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Development of Bloom Marking Reading Device

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Abstract:

In the charging of blooms into heating furnace at the Billet Plant, Kurashiki Steel Bar & Wire Rod Dept., Steel Bar & Wire Rod Division, JFE Steel, operators visually confirm tracking information and the actual items (such as markings, labels, and hand markings) to prevent incorrect charging and the outflow of foreign materials. However, since this process relies heavily on human intervention, there was a significant risk of human error. To address this issue and achieve zero incorrect charging into the heating furnace and zero outflow of foreign materials, we have developed an automatic bloom marking reading device that reads the engraved characters and matches them with the tracking information, and begun its practical operations.

In this report, we will outline the background, specifications, and an overview of the developed bloom marking reading device.

1. Introduction

The Billet Plant, Kurashiki Steel Bar & Wire Rod Department, Steel Bar & Wire Rod Division (hereinafter referred to as Billet Plant), JFE Steel produces round and square section billets using blooms as the main material. When charging blooms into the heating furnace, the operator visually checks the markings on the actual material (engraved markings, labels, hand markings) against the tracking information to prevent incorrect charging and outflow of foreign materials. However, since this process relies on human intervention, there is significant risk of human error.

Therefore, with the aim of achieving zero incorrect charging of the heating furnace and zero outflow of foreign materials, JFE Steel developed a bloom marking reading device that automatically reads engraved characters and checks the results against the tracking information.

This paper introduces the background to the development of the bloom marking reading device, the specifications of the device and the results achieved.

2. Overview of the Billet Plant and Heating Furnace Entry Side Material Management

The Billet Plant comprises a heating line, rolling line and finishing line, and produces round and square section billets using blooms as the starting material. The materials charged into the heating furnace are slabs, blooms, etc. produced by Kurashiki No. 2, 3 and 4 continuous casters.

Three types of material identification methods are used, engraved characters, labels and hand marking. Either one or multiple types of identification are applied to the end surface of the material.

Material identification management at the entry side of the heating furnace is important. Charging foreign material (i.e., material different from the tracking information) will not only cause operating loss in the total subsequent processes, but may also lead to QA problems if foreign material is released to customers. Therefore, operators visually check and compare the tracking information and the engraved characters, labels, and/or hand marking of the actual material before charging it into the heating furnace, and only charge the actual material into the heating furnace after confirming that the material matches the tracking information.

Figure 1 shows the flow of the manufacturing process in the Billet Plant, and **Photo 1** shows examples of the three types of material identification.

3. Development of Bloom Marking Reading Device

3.1 Background of Development

Because there is a risk of incorrect charging due to human error in material identification management at the entry side of the heating furnace, the aim was to achieve zero incorrect charging/zero outflow of foreign material by developing a device that automatically reads engraved characters, printed labels and hand marking and compares the material markings with the

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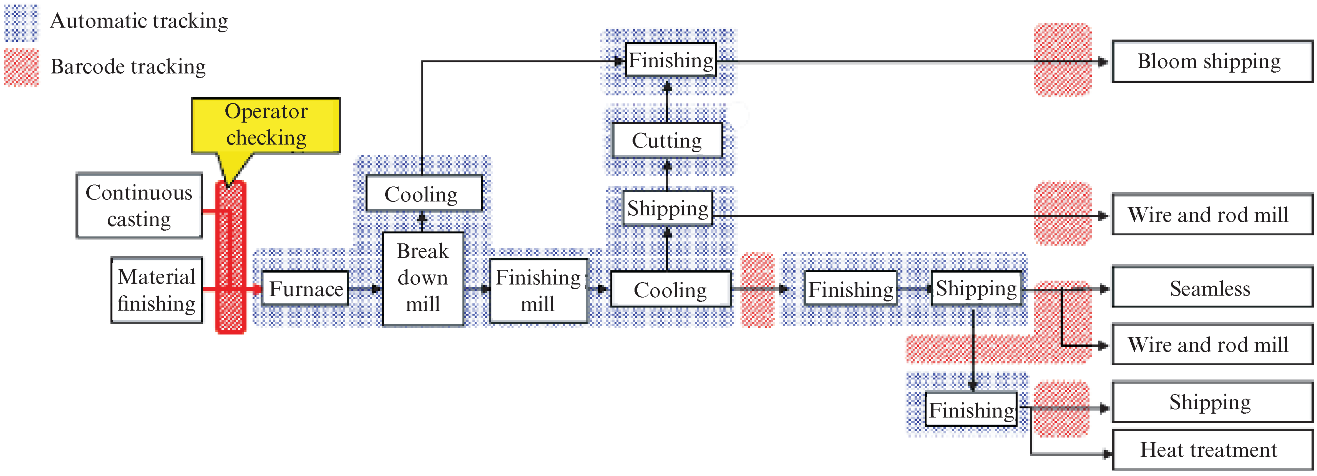

Fig. 1 Manufacturing process flow in Billet Plant

a) Engraved character b) Labels c) Hand marking

Photo 1 Photographs of engraved character, label and hand marking

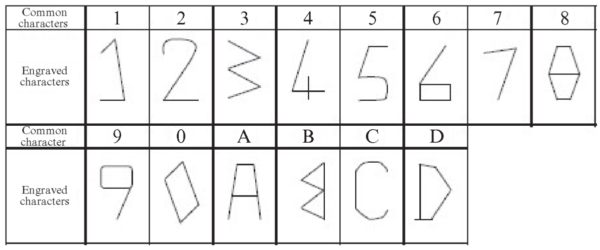

Fig. 2 Type of engraved characters in bloom identification

tracking information.

Here, hand marking refers to characters written by hand on the bloom end surface. Since the effects of individual writing habits in handwriting, the surface condition of the bloom end, etc. are frequently problems that affect marking reading, the aim in this project was to automate reading of engraved characters and printed labels.

3.2 Specifications of Engraved Characters and Labels

The specifications and targets for the reading accuracy of engraved characters and labels are as follows.

1) Specifications of engraved characters and labels
- Material temperature: Room temperature to max. 800°C
- Material stopping accuracy: Within ±50 mm
- Reading surface: Torch cutting machine surface, uneven/curved parts
- Engraved characters (types of engraved characters are shown in **Fig. 2**)

  Types: 10 numerals (0 to 9), 4 alphabetic characters (A to D)

  Dimensions: W10 × H20 mm, depth: 0.1 to 3.0 mm
- Labels: Code 39 barcodes, W109 × H80 mm

2) Target reading accuracy
- Engraved character reading rate (concordance rate): 95 % or more
- Label reading rate: 100 %

3.3 Study of Engraved Character Reading Methods

The key points in the development of the reading device were as follows:

① Feasibility: The device must not be damaged even under a high-temperature environment, and must be able to achieve stable reading.

② Reliability: The device must not be significantly affected by the condition of the reading surface, and must be resistant to external disturbances and maintain the target reading rate even when the stopping position varies.

As the candidate reading methods, the Camera + illumination switching method and the 2D Laser distance measurement method were selected, and their effectiveness was confirmed by preliminary tests and verification (**Table 1**).

1) Camera + illumination switching method

This is a method in which the shadows formed in the engraved area are captured by photography, with the camera and lighting arranged directly facing the

Table 1 Comparative analysis of methods for reading engraved characters

Method	Overview
Camera + illumination switching method	Capturing material end face using camera andfour-direction illumination →Obtaining shadow images of engraved charactersurface by switching between four illumination sources
2D Laser distance measurement method	Measurement of distance to material end faceusing 2D laser distance meter →Recognition of engraved characters by detectingsurface variation as distance changes

material end surface, and characters are recognized by image processing.

The results of a preliminary test confirmed that character recognition is possible with room temperature materials by illuminating the material either from the two sides (right and left) or from above and below, and reading the characters as relief images based on the difference in appearance. However, with high temperature materials, it was found that character recognition is not possible because clear shadows are not formed in the engraved area due to the effect of self-luminance. Therefore, this method was not adopted.

2) 2D Laser distance measurement method

In this method, character recognition is performed based on distance data obtained by measuring the distance from the sensor to the material end surface with a laser distance meter. Reading was possible even when the material stopping position varied, as variations in the depth of the engraved characters could be captured as changes in distance.

On the other hand, the following issues were found:

① Due to the limited measurement range of the distance meter, the distance from high temperature objects is short, and

② To obtain data as a 3D profile, the distance meter itself must be scanned over the material end surface.

4. Overview of Processing by Marking Reading Device by 2D Laser Distance Measurement Method

4.1 Principle of Character Extraction

Engraved characters are extracted by their 3-dimensional profiles using a mechanism that scans the distance meter over the material end surface, as described in Chapter 5 below. This chapter explains the principle of the character extraction technique using one cross section of the 3-dimensional profile.

The surface condition of the end surface includes torch slag and floating scale, which are captured as convex shapes when seen from the distance meter, whereas the characters are captured as concave areas due to the depth of engraving. This point is used in character recognition.

First, all the distance values for one cross section are averaged, and the average value is used as the reference plane. Convex shapes above the reference plane are treated as external disturbances, while concave areas below the reference plane are recognized as depth areas of the engraved characters, and threshold processing is performed.

A character map is generated by applying this processing to all the cross sections of the 3-dimensional profile. An overview of the character extraction process is shown in **Fig. 3**.

4.2 Overview of Character Segmentation

After the character map is generated, character segmentation processing is performed. First, cumulative processing of the luminance values of the vertical columns (Y axis) and horizontal rows (X axis) of the character map is carried out. Parts that appear to be characters, that is, areas with many concavities, display high cumulative values, while the cumulative values of

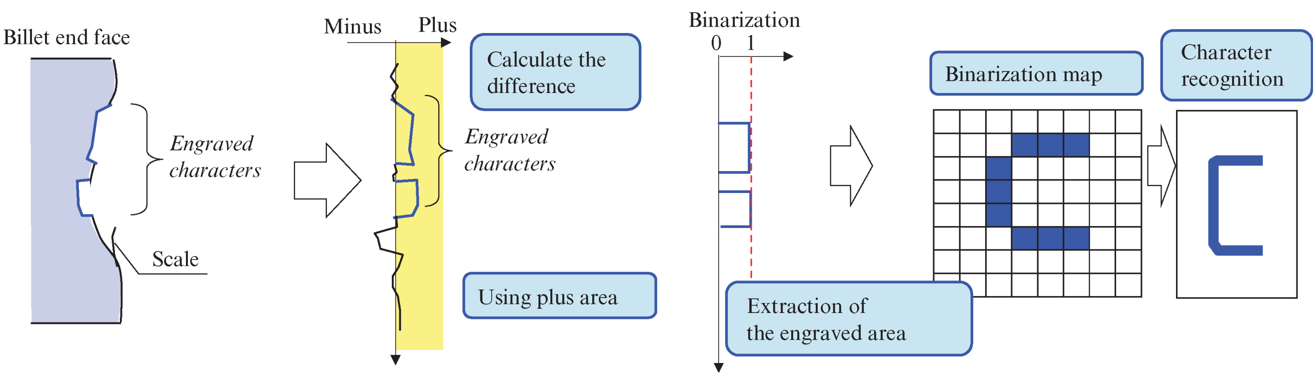

Fig. 3 Overview of character extraction

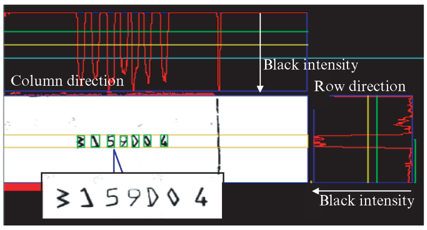

Fig. 4 Overview of character segmentation

Fig. 5 Example of registered dictionary

the character boundary and surrounding area are low.

The cumulative values of the vertical columns are used in extraction of the height direction of the characters. The cumulative values of the horizontal rows are used in extraction of the width of each individual character by extracting points where sudden changes occur.

Character recognition is not possible if character segmentation fails. Therefore, as an additional feature designed to prevent segmentation failure (extraction of external disturbance which are not characters), the system also checks whether the number of parts where sudden changes occur in horizontal rows corresponds to the number of characters, and whether the height and width of the extracted parts is appropriate or not. An overview of character segmentation is shown in **Fig. 4**.

4.3 Character Collation

In character collation, each segmented character is checked against a registered dictionary using a generally known pattern matching technique, and the character with the highest concordance rate (agreement rate) is treated as the recognized character. An example of the registered dictionary is shown in **Fig. 5**.

5. Overview of Bloom Marking Reading Device Main Unit

The sensor box, which is equipped with a 2D laser distance meter and barcode reader, has a scanning mechanism that enables on-line and off-line scanning of the end surface of stopped materials, and was designed so that the sensor box itself will not be exposed to a high temperature environment for an extended time when 3D profiles are acquired by the laser distance meter.

As additional environmental measures, the sensor box is made of SUS and is cooled with a vortex cooler, and hot mirrors are used in the windows of the measuring instruments. As a result, the temperature inside the sensor box can be kept to no more than 35˚C, even in operation with hot materials (approx. 700˚C), reducing the risk of instrument failure.

An overview of the reading device main unit is shown in **Fig. 6**, and the external appearance of the sensor box is shown in **Photo 2**. The device specifications are as follows.

1) 2D distance meter: Manufactured by Keyence (LJ-V7300)
   - Field of view: 210 mm
   - Measurement range: 155 to 445 mm
   - Sampling speed: 16 µs

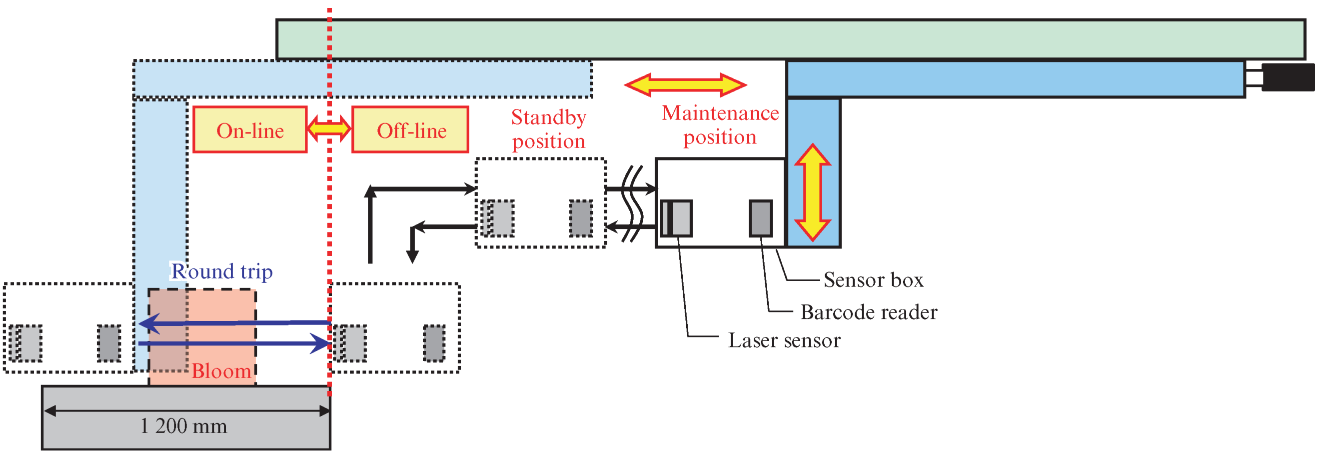

Fig. 6 Overview of reading device main unit

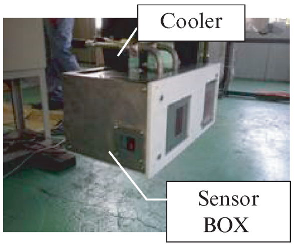

Photo 2　Exterior of sensor BOX

2) Barcode reader: Manufactured by Keyence (SR-1000W)
   - Scanning speed: 300 mm/s
   - Traveling stroke: 4 700 mm
   - Vertical stroke: 270 mm

6. Conclusion

With the aim of achieving zero incorrect charging and zero outflow of foreign material at the Billet Plant, Kurashiki Steel Bar & Wire Rod Department, Steel Bar & Wire Rod Division, JFE Steel, a bloom marking reading device was developed in-house. Concretely, a bloom marking reading device using a sensor box equipped with a 2D laser distance meter and a barcode reader was developed in order to stably acquire 3D profiles of engraved characters under a high temperature environment.

The reading rates after startup of the bloom marking reading device cleared the targets for reading accuracy of 96 % for engraved characters and 100 % for printed labels, contributing to improvement of product quality.