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Minute Surface Defect Detection Technology for Round Bars†

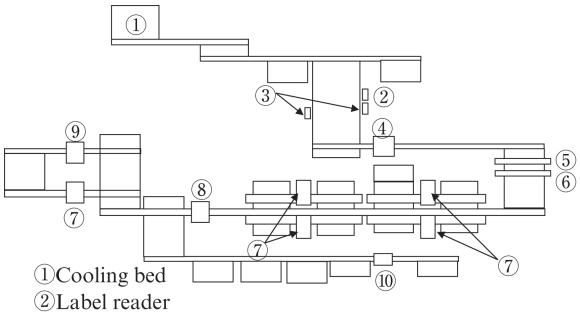
1. Introduction

The JFE Steel West Japan Works (Kurashiki) Billet Mill produces round billets with diameters of ϕ90–450 mm. Inspections for surface defects are performed by automatic testing by the Magnetic Leakage Flux Tester (MLFT). As a higher level of surface quality is demanded in response to increasing use of these products in applications with strict quality requirements, a higher level of defect detection performance has become necessary. Therefore, the Billet Mill established a 2-level judgment method, which is a detection technology for minute surface defects that cannot be detected by conventional flaw detection methods. This report introduces the newly-developed technology.

2. Outline of Billet Mill Equipment

2.1 Round Billet Finishing Process

Surface and internal inspections and conditioning of round billets rolled by the Billet Mill are performed at the round billet finishing yard shown in **Fig. 1**. As treatment, after deburring of both ends of the billet, surface inspection by the MLFT and internal inspection by the Automatic Ultrasonic Tester (AUT) are performed, and surface defects are removed and conditioned by grinding. In this continuous line layout, after conditioning, the condition of remaining defects in the conditioned part is inspected by a Manual Magnetic Tester (MMT), and if remaining defects are found in the conditioned part, grinder conditioning is performed once again[1].



①Cooling bed
②Label reader
③Deburring machine
④Shot blast
⑤Magnetic Leakage Flux Tester (MLFT)
⑥Automatic Ultrasonic Tester (AUT)
⑦Grinder
⑧No.1 Manual Magnetic Tester (MMT)
⑨No.2 Manual Magnetic Tester (MMT)
⑩Peeling machine

Fig. 1 Layout of round billet finishing yard

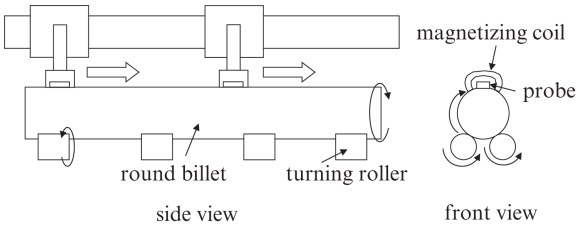


Fig. 2 Schematic of MLFT

2.2 Outline of MLFT

A schematic diagram of the MLFT used in surface inspections of round billets is shown in **Fig. 2**. The entire circumference of the round billet is inspected by moving the magnetizing coil and detection probe to the billet longitudinal direction while the billet is rotated by the turning roller. When a round billet is magnetized by the magnetizing coil, magnetic flux leaks from flaws. (In the following "flaw" is defined as a signal detected by the MLFT, and "defect" is defined as a harmful flaw.) Surface defect detection is performed by detecting that leakage magnetic flux with the probe.

3. Development of Minute Surface Defect Detection Technology

3.1 Outline of 2–Level Judgment Method

Figure 3 shows a schematic diagram of the magnetic flux leakage when a round billet is magnetized. In case (a), which is a sharp deep scratch, a large amount of magnetic flux leakage occurs, and this is output as a large flaw signal. On the other hand, case (b), which is a minimal flaw with a shallow depth, the flaw signal output is small because the magnetic flux leakage is slight. Stricter defect detection inspection standards are generally applied as a countermeasure to prevent ship-

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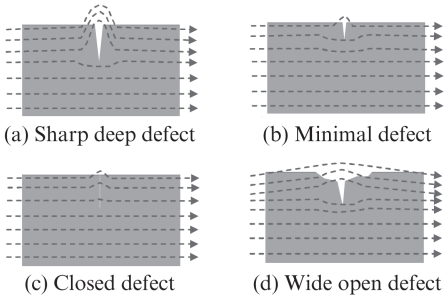

Fig. 3 Schematic of leakage magnetic flux in the defect

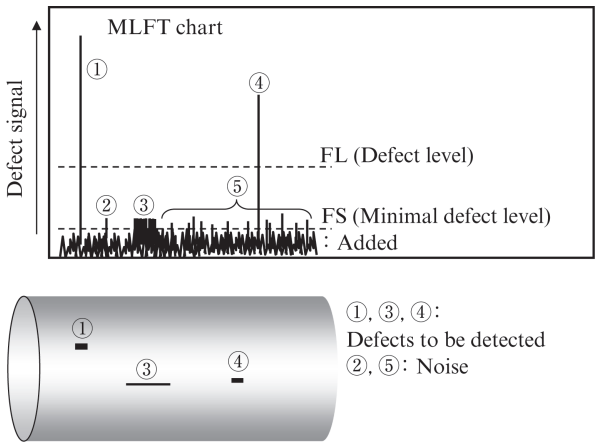

Fig. 4 Schematic of 2 level judgment method

ment of billets with shallow surface defects to severe applications, but this results in increased detection of noise caused by surface roughness or vibration during transportation, in other words, overdetection. Similarly, because magnetic flux leakage is also small in case (c), which is a closed defect and case (d) which is a defect with a wide opening width at the surface, overdetection will increase if a strict detection standard is applied. To avoid this problem, JFE Steel developed the minute surface defect detection technology (2-level judgment method), which suppresses overdetection and detects only harmful defects.

As shown in **Fig. 4**, the 2-level judgment method is provided with a function that detects defects which are below the conventional defect detection level (FL). To prevent overdetection due to noise, the minute defect level (FS) is given as a function that detects not only the flaw signal height as a judgment item, but also extracts and detects minute defects with continuity in the longitudinal (rolling) direction by adding continuity as a condition for defect judgments. As a result, in addition to the defects detected by the conventional technique ((1) and (4) in Fig. 4), it is also possible to detect shallow defects ((3) in Fig. 4), which had been hidden by base noise when using the conventional technique, by preventing overdetection ((2) and (5) in Fig. 4) due to noise.

Table 1 Setting items of 2 level judgment

New standard	Explanation
Threshold of FS	Threshold amount of continuous defect depth
Effective length of FS	Not judging defects below the setting length
Application of 2 level judgment	Whether to apply 2 level judgment
Marking	Whether to mark defect areas

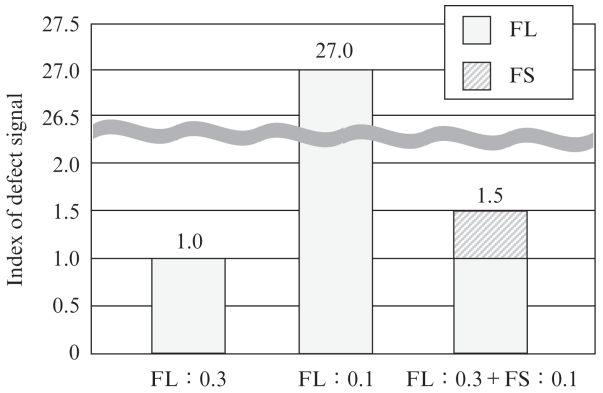

Fig. 5 Index of defect signal for each condition

The 2-level judgment method is a function in which a detection level lower than the conventional judgment method is set, and only harmful minute defects which are hidden by base noise are extracted by simultaneously judging the continuity of signals. The new setting items of the 2-level judgment method shown in **Table 1** were added in order to provide this function.

3.2 Results of Verification Test

In order to verify the defect detection function by the 2-level judgment method, a comparative evaluation of the defect detection function with the conventional method was carried out using the same billet. The following three levels were used in this evaluation experiment.

Level 1 FL: 0.3 mm (conventional standard)
Level 2 FL: 0.1 mm (strict standard using conventional method)
Level 3 FL: 0.3 mm+FS: 0.1 mm and continuous α mm or more (2-level judgment method; α was determined by investigation of actual defects)

Figure 5 shows the index of defect signals under the conditions of each case, assuming the number of defect signals is 1.0 when detection is performed under the conventional standard of Level 1. Because base noise is detected under the strict judgment standard of Level 2, judgment of defects is difficult. However, by using the 2-level judgment standard, which includes continuity, only defects with continuity can be extracted selectively

from noise. Thus, this experiment confirmed that it is possible to detect defects below the conventional standard by using the 2-level judgment standard.

4. Conclusion

In MLFT inspections at the Billet Mill, it was possible to improve defect detection performance while suppressing overdetection by adding defect continuity to the conditions for judgment of defects. In the future, we will work proactively to develop new technologies that respond to the constantly higher product quality needs of customers.

Reference

1) JFE Technical Report. 2010, vol. 15, p. 44–46.

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