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Analysis of coil break defects

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ABSTRACT

Coil breaks are narrow, irregularly changing deformation lines on low carbon steel strips. They can appear in many metallurgical manufacturing processes, such as pickling, galvanizing, cold rolling, processing on slitting or cutting lines, etc. They cause difficulties in many steel plants, since they are considered as serious surface defects leading to esthetical problems on the end product. In this paper, the types, visual appearance and microscopic properties of coil breaks are investigated. The roughness and waviness of the break lines were characterised using a contact-type surface roughness tester, while the microscopic deformation lines were studied using Hirox and Zeiss optical microscopes. The location, arrangement and relation to the microstructure can help to understand the formation mechanism of these surface defects.

1. Introduction

Low carbon steel strips are widely used for cold and hot forming applications. The raw material is a continuously cast slab, which is preheated to 1200 °C and hot rolled to reach the required strip thickness. The hot rolling occurs between 1100 °C and 880 °C and it is followed by cooling of the strip to the coiling temperature. This temperature is ranging between 550 °C and 750 °C depending on the required mechanical properties and final application [1,2]. When the strip has been cooled to the given temperature, it is coiled and cooled in a coil store. Hot rolled coils are processed on other production lines (slitting, cutting, pickling lines, etc.) if their temperature decreased below 70 °C. To reach this temperature, usually 3–4 days are necessary. Coil breaks can form, if the material exhibits discontinuous yielding with high upper yield point and the conditions for periodical elastic-plastic deformation are fulfilled [1–4]. Periodic elastic-plastic instability can usually occur when the strip is subjected to bending stresses during processing of the strip. For instance, the uncoiling process prior to the pickling operation generates bending stresses, which can lead in some cases to the alternating elastic-plastic behaviour. Fig. 1 shows a simple sketch about the formation of coil breaks during uncoiling of a steel strip.

When the forthcoming ring of the coil is subjected to uncoiling, then it tries to keep its curvature. This generates tension stress on one side and compression stress on the other side of the strip. When the stress reaches the local yield strength of the material, plastic deformation occurs in a narrow band (e.g. a coil break line). This narrow band behaves like a plastic joint between two elastically deformed regions. The elastic deformation energy of these regions serves as driving force for the deformation of the plastic band. The elastically and plastically deformed bands on the surface of the strip create peaks and valleys. These deformation bands cause serious surface imperfections when the strip is painted or coated; moreover, the waviness, roughness and final surface defects strongly influence the final product quality [5]. The appearance of coil breaks could change during the processing of the strip. The peaks get into contact with the transferring rolls and become bright, while the valleys remain matt. In some cases, for instance if the deformation in the tension leveller (equipment used for flattening the sheet) is large, coil breaks become fragmented. Unfortunately, the relatively high plastic deformation in the tension leveller (1–1.5% engineering strain) could not eliminate completely coil breaks.

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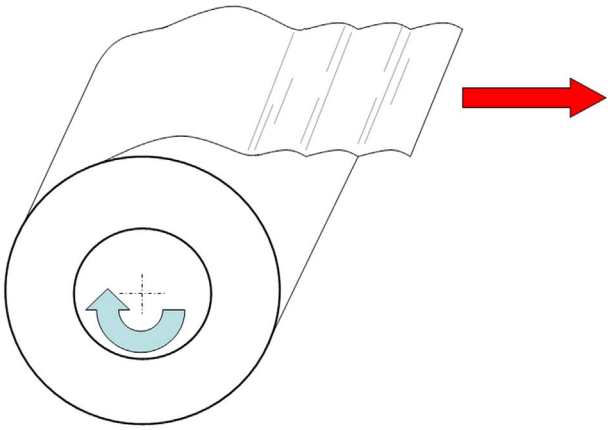

Fig. 1. Formation of coil breaks during uncoiling.

The formation of coil breaks depends on many factor, including the steel chemistry and microstructure, hot rolling parameters, the geometry of the strip (waviness, crossbow, crown etc.), the parameters of uncoiling such as speed, coil temperature, mechanical alignment, stiffness or mechanical vibration of the uncoiling equipment [3,4]. It is almost impossible to avoid completely this surface defect, although a plenty of attempts have been made [6–8].

In the industrial practice coil breaks are characterised according to their visual appearance. The severity of coil break defect is ranked into four groups (termed as grade number) on the basis of visual observation. Since the classification is based on visual inspection, the human factor can cause a large scatter in the evaluation of the severity of coil break defects. With the help of industrial qualifying persons, four typical samples were selected to introduce the coil break defects shown in Fig. 2.

As it was mentioned earlier, coil breaks can form if the steel exhibits discontinuous yielding. The elastic-plastic discontinuous deformation mechanism is widely studied using static tensile tests. During a conventional tensile test, the rate of deformation is quite small (static), and uniaxial tensioning is applied. The characteristic feature of coil break defects are the bending stress state and the rate of their formation; for instance, when the strip is uncoiled prior to pickling the amount of engineering strain could reach 0.5% within 0.01 s representing an extremely high strain rate. Although the usual discontinuous yielding phenomenon is widely studied in the past 60 years, the morphology, surface topography and formation mechanism of break lines are rarely investigated [1,3].

Recently optical analysis, interferometry, slicing techniques, multifocus imaging and image postprocessing are used to analyse the surface topography [9–14]. Among the novel techniques, the traditional 2-dimensional **topographic evaluation** is also used [15]. In this study, the surface roughness and waviness parameters, the types and distribution of coil breaks are investigated.

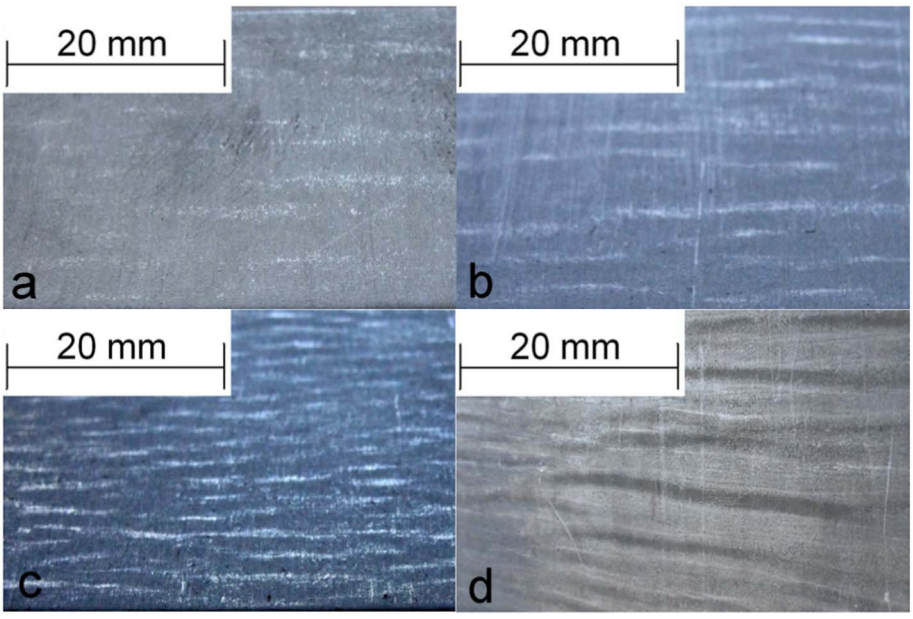

Fig. 2. Coil breaks ranking according to visual observations: 1st grade (a.), 2nd grade (b.), 3rd grade (c.), 4th grade (d.).