Electromagnetic Measurement on Singular Joint Gap of the Rails*1

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This paper describes the measurement results of a normal joint gap and a singular joint gap of the rails using voltage detecting type rail joint gap sensor. In the case of a singular joint gap, the minimum value of a joint gap is able to be obtained by comparing the output voltage of two detecting coils that placed it toward the rail width and the measurement results of a normal joint gap.

Keywords: rail ways, joint gap of the rails, electromagnetic sensor, voltage detecting type rail joint gap sensor, eddy current.

1. Introduction

An electromagnetic sensor is already used in a measurement of rail displacement because measurement is possible in any weather condition [1] [2]. The authors considered about a measurement method of joint gap of the rails using impedance detecting type and voltage detecting type rail joint gap sensor by air-core coils for rail joint gap measurement [3] [4]. This paper described as follows: (1) structure of voltage detecting type rail joint gap sensor, and measuring method of singular joint gap of the rails; (2) measurement of singular joint gap of the rails.

2. Structure of voltage detecting type rail joint gap sensor

Fig. 1 shows a structure of voltage detecting type rail joint gap sensor. The voltage detecting type rail joint gap sensor is comprised four detecting coils under one exciting coil. Here, a joint gap of the rails is measured by using two detecting coils A and B.

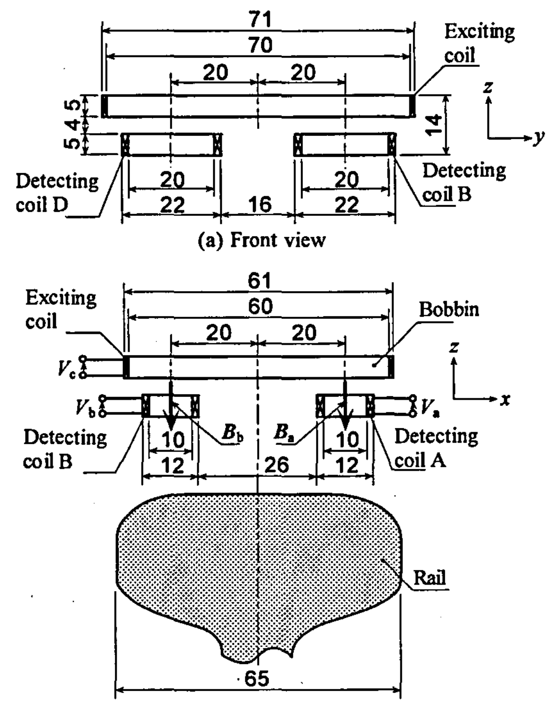

Fig. 1 Structure of voltage detecting type rail joint gap sensor (unit : mm).

The output voltage, V_a and V_b (V), of the detecting coils A and B are given by (1) and (2).

$$V_a = -N_d \frac{d\Phi_a}{dt} = -N_d \frac{d\left(\int B_a \cdot n_d dA_d\right)}{dt}, \quad (1)$$

$$V_b = -N_d \frac{d\Phi_b}{dt} = -N_d \frac{d\left(\int B_b \cdot n_d dA_d\right)}{dt}, \quad (2)$$

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where Φ_a is the flux (Wb) of detecting coil A, N_d is the number of turns of detecting coil, $\boldsymbol{B}_a$ is the linkage flux density (T) of detecting coil A, $\boldsymbol{n}_d$ is the unit method line vector of area of detecting coil, A_d is the area (m^2) of detecting coil, t is the time (s), Φ_b is the flux (Wb) of detecting coil B, and $\boldsymbol{B}_b$ is the linkage flux density (T) of detecting coil B.

The output voltage, V_a and V_b, increase in the case that the detecting coils is in the upper part of a joint gap. Because, flux occurred by eddy current decreases in the upper part of a joint gap.

Fig. 2 shows a model of a singular joint gap of the rails. A joint gap, δ, is defined with the minimum value in interval of rail A and B. An edge face of rail A is vertical toward a longitudinal direction of rail. An edge face of rail B is shaved obliquely shown in Fig. 2 (a). In the case that an edge face of rail B is vertical toward a longitudinal direction of rail is called by normal joint gap, and an edge face of rail B is shaved obliquely is called by singular joint gap.

3. Measuring method of singular joint gap of the rails

Fig. 3 shows the measurement block of singular joint gap of the rails using voltage detecting type rail joint gap sensor. Output voltage, V_a and V_b, of detecting coils A and B, respectively, are measured at lift-off, z = 7 mm, rail displacement, x = 0 mm, frequency, f = 1 MHz, and exciting voltage, V_c = 20 V when they displace it toward a longitudinal direction of rail (in the direction of y-axis).

4. Measurement of singular joint gap of the rails

Fig. 4 shows the characteristics of output voltage, V_a and V_b, vs. displacement, y at $\delta \simeq$ 0 mm (rail A and rail B

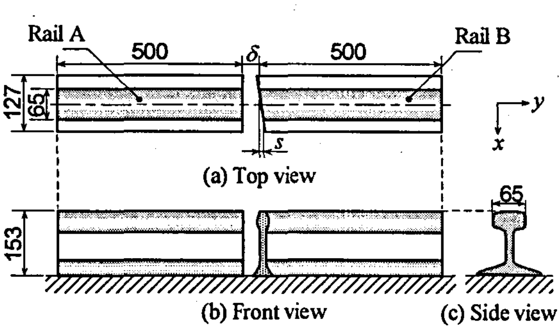


Fig. 2 A model of singular joint gap of the rails (unit : mm).

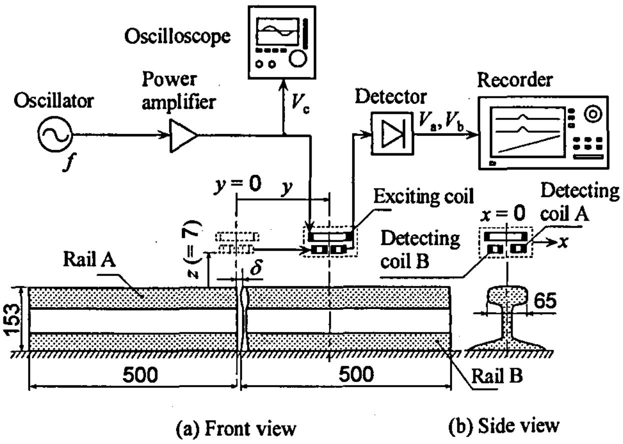


Fig. 3 Measurement block of singular rail joint gap using voltage detecting type rail joint gap sensor (unit : mm).

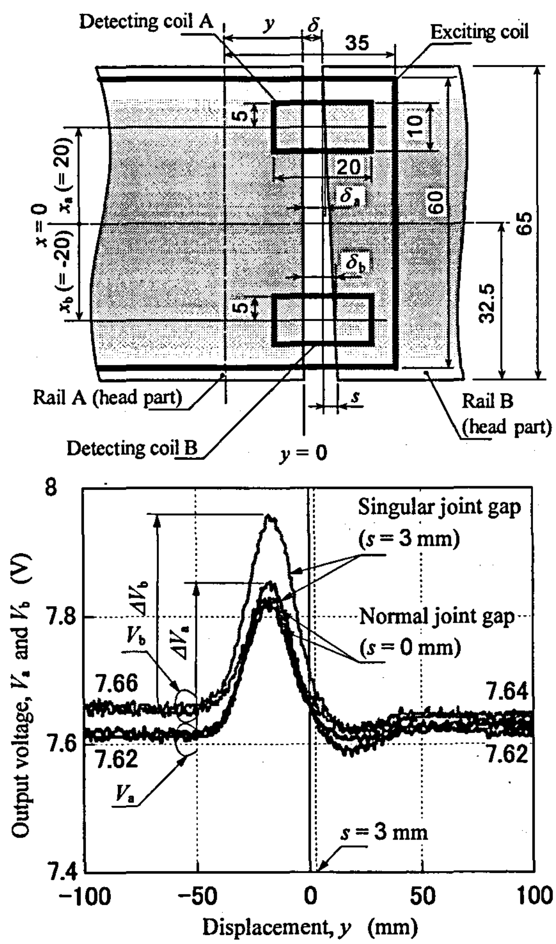
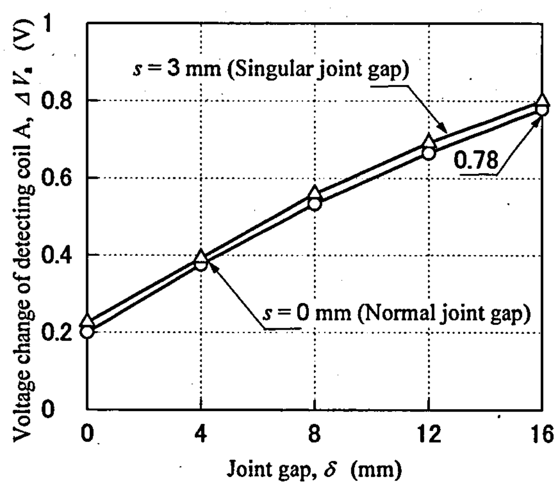


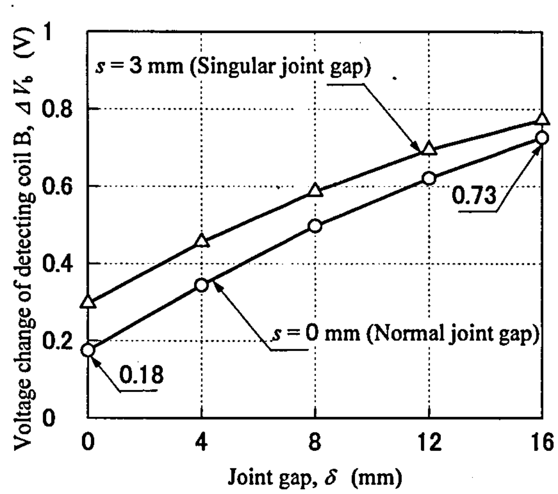
Fig. 4 Characteristics of output voltage, V_a and V_b, vs. displacement, y (measuring condition : z = 7 mm, x = 0 mm, f = 1 MHz, V_c = 20 V, $\delta \simeq$ 0 mm).

are contacting). Output voltage, V_a and V_b increases in the upper part of a joint gap. The result indicated in the upper part of a joint gap that output voltage, V_a and V_b agrees for the most part and $V_a < V_b$ on the singular joint gap in the rail (s = 3 mm). This difference means that a joint gap in the location of detecting coil B is 1.8 mm bigger than that in the location of detecting coil A. Here, the voltage change of a detecting coils A and B, V_a and V_b are defined with ΔV_a and ΔV_b.

Fig. 5 shows the characteristics of voltage change, ΔV_a and ΔV_b, vs. joint gap between the rails, δ. The voltage change of a detecting coil B, ΔV_b, is increasing in comparison with the change of the voltage change of detecting coil A, ΔV_a, according to the change of a joint gap of the rails.



(a) Voltage change of detecting coil A, ΔV_a



(b) Voltage change of detecting coil B, ΔV_b

Fig. 5 Characteristics of voltage change, ΔV_a and ΔV_b, vs. joint gap of the rails, δ (measuring condition : z = 7 mm, x = 0 mm, f = 1 MHz, V_c = 20 V).

As shown in Fig. 4, minimum value of a joint gap, δ_c (m), is given by (3).

$$\delta_c = \delta_a - s\left(\frac{1}{2} - \frac{x_a}{w}\right) = \frac{2(x_b\delta_a - x_a\delta_b) + w(\delta_b - \delta_a)}{2(x_b - x_a)}, \quad (3)$$

where δ_a is the joint gap (m) under the detecting coil A, x_a is the location (m) of detecting coil A, w is the width (m) of rail, x_b is the location (m) of detecting coil B, and δ_b is the joint gap (m) under the detecting coil B.

From the result of Fig. 5, joint gap of the rails, δ_a and δ_b (m), are expressed with twice function.

$$\delta_a = 1.38\times10^{-2}\Delta V_a^{\,2} + 1.39\times10^{-2}\Delta V_a - 3.29\times10^{-3} \quad (4)$$

$$\delta_b = 1.71\times10^{-2}\Delta V_b^{\,2} + 1.34\times10^{-2}\Delta V_b - 2.81\times10^{-3} \quad (5)$$

Substituting (4) and (5) into (3), minimum value of a joint gap, δ_c, is calculated using the characteristics (s = 0 mm) shown in Fig. 5. The joint gap of the rail, δ_a and δ_b, are calculated in the case of s = 0 mm in Fig. 5.

Fig. 6 shows the comparison with calculated values of joint gap and joint gap of the rails. It shows that the joint gap of the rails is agreeing within ±0.9 mm in the case of s = 3 mm.

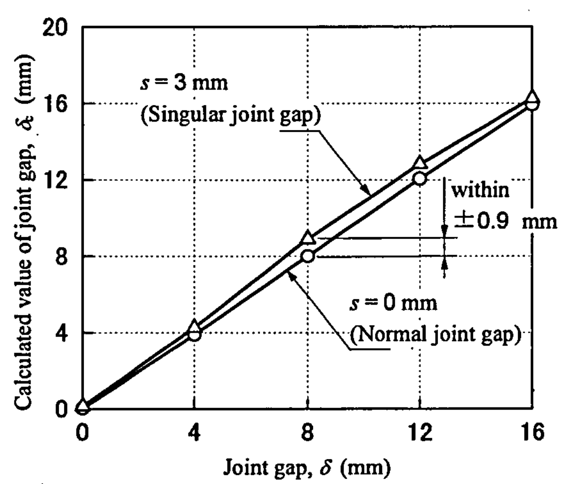


Fig. 6 Comparison with calculated value of joint gap and joint gap of the rails (measuring condition : z = 7 mm, x = 0 mm, f = 1 MHz, V_c = 20 V).

5. Conclusion

In this paper, it expressed about the method that the minimum value of a joint gap of the rails was measured even in the case of a singular joint gap by comparing the measurement results of a normal joint gap using voltage detecting type rail joint gap sensor. The following results were obtained.

(1) A singular joint gap of the rails was measured by the output voltage of two detecting coils that placed it toward the rail width, and could identify it clearly with a normal joint gap.

(2) The joint gap between the each rail was agreeing within ± 0.9 mm in the case of $s = 3$ mm in a singular joint gap of the rails at lift-off, $z = 7$ mm, rail displacement, $x = 0$ mm, frequency, $f = 1$ MHz, and exciting voltage, $V_c = 20$ V.

References

[1] S. Kishimoto : Non-contact measurement of the rail displace-ment by eddy current sensor, Journal of Japanese Society for Non–destructive Inspection, Vol. 40, No. 9, pp. 624–630, 1991.

[2] Y. Suda, A. Nagato, K. Tokuoka and S. Miura : New Rail, Japan Railroad Institution Society, p. 485, 1997.

[3] S. Watanabe, T. Mizuno, T. Nakajima, S. Enoki, K. Takeshita, S. Kishimoto and H. Yamada : Impedance characteristics of probe coil for rail joint gap measurements, Journal of the Magnetics Society of Japan, Vol. 24, No. 4–2, pp. 863-866, 2000.

[4] S. Watanabe : Study on electromagnetic sensors for non–contact measurement of rail wearing depth and rail joint gap, Doctors Thesis, Shinshu University, pp. 82–104, 2000.