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1. Introduction

Drawing-Redrawing (DRD) can, a kind of 2-piece can, has advantages of good seal function and toughness against difference between internal pressure and external pressure. By making use of these advantages, DRD cans are applied to usages in which seaming and retort sterilization is made after food packing. For example, they are used as tuna cans and pet food cans[1]. In making of DRD cans, tin-free steel sheets excellent in paint adhesion[2] is painted beforehand and cans are made continuously by utilizing lubricativeness of the painted film. Usually, high-strength extra-thin steel sheets, namely tin mill b packing.

Conventionally, to evaluate nonmetallic inclusions (otherwise flaws) in TMBP, magnetic particle testing (MT)[3] and magnetic flux leakage (MFL) testing[4] have been used. However, since only sheet samples can be evaluated by use of the conventional MT, customers have demanded flaw detection throughout the entire volume of a coil. As for on-line flaw detection in the cold rolling process using the conventional detector based on MFL technique, time lag from the steelmaking process to the detection of nonmetallic inclusions in the cold rolling process is so long that lengthy time is required until the detection results are fed back to the steelmaking process.

In view of this situation, JFE Steel has developed an on-line high-frequency ultrasonic detecting system for internal non-metallics in as-hot-rolled steel strip (OHDIN)[5,6] and has installed it in the No. 6 pickling line in the No. 1 cold rolling facilities at East Japan Works (Chiba)[7]. This report outlines OHDIN as installed in the No.6 pickling line, its operation method, and its usefulness.

2. Development of OHDIN in No. 6 Pickling Line

2.1 Flaw Detection Method and Its Features

Figure 1 shows an outline of a flaw detection method developed and used in OHDIN. A transmitting probe array and a receiving probe array are arranged opposite each other in water, with a steel strip interposed. A line-focused ultrasonic beam (25 MHz in frequency) is sent into the steel strip and two flaw echoes given as follows are received by the receiving probe array. Hereinafter, this method is referred as a flaw detection method using ultrasonic line sensor.

(1) Flaw echo reflected first at a internal flaw and next at the surface wall of the strip.

(2) Flaw echo reflected first at the back wall of the strip and next at a internal flaw.

procedure. Representative cross-sectional views of detected nonmetallic inclusions are also shown in Fig. 4. It is confirmed that an inclusion with 5×10^{-5} mm^3 in the minimum volume can be detected with signal-to-noise ratio of approximately 10 dB. The detectability in on-line testing was equivalent to that in the experiment in the laboratory. As for the conventional MFL testing, it is said that the inclusion with a volume 5×10^{-4} mm^3 is critical for the detection[4,10]. The inclusion, which is 1/10 times smaller in volume than the conventional critical one, can be detected by use of OHDIN. There were no false indications in above-mentioned tests. Some false indications against which countermeasures had been taken and a small number of surface flaws detected were not classified as false indications.

3. Operation of OHDIN in No. 6 Pickling Line

3.1 Nonmetallic Inclusion Information System

A nonmetallic inclusion information system has been built in order to rapidly feed nonmetallic inclusion information obtained by OHDIN in the No. 6 pickling line back to the steelmaking process. The system configuration is shown in **Fig. 5**. The nonmetallic inclusion information and coil information are sent to the host computer so that a database in which the nonmetallic inclusion information is related with the operating conditions in the steelmaking process is built. The system shows information required for quality control on the basis of the database. Examples of factors to be operated in the steelmaking process are shown in **Table 1**. ditioic

Therefore, the following operating methods have been built and standardized.

(1) A method for keeping detectability

(2) A method of daily check

3.2.1 Calibration method

The detecting heads are arranged on a C-shaped frame as shown in **Fig. 7** so that the detecting heads can be retracted out of the production line during the operation of the production line. This makes maintenance work easy.

The important point to keep the detectability of the detecting system is to keep the transmitting probe array and the receiving probe array, that are opposed to each other with the steel strip interposed, in the prescribed positional relationship. If the point is gained, constant high detectability can be kept. To evaluate the positional relationship mentioned above, the detecting system has a test piece and a probe positioning mechanism.

Figure 8 shows a simplified waveform of the ultrasonic signal obtained by the detecting system. The positional relationship between the transmitting probe array and the paired receiving probe array is adjusted so that the first through-transmitted wave T1 and the second through-transmitted wave T2 have amplitudes within each prescribed range. The positional relationship is adjusted not only on the occasion of the replacement of a probe array and the findings of a probe with insufficient sensitivity in the daily check described later, but also periodically at determined intervals.

3.2.2 Tfmethod

In utilization of OHDIN as a quality assurance

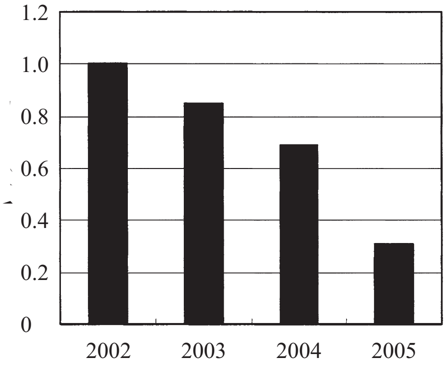

Fig. 10 Recent trend in inclusion index of product

ity assurance instrument and the nonmetallic inclusion information system was built. As a result, it has become possible to rapidly feed nonmetallic inclusion information back to the steelmaking department and the conditions of the steelmaking have been optimized. The defect index has been greatly improved.

5. Conclusions

For quality assurance and quality control of TMBP for DRD cans, an ultrasonic nonmetallic inclusion detecting system (OHDIN) was installed on the entry side of the No. 6 pickling line of the No. 1 cold rolling facilities at JFE Steel's East Works (Chiba). After the verification of detectability and the development of an operation method described below, the detector is in operation as a quality assurance instrument:

(1) It was confirmed that a nonmetallic inclusion with 5×10^{-5} mm^3 in the minimum volume can be detected with signal-to-noise ratio of approximately 10 dB in on-line condition.

(2) A sensitivity calibration method and a daily check method have been developed and standardized.

Furthermore, an information system, which enables nonmetallic inclusion information to be rapidly fed back to the steelmaking process and to be showed comprehensively, was built. As a result, the quality of TMBP for DRD cans was greatly improved and defects in DRD cans manufacturing were also greatly reduced.

At present, JFE Steel is considering the installation of this detecting system in other production lines so as to improve internal quality of other steel sheet products.

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