JFE TECHNICAL REPORT
No. 24 (Mar. 2019)

Dark Surface Hot-Rolled Steel Sheet "KROJEX™"

1. Introduction

Non-pickled steel sheet materials, in which oxide scale adheres to the surface of a hot-rolled steel sheet, are used in applications such as truck frames and Chinese frying pans. Therefore, high scale adhesion performance is necessary from the viewpoints of improving surface appearance and preventing red rust generation due to exfoliation of the scale. Moreover, in the Southeast Asian countries, beginning with Indonesia, there is extremely high need for the indigenous design property of high degree of blackness in exterior materials for housing, in that "black is a symbol of strength and gives added value to building products."

Based on the conditions mentioned above, JFE Steel developed the dark surface hot-rolled steel sheet "KROJEX™," which offers a combination of high scale adhesion performance and high degree of blackness. This article introduces the product features of the dark surface hot-rolled steel sheet "KROJEX," together with an example of application.

2. Product Features

2.1 Surface Appearance and Blackness

Figure 1 shows photographs of the surface appearance of the dark surface hot-rolled steel sheet "KROJEX" and a conventional non-pickled hot-rolled steel sheet. For a quantitative evaluation of blackness, the $L^* a^* b^*$ color space regulated in the JIS Z 8729 standard was used as an evaluation index, as this is generally considered to be close to the human visual sense, and the $L^* a^* b^*$ indexes of the surfaces of the steel sheets were measured using a spectrophotometer (Nippon Denshoku Industries Co., Ltd., handy-type spectrophotometric type color difference meter NF555). The value of lightness L^* which is visually recognized as "sufficiently black" is about 30 or less. The L^* value of conventional non-pickled hot-rolled steel sheets is 39, and the entire surface displays a gray color and is whitened. On the other hand, the L^* value of the dark surface hot-rolled steel sheet "KROJEX" is 25, and the steel sheet surface has a beautiful black color.

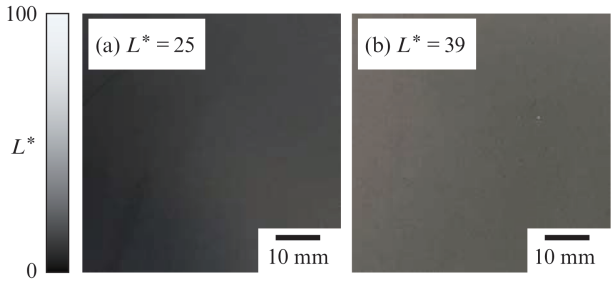

Fig. 1 Surface appearances and L^* values of (a) KROJEX™ and (b) non-pickled conventional hot-rolled steel sheet

2.2 Scale Adhesion Performance

To evaluate scale adhesion performance, cellophane tape was applied to the surface and then peeled from the dark surface hot-rolled steel sheet "KROJEX" and the conventional non-pickled hot-rolled steel sheet after a bending test by the pressing bend method (JIS Z 2248), and amount of the scale adhered to the tape was investigated. The conditions of the bending test were a ratio of r/t=4 of the pressing tool tip radius r and the test piece sheet thickness t. Bending angle was 180 degrees. **Figure 2** shows the results. Only a slight amount of scale had adhered to the tape peeled from the dark surface hot-rolled steel sheet "KROJEX" after the bending test, showing the "KROJEX" had excellent scale adhesiveness after the bending test.

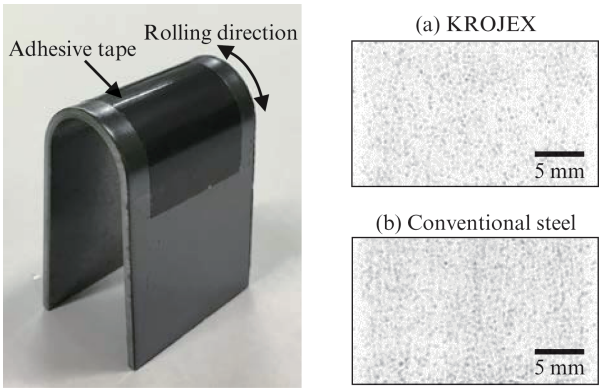

Fig. 2 Adhesion test results of (a) KROJEX™ and (b) non-pickled conventional hot-rolled steel sheet by adhesive tape after bending test

† Originally published in *JFE GIHO* No. 41 (Feb. 2018), p. 87−88

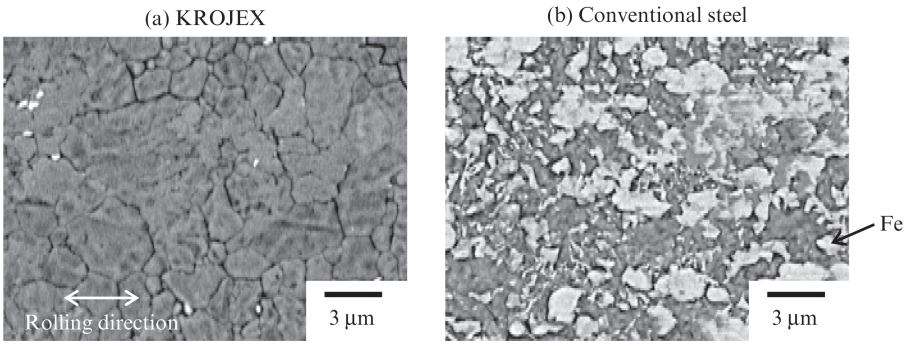

Fig. 3 SEM-BSE images of surfaces of (a) KROJEX™ and (b) non-pickled conventional hot-rolled steel sheet

Table 1 Mechanical properties of KROJEX™ and the conventional hot-rolled steel sheet

	Yield point (MPa)	Tensile strength (MPa)	Elongation (%)
KROJEX™	229	350	44
Conventional steel	221	342	44

JIS no. 5 specimen for tensile test (Thickness: 1.6 mm)

2.3 Microstructure

Scanning electron microscope backscattered electron (SEM-BSE) images of the scale surfaces of the dark surface hot-rolled steel sheet "KROJEX" and the conventional non-pickled hot-rolled steel sheet are shown in **Fig. 3**. Fe had precipitated in granular form at the scale surface of the conventional non-pickled hot-rolled steel sheet. This is due to the formation of Fe on the scale surface by the eutectoid transformation ($4FeO \rightarrow Fe_3O_4 + Fe$) of the oxide scale formed during the coiling process, and it is thought that the color tone of the Fe itself that precipitated at the surface led to the inhomogeneous color of the scale of the conventional non-pickled sheet, and whitening shown in **Fig. 1**(b)[1]. JFE Steel established a technology that suppresses the formation of Fe at the outermost surface layer, which is the cause of scale whitening, while also increasing the adhesiveness of the scale/steel interface, by microstructural control of the scale surface and interior, and thereby realized the high blackness color tone and high adhesion performance of the dark surface hot-rolled steel sheet "KROJEX."

2.4 Mechanical Properties

The results of a tensile test (JIS Z 2241 No. 5 tensile test piece, sheet thickness: 1.6 mm) of the dark surface hot-rolled steel sheet "KROJEX" and the conventional non-pickled hot-rolled steel sheet are shown in **Table 1**. Even though the morphology of the scale differed greatly, as shown in the previous section, yield strength, tensile strength and elongation displayed similar values, showing that the changeover from the conventional non-pickled hot-rolled steel sheet to "KROJEX" can be carried out easily.

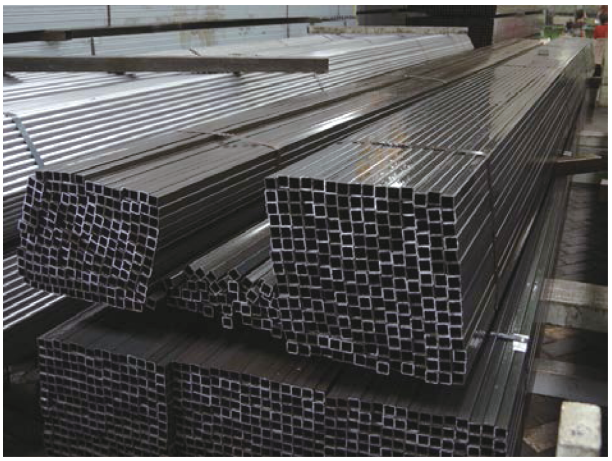

Photo 1 Application of KROJEX™ to square pipe in Indonesia

3. Example of Application

As an example of an application of the dark surface hot-rolled steel sheet "KROJEX," **Photo 1** shows square steel pipes of "KROJEX" for building material use in Indonesia. Exfoliation of the scale was not observed, even after the final product was formed, and the product was favorably evaluated as having a beautiful black color by customers.

4. Conclusion

The dark surface hot-rolled steel sheet "KROJEX" introduced in this article responds to the latent needs for scale adhesiveness and black color tone, and thus greatly increased the commercial value of non-pickled hot-rolled steel sheets. "KROJEX" has attracted extremely high attention, both in Japan and overseas, and a further expansion of demand is expected in the future.

Reference

1) Seto, K.; Sakurai, Y. Influence of Scale Properties on Surface Characteristics of Steels. The Iron and Steel Institute of Japan, Tokyo, Nissei Eblo, 2005, p. 101.

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