

# Improvement of Billet Magnetic Particle Testing System and Surface Defect Analysis System

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## Abstract

*A newly improved AMG (automatic magnaflux flaw detector) and surface defect analysis system for billet inspection and conditioning line at Kimitsu Works is introduced. The problem of AMG was (1) To improve the reliability of minor defect detection, (2) To decrease the over detection and false detection. Improvement was achieved through configuration optimization of UV lighting, and renewal of camera and image processing system. A computerized system for improving billet quality based on feedback of billet inspection information was established. As a result of the improvement measures presented above, the reliability of the billet inspection and conditioning work as well as the billet quality forming at the steel-making, continuous casting and billet rolling processes improved dramatically.*

## 1. Introduction

The wire rod mill of the Kimitsu Works of Nippon Steel & Sumitomo Metal Corporation produces a wide range of products ranging from commercial grade wire rods to special steel wire rods such as those of steel tire cords, bridge cables, cold heading use and so forth. The demand for reducing surface defects of these products is growing stronger year by year, and the reduction of wire rod surface defects has become a matter of urgency. To reduce the surface defects of wire rods, it is important to detect the surface defects of the material billets in a reliable manner and to remove them as well as to prevent the occurrence of surface defects in the wire rod rolling.

In the Kimitsu Works, an automatic magnaflux flaw detector (hereafter referred to as AMG), billet surface defect inspection equipment, was introduced in 1996. Partial modifications have been made. However, drastic modification has become more strongly required to cope with the growing needs of guaranteeing the surface defects more strictly. Furthermore, in order to enhance the surface quality through improvement in the quality-implanting production technology by feeding back the defect information obtained by AMG, the introduction of a system capable of grasping the surface defect information quantitatively and quickly by AMG has become necessary.

This article reports the modification of AMG implemented as the measure therefor and the introduction of the surface defect analysis system to AMG.

## 2. Layout of Billet Conditioning Line and Outline of AMG

The layout of the billet conditioning line and the main specification of AMG are shown in **Figs. 1, 2** and in **Table 1**, respectively. In the billet conditioning line, after removing the surface scale by shot blasting, surface defects are detected by AMG. In AMG, a billet travels at 30m/min. and fluorescence magnetic particle liquid is sprayed onto the billet. The billet is then magnetized while traveling by the magnetizing equipment. The magnetizing equipment employs a compound magnetizing system consisting of yoke coils and a ring coil. It is an inspection system that enables the detection of not only linear defects stretching in the longitudinal direction of the billet, but also defects of indeterminate form such as scabs lying in the vertical direction. By magnetization, magnetic flux leakage is developed around the defect on the billet surface where the fluorescence magnetic particles concentrate. The concentrated fluorescence magnetic particles are visualized by the radiated ultra violet light of high brightness and a photo of the image is taken by CCD cameras as an image of possible defects. Whether the image is harmful or harmless is determined by an image-processing system, and defect mapping is developed inside the system. Based on the information, the defects are identified by paint markings provided by marking equipment and removed by a manually-operated billet grinding machine.

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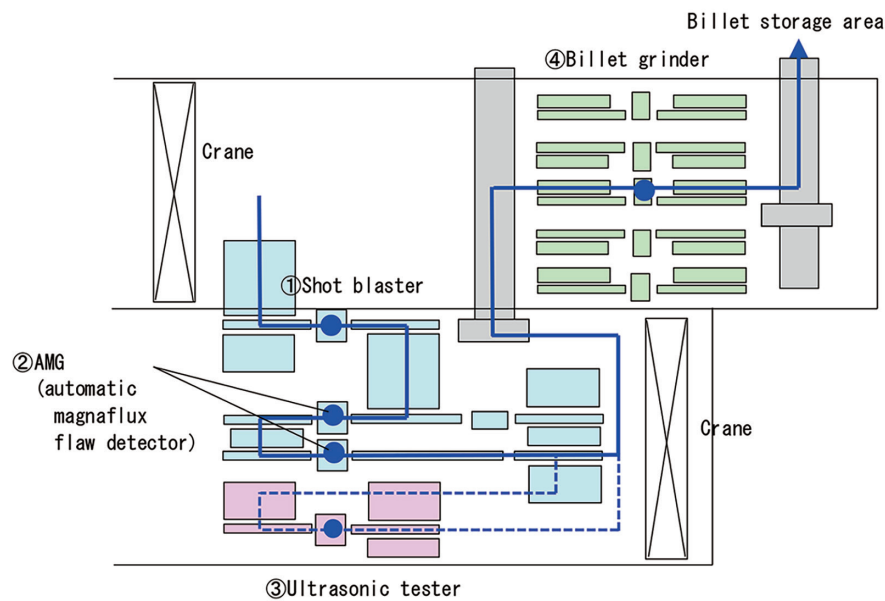


Fig. 1 Billet conditioning line layout

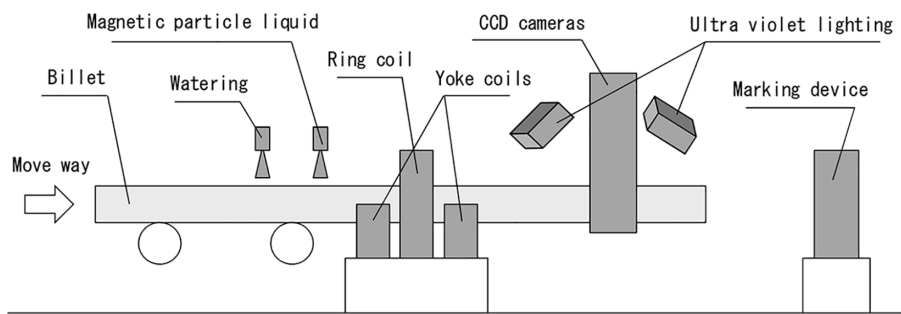


Fig. 2 Equipment outline of automatic magnaflux flaw detector

Table 1 Main specifications of automatic magnaflux flaw detector

Inspection speed	30 m/min
Detectability	Seam: Depth $\geq 0.3$ mm Scab: Depth $\geq 0.3$ mm
Magnetization	Ring coil of one set and yoke coil of 2 sets
Camera detector	CCD cameras of 3 sets per one billet surface
Data processing system	Parallel processing by several general-purpose computer

**3. Remodeling of Automatic Magnaflux Flaw Detector (AMG)**  
**—Measures for Improving Billet Surface Defect Detectability Accuracy—**

Subjects for improving the billet surface defect detectability accuracy are: (1) Improvement in minor defect detectability, and (2) Reductions of over detection and false detection, and the following measures were implemented. (i) Renewal of cameras, (ii) Optimization of the locations of the ultra violet lighting, and (iii) Updating of the image-processing system.

**3.1 Renewal of camera**

Camera images taken before and after the renewal are shown in

**Fig. 3.** In the image taken by a conventional analogue type camera, the brightness of the defect is poor and minor defects in particular were unclear and difficult to detect. As a countermeasure, digital cameras were introduced, the optical lenses and the filters were renewed, and the shutter speed and the internal software of the camera were optimized. As a result thereof, the brightness of the defect image was increased, further clarifying the image, and the detectability of minor defects was improved.

**3.2 Optimization of location of high brightness ultra violet lighting**

Before renewal, there were indications showing high brightness in the brightness distribution within the scope of the camera, and

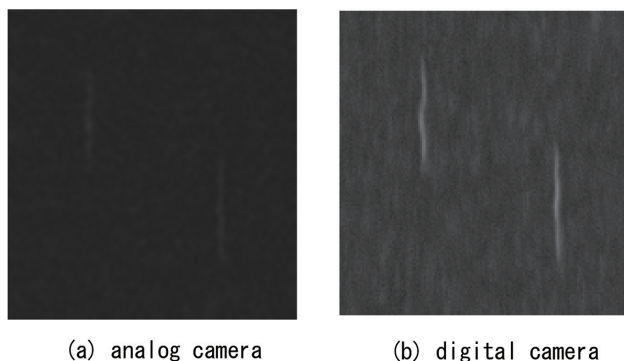


Fig. 3 Defect image of (a) analog camera and (b) digital camera

harmless defects and/or patterns similar to those of harmful defects were detected as harmful defects. Therefore, the working efficiency of the defect-removing operation by billet grinders in the subsequent process was deteriorated. The high brightness ultra violet lighting was directed to the scope of the camera diagonally from two sources, one before and another after the camera, respectively. Due to the difference in the respective lighting condition such as distance and angle, an uneven brightness distribution was caused. Then, as a countermeasure, the locations and the angles of the radiation of the high brightness ultra violet lighting were optimized and over detection and false detection were reduced.

### 3.3 Updating of image-processing system

An image-processing system to discriminate the image of a defect thus photographed as to whether it is harmful or harmless was developed by our company and introduced. In the new system, a noise-removing function reduced over detection and false detection significantly. Furthermore, improvement in the detection accuracy of harmful defects was promoted by the functions of intensifying the contour of defects and the related processing.

Each defect thus detected is endowed with a defect code such as that of seam and scab automatically based on the representative numerical values such as those of brightness, area and aspect ratio. To pursue the cause of the defects, vital data such as defect code, size and location are transmitted to the AMG defect analysis system.

With the implementation of the abovementioned three measures, the detection accuracy of minor harmful defects was enhanced while reducing the false detection and over detection in the interim.

## 4. Construction of AMG Flaw Analysis System —Reinforcement and Quick Implementation of PDCA for Improving Quality—

For the effective implementation of the billet surface quality improvement measures, it is important to grasp the defect information at AMG quantitatively and quickly. The quality-improvement PDCA needs to be implemented by analyzing the cause based on the data, and by the feedback of the countermeasures to the previous production stage.

Conventionally, only the number of defects of a billet obtained at AMG was stored in the system. When the detailed defect data such as that of the form and the location was required, the data was collected manually by applying the flying magnaflux flaw detector system to the billets, observing such defects, and recording them on paper sheets. Accordingly, the working efficiency was poor and the analysis to identify the cause and the implementation of countermeasures took time.

In the introduced AMG defect analysis system, such information as the image of the defect form, location, size and code are stored in the system, which enables us to grasp the state of the occurrence of defects. An example of the defect image developed by the AMG defect analysis system is shown in Fig. 4. Furthermore, the system is constructed as shown in Fig. 5, and access to the state of defect occurrence and defect images for confirmation immediately after AMG inspection has been made possible for the respective production division and quality control division via the in-steel-works OA network.

By utilizing the system, early identification of materials with abnormal surface defects has been enabled. Furthermore, whenever quality abnormality takes place, a quick and accurate analysis of the cause and study on the countermeasures have become possible due to the detailed billet surface defect data stored in the system. As shown in Fig. 6, with the effective implementation of the quality improvement measures, the billet quality has been improved and the

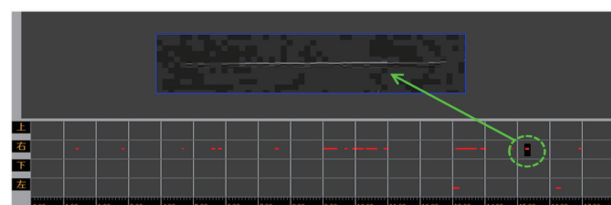


Fig. 4 Flaw image of automatic detector

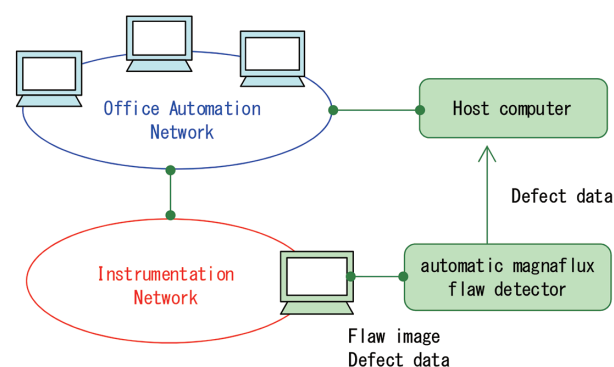


Fig. 5 System diagram

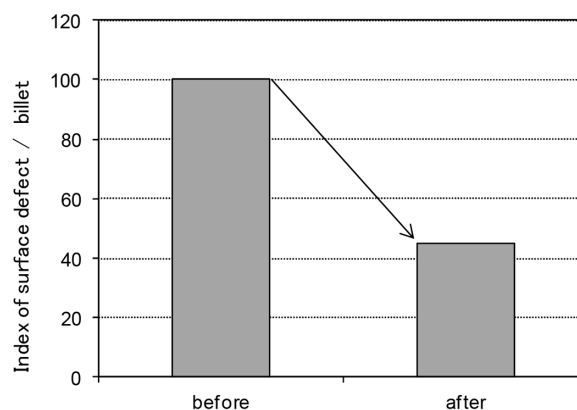


Fig. 6 Index of surface defect of before and after improving

billet surface defects have been greatly reduced.

## 5. Conclusion

Based on the abovementioned quality improvement measures, the billet surface defect assurance capability has been enhanced and the quality-implanting production technology has also been enhanced by reinforcing and rapidly implementing the quality im-

provement PDCA. Hereafter, to respond to customers' requests for further quality improvement, we are determined to fully utilize the abovementioned measures and to maintain efforts to further improve quality always.

## Reference

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