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Technology

Set Up of Laser Thickness Gauge in No. 2 Tension Leveler

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Abstract

In the refining process of Shunan Area Yamaguchi Works, Nippon Steel Stainless Steel Corporation, the thickness of the entire length of coils is measured by a thickness gauge in multiple lines for the shipping work. The purpose of the measurement is to prevent the leakage of coils with an excessive thickness change to the customer. However, the contact trace caused by the contact thickness gauge creates a problem on the surface quality of coils. In order to solve this problem, a laser thickness gauge is set in the No. 2 tension leveler.

1. Introduction

Strip thickness is measured with X-ray thickness gauges in the entire cold strip mill at the Shunan Area Yamaguchi Works of Nippon Steel Stainless Steel Corporation. Thickness gauges are also installed on finishing lines in the finishing process. These thickness gauges are used to measure the thickness of strip products with severe thickness requirements and to check for excessive thickness changes. We make these efforts to prevent off-gauge products from being shipped out.

The thickness gauges used in the finishing process at the Shunan Area are of the contact type. The contact thickness gauges help to prevent off-gauge products from being shipped out but have the problem of contact marks with measuring heads. Non-contact laser thickness gauges were installed as new thickness gauges on the No. 2 tension leveler line (hereinafter referred to as the No. 2 TL) and helped to solve the contact mark problem. The results achieved are reported here.

2. Types of Thickness Gauges

2.1 Comparison of specifications of thickness gauges

Before installation, we compared four types of thickness gauges: contact thickness gauge, non-contact X-ray thickness gauge, non-contact γ-ray thickness gauge, and laser thickness gauge.

Table 1 shows the comparison results of the four types of thickness gauges. The contact thickness gauge has a measurement accuracy of ±1 μm and a measurement spot diameter of φ1.0 mm. Despite its excellent measurement accuracy, the contact thickness gauge requires replacement of the measuring heads that directly contact the steel strip. The cost of operating and maintaining the contact thickness gauge is high. Contact marks are also a problem.

Table 1 Comparison of thickness measurement methods

Machine type	Laser type	Contact type	γ-ray type	X-ray type
Measure range	0.1–6.0 mm	0.1–9.0 mm	0–5.0 mm	0.1–8.0 mm
Spot idameter	φ0.1 mm	φ1.0 mm	φ40 mm	φ40 mm
Measure accuracy (thickness: 1.0 mm)	±1 μm	±1 μm	±3 μm	±3 μm
Measure time	1–1 000 msec	1–2 000 msec	200 msec	10 msec
Risk	Influence to the surface quality	Contact trace	Unable to measure the steep change of thickness	Unable to measure the steep change of thickness
	Laser class: 3B (legal compliance is necessary)	Running cost	Influence of component	Influence of component
			Radiation legal compliance is necessary	Radiation legal compliance is necessary

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The radiation thickness gauges have the greatest advantage in that no contact marks occur. Because their measurement spot diameter is φ40 mm, however, their measurement accuracy is ±3 μm and is inferior to the ±1 μm for the contact thickness gauge. Furthermore, handling of X-rays requires qualified operators and safety measures such as equipment for protection from exposure.

As compared with the contact and radiation thickness gauges, the laser thickness gauge is of the non-contact type and leaves no contact marks. The measurement spot diameter is φ0.1 mm. The measurement accuracy is ±1.0 μm and the same as that of the contact thickness gauge.

2.2 Measurement principle

2.2.1 Measurement principle of contact thickness gauge

Figure 1 shows the measurement principle of the contact thickness gauge. The strip is sandwiched between the upper and lower measuring heads. The displacement of the measuring heads is extracted as strip thickness deviation. The sampling period is 10 msec. As the measuring heads hold the strip to measure the thickness, the resulting contact marks may become a problem for mirror-finished strip products or strip products with strict surface quality requirements.

2.2.2 Measurement principle of non-contact radiation thickness gauge

Figure 2 shows the measurement principle of a non-contact radiation thickness gauge. The strip is irradiated with radiation. The strip thickness is calculated from the amount of incidental radiation and the amount of transmitted radiation. In Equation (1), t is the strip thickness, Io is the amount of incident radiation, I is the amount of transmitted radiation, μ is the mass absorption coefficient of the strip, and ρ is the density of the strip. As the strip thickness is calculated from the mass absorption coefficient and density of the strip by Equation (1), the correction value varies with the chemical composition of the strip steel. Even if the steel type of the strip is the same, the correction value varies with the unevenness of the chemical composition and may affect the strip thickness accuracy.

$$t = \log_e \left(\frac{Io}{I} \right)^{1/(\mu \cdot \rho)} \tag{1}$$

2.2.3 Measurement principle of laser thickness gauge

Figure 3 shows the measurement principle of the laser thickness gauge. The laser thickness gauge irradiates the laser from above and below the strip. The strip thickness is calculated by subtracting the distance from the upper laser sensor to the strip and the distance from the lower laser sensor to the strip from the distance between the upper and lower laser sensors. In Equation (2), t is the strip thickness, L_{dis} is the distance between the upper and lower laser sensors, L_{up} is the distance from the upper laser sensor to the strip, and L_{low} is the distance from the lower laser sensor to the strip.

$$t = L_{dis} - (L_{up} + L_{low}) \tag{2}$$

Table 2 shows how the strip thickness is measured in the laser thickness gauge. The sampling period of the laser thickness gauge is 0.0125 msec (80 kHz). The average value calculated within the evaluation time from the sampled data is extracted as the thickness data. The maximum and minimum values between pulses (156 mm

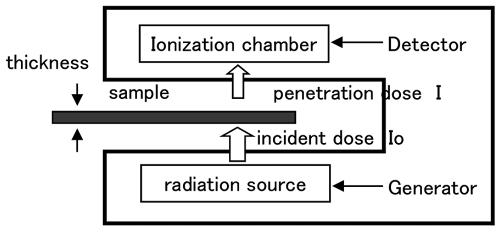


Fig. 2 Radiation thickness gauge

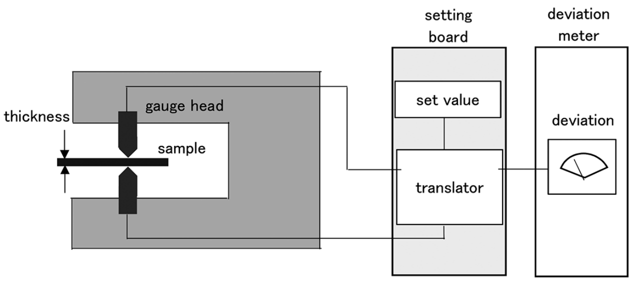


Fig. 1 Contact thickness gauge

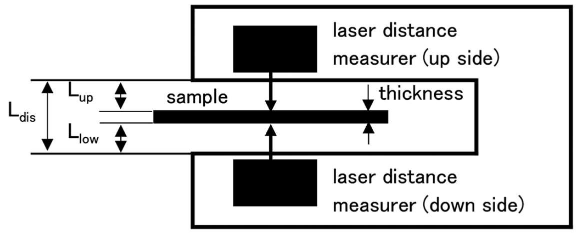
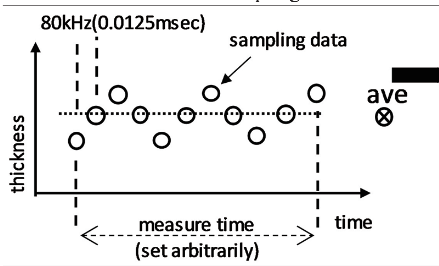
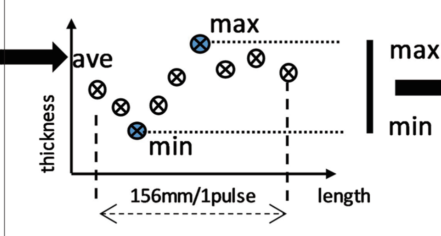
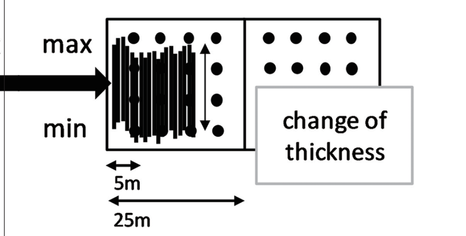


Fig. 3 Laser thickness gauge

Table 2 Outline of data recording of laser thickness gauge

① Data sampling	② Set gauge data to length	③ Print to chart
		
Sampling period: 80 kHz Thickness = Average data collected in measure pitch	Thickness data is set to the coil length. The max and min of thickness are connected by line and printed to chart.	Coil length in chart: 1 mm = 5 m Thickness data in 5 m (32 pulses) is printed in chart. The line which connect the max and min of thickness is used to recording the thickness of coil.

each) from the average thickness data within the evaluation time are printed as a strip thickness chart. The measurement results printed on the chart are continuous data showing the strip thickness variation between the pulses.

Figure 4 shows the relationship between the strip speed and the measurement interval by evaluation time. With the contact thickness gauge (10 msec), the measurement interval increases as the strip speed increases. With the laser thickness gauge (0.0125 msec), the measurement interval scarcely changes. These results show that the laser thickness gauge can stably measure the strip thickness without being affected by the strip speed.

3. Verification of Measurement Accuracy of Laser Thickness Gauge

3.1 Effect of strip speed

One of the reasons for using a thickness gauge in the finishing process is the detection of excessive strip thickness changes. In particular, the strip thickness portions (hereinafter referred to as roll stop marks) arising from work roll marks when the line is stopped for inspection, for example, may be within the specified thickness tolerances but may not meet the user application requirements and may result in defective products. The contact thickness gauges now in use cannot sometimes measure roll stop marks at high strip speed. In such a case, the strip speed is reduced to measure the strip thickness. Accordingly, we verified whether the thickness gauges could measure the roll stop marks at high strip speed.

The verification measurements were made at strip speeds of 30 mpm, 60 mpm, and 200 mpm or the maximum strip speed on the rolling line where the contact thickness gauges are installed. The range of the strip thickness change on the chart where the roll stop mark occurred was compared.

Table 3 shows the results of verifying whether the roll stop marks can be measured. The contact thickness gauge can measure strip thickness changes on the plus and minus sides as compared with the strip thickness before and after the roll stop marks at strip speeds of 30 mpm and 60 mpm, but cannot measure the strip thickness changes on the minus side at the strip speed of 200 mpm. On the other hand, the laser thickness gauge can measure the strip thickness changes at the roll stop marks on both plus and minus sides even at the strip speed of 200 mpm.

The roll stop marks are measured with the present contact thickness gauges at the strip speed of 30 mpm. This low strip speed hampers the measurement efficiency. The laser thickness gauge, on the other hand, can measure the roll stop marks without being affected by the strip speed. The strip can be run at the maximum speed without any drop in the measurement efficiency.

3.2 Effect of different surface finishes

The spot diameter of the laser thickness gauge is so small that the difference in strip surface finish may affect the measurement results. Given this possibility, we compared the results of measurement with three types of steel strip with different surface finishes.

The range of the strip thickness change on the measured strip thickness charts was compared. **Figure 5** shows the effect of different surface finishes on the measurement results. The range of the

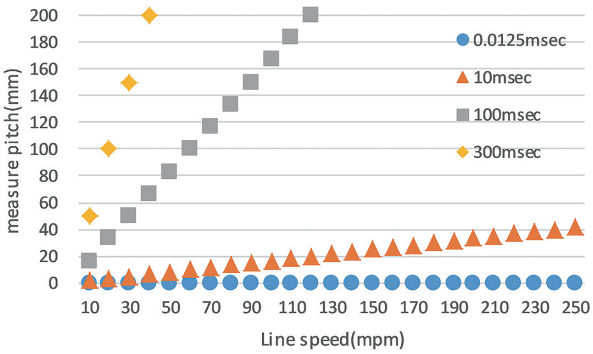


Fig. 4 Influence of line speed to the measure pitch

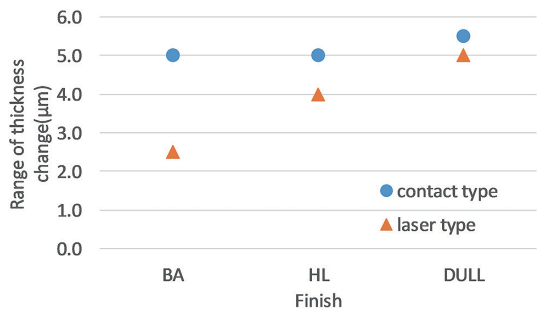
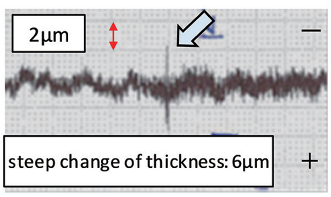
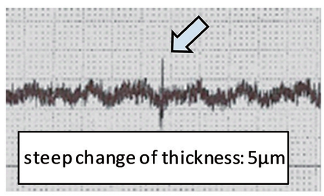
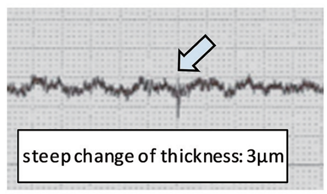
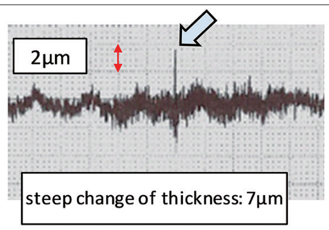
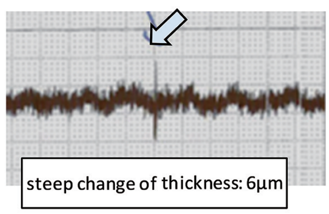
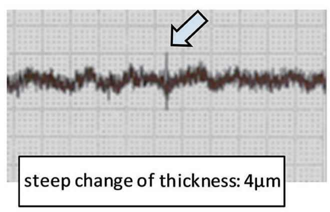


Fig. 5 Influence of surface finish to measure accuracy

Table 3 Comparison of device and evaluation time

	Line speed 30 mpm	Line speed 60 mpm	Line speed 200 mpm
Contact thickness gauge	 2μm − steep change of thickness: 6μm +	 steep change of thickness: 5μm	 steep change of thickness: 3μm
Laser thickness gauge in No.2 TL	 2μm steep change of thickness: 7μm	 steep change of thickness: 6μm	 steep change of thickness: 4μm

strip thickness change measured with the contact thickness gauge is about 5 μm regardless of the strip surface finish. The range of the strip thickness change measured with the laser thickness gauge was 2.5 μm for small surface roughness and 5 μm for large surface roughness. This is probably because the laser thickness gauge measures small surface irregularities.

4. Conclusions

We measured the strip thickness with contact thickness gauges in the finishing process at the Shunan Area Yamaguchi Works. We had to address the problem of preventing contact marks. Before we installed new thickness gauges at the No. 2 TL, we compared various thickness gauges to prevent the contact mark problem. According to the results of comparison, we selected and installed non-contact laser thickness gauges. These non-contact laser thickness gauges allowed us to prevent the occurrence of contact marks with the measuring heads of contact thickness gauges and to measure strip thickness with the same accuracy as that obtained with the contact thickness gauges.

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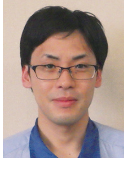

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