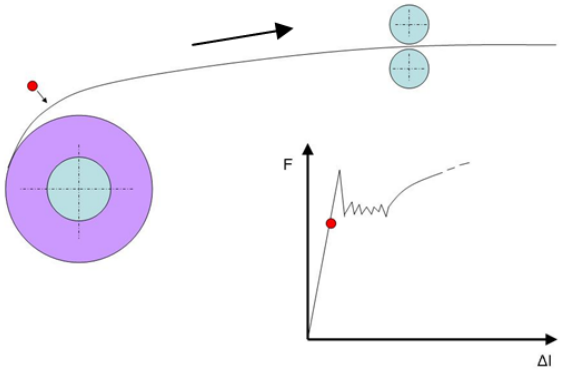
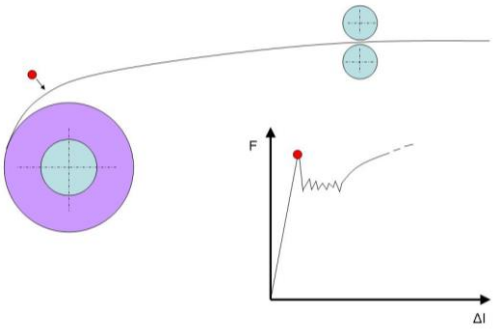
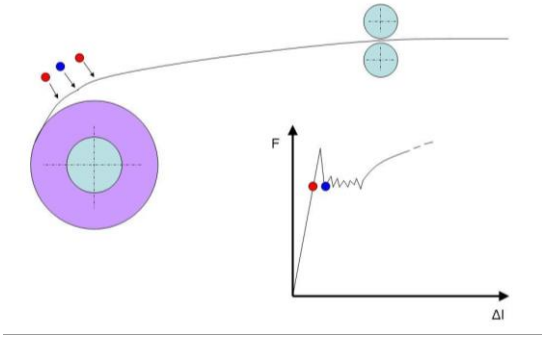
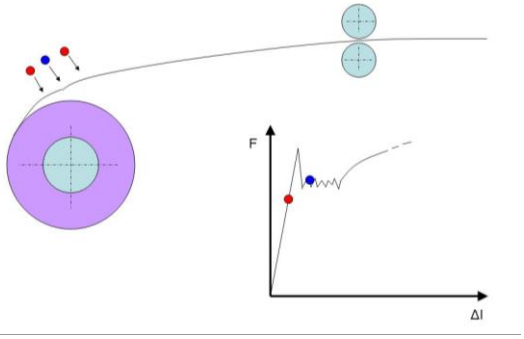


Fig. 3. The initial stage of a tensile test diagram and the definition of quantities connected to coil break formation [12]

The difference between the upper and lower yield strength is called as spike heigth. The main metallurgical reason of coil break formation. is a large spike heigth. An extended yield point elongation is also necessary but not sufficient for coil break formation. The formation of coil breaks occurs according to the following sequence [12].

	
1. Decoiling begins, the bending stress in the steel increases, since the strip try to keep its curvature. Recently it does not reach the yield stress.	2. When the bending stress reaches the yield stress, the strip flows (yields) in a narrow band.
	
3. The plastic deformation is localised only in a narrow band, it behaves like a plastic knuckle joint. The stress necessary for the deformation of this plastic knuckle equals to the lower yield stress. The elastic strain energy around the plastic knuckle sustains the plastic deformation.	4. The plastic knuckle is hardening, since it deforms plastically, during that, the elastic strain energy decreases below a critical limit, under which the knuckle could not deform further.

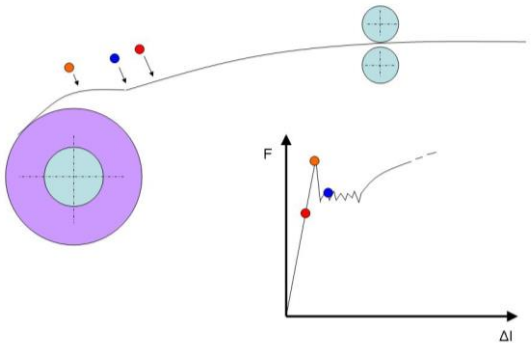
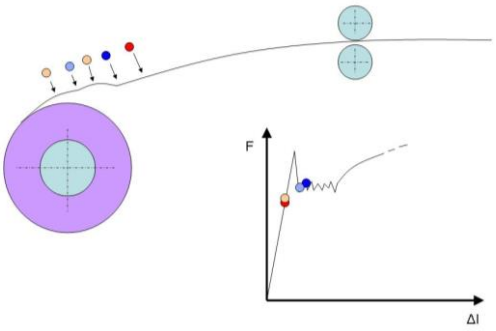
	
5. The decoiling process continues, and the strip try to keep its curvature again, so the bending stress increases.	6. When the bending stress reaches again the yield stress, the material yields and a second plastic knuckle forms.

Fig. 4. The formation mechanism of coil breaks in a general decoiling process [12]

In a lot of production lines, the decoiler is equipped with a so-called anti-coil break roll. This anti coil break roll is subjected to make continuous bending during decoiling. This continuous bending cause in every small volumes plastic deformation, which removes the discontinuous yielding phenomenon. If this anti coil break roll is not properly adjusted, then it could not prevent, but it even could cause coil break formation.

4 Prevention and treatment of coil breaks

Once coil breaks are formed, they could not be completely removed, only their intensity can be decreased. During the pickling process, the elastically deformed regions become shiny because they slip around the transferring rolls, but the valleys (the deformed regions) remains darker and matt. The strong waviness of the surface of severe coil breaks can be decreased only by cold rolling, however, the previous break marks (especially their border lines) remain visible. Medium coil breaks can be reduced by skin pass rolling, but this reduce the productivity and cause additional costs. In some production lines, light coil breaks can be partially removed by increasing the deformation at the tension flattener, but of course, this is not a correct solution.

As it was demonstrated, coil breaks should be prevented and not removed after their formation. In order to avoid coil break formation, many attempts have been made in steel plants, including [12]:

1. Applying a so-called anti coil break roll during decoiling [2,3].
2. Controlling the dimensional inequalities, the shape of the strip and reduction of the misalignment of processing equipments [4]

3. Adjusting the anti coil break roll pressure and strip tension [3]
4. Fine adjusting the hot rolling parameters [3-6]
5. Decreasing the free interstitial content by microalloying [4,5]
6. Adjusting the time delay between hot rolling and further processing and controlling the temperature of coils being processed [7]

These methods reduce the sensitivity of the steel to coil break formation, or remove the discontinuous yielding of the strip using previos continuous deformation.

Acknowledgement

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