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Three-poles Touch-type Corrosion Sensor for Edge Detection of Initial State of Iron Rust

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Abstract

Some nondestructive diagnostic methods including various types of corrosion sensors have been investigated. Under these conditions, a new structure of sensor that has a pair of electrode and magneto-supply was proposed. In order to detect the edge of the iron rust part, three-poles touch-type corrosion sensor is now proposed. The iron rust pattern where the sensor touches is estimated by means of the impedance of the sensor, and the edge of the iron rust is recognized by comparing the three measured impedances. As the result, our proposed sensor is useful to detect the initial state of iron rust.

1. Introduction

Some nondestructive diagnostic methods including various types of corrosion sensors have been recently investigated[1]-[6]. Under these conditions, in our study, initial corrosion detecting and autonomous sensing of iron rust are especially focused. A new technical approach called multi-functional sensing [7][8]is adopted. The multi-functional sensing is able to extract some information in mono-structural sensor comparing between measurement data and prepared database. Some primitive corrosion sensors functioning as a corrosion diagnosis system is investigated[9]. Final purposes of our study are the detection of initial state of iron rust, the recognition of the pattern of the iron rust, and the diagnosis of metal corrosion using the multi-functional sensor.

A new structure of touch-type corrosion sensor for autonomous sensing system is now presented. This sensor composes of three electrodes and three coils for edge detection of iron rust. Scanning three nodes of this sensor, three measurement data as combination between the poles are obtained, and the unbalance of these data reveals when the electrodes touch iron rust part. And the existence of iron rust in the place where the sensor touched is estimated and the edge of iron rust is also detected. Adopting six rules of movement of the sensor, the sensor autonomously moves along the edge of iron rust.

As the result, this sensor is found to be useful as a detecting device for the initial state of iron rust.

2. Three-Poles Touch-type Corrosion Sensor with Magneto-Supply

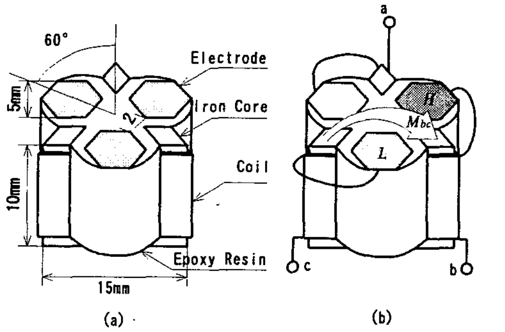

Fig.1 Three-poles Touch-type Corrosion Sensor

This sensor has three hexagonal electrodes and three coils shown in Fig. 1(a). The width of electrode is 5mm, and each interval is 2mm. Copper wires are wound on the iron core with three poles as magneto-supply. The coil is connected to the electrode in series. The magnetic flux generated by the coils flows across the current pass shown in Fig 1(b). The eddy current of this flux affects the current pass, and the main current which flows the surface of the iron model. By the current flows the surface, the sensor can be realized high-sensitivity detection of iron rust layer.

3. Iron Rust Model

An example of movement of the sensor along the edge of iron rust part is shown in Fig.2(a). Touch patterns of the sensor are considered for four basic elements shown in Fig.2(b). The impedance between each terminal a, b, c of the sensor is measured for the recognition of four basic elements of touch pattern. Three kinds of models used in these experiments are shown in Table 1.

Table 1. Iron Rust Models

No.	Statement of Surface
1.	Clean surface
2.	Part of Iron Rust
3.	Covered with Iron Rust

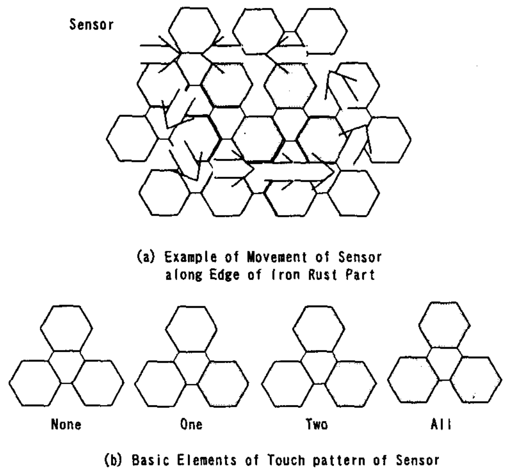

Fig.2 Example of Movement of Sensor along Edge of Iron Rust Part and Basic Elements of Touch Pattern of Sensor

A polished iron plate is used as Model 1. Model 2 is made of the distilled water put on the iron plate. Model 3 is made with the high-temperature-oxide in the electric furnace.

4. Principle of Measurement

An equivalent circuit of sensor that has one pair of electrode is shown in Fig. 3. When the sensor is put on iron rust layer, the iron rust layer is expressed between iron plate and the electrode of sensor. Then, it seems like a capacitance, which consists of the iron plates, iron rust layer, and the electrodes of the sensor. For instance, when the impedance of iron rust through the iron plate is Z_r and the impedance of parallel elements is Z_0, we can denote as:

$$C_r = \varepsilon \frac{S}{d} \quad (1)$$

$$R_r = \rho \frac{d}{S} \quad (2)$$

$$Z_r = \frac{1}{\left(\frac{1}{R_r} + j\omega C_r \right)} \quad (3)$$

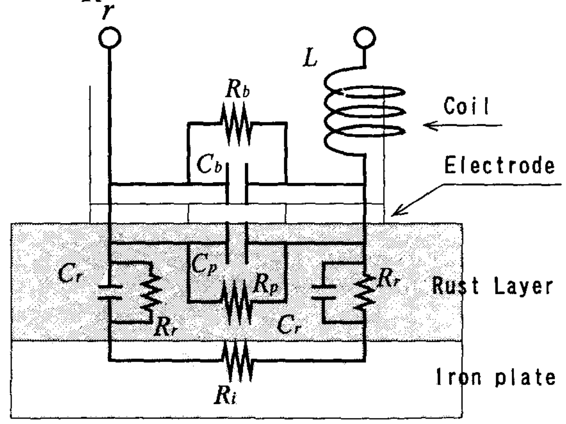

Fig.3 Equivalent Circuit of Sensor and Iron Rust Layer

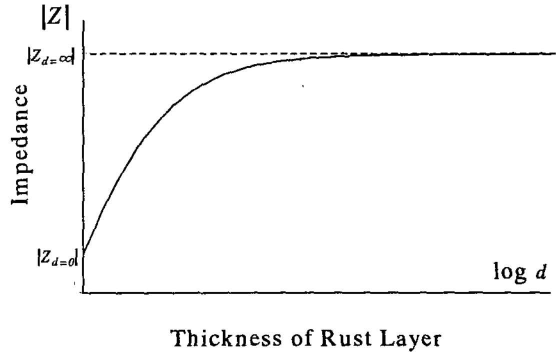

Fig.4 Theoretical Value of Impedance of Touch-type Corrosion Sensor with Magneto-supply

where d is the thickness of iron rust layer, ε is the dielectric constant of iron rust, ρ is the conductive constant of iron rust, and S is the surface size of electrode of the sensor. In order to diminish the voltage impressed on the impedance of iron rust Z_r, the coil is connected to the electrode in series. The whole impedance of the sensor is written as:

$$Z = \frac{1}{\left(\frac{1}{2Z_r + R_i} + \frac{1}{Z_0} \right)} + j\omega L \quad (4)$$

Where, Z_0 is the whole parallel element which consists R_b, C_b, R_p and C_p, R_{iron} is the resistance of the iron plate, and L is the inductance of the coil. In the case of very thin rust layer, the impedance of iron rust Z_{rust} is very small, and the insulation of iron rust layer between the electrode and the iron plate is broken down. Connecting the coil in series in the case of very thin iron rust layer, the impressed voltage to the impedance of iron rust Z_{rust} is diminished and high-sensitive detection is realized.
Theoretical value of impedance of touch-type corrosion sensor with magneto-supply in the relation of the thickness of rust layer is shown in Fig.4. The impedance of the sensor increases when the thickness of the iron rust increases. Therefore, the thickness of iron rust is estimated, by means of measuring the impedance of the sensor.
The equivalent circuit of three-poles touch-type corrosion sensor is expressed as shown in Fig. 5. The impedance of sensor is expressed as three-phases connection. The impedance between two terminals of three is measured in the experiment. The impedance including the node of electrode which touches iron rust part is high, and then the iron rust is recognized. Threshold impedance to judge the existence of iron rust is adopted.

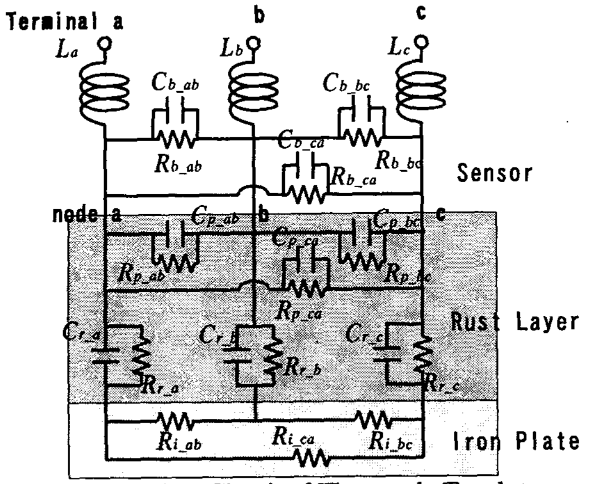

Fig.5 Equivalent Circuit of Three-pole Touch-type Corrosion Sensor

5. Experiments and Results

Basic elements "None" shown in Fig.2(b) using Model 1 covered with clean surface, basic elements "One" and "Two" using Model 2, and basic element "All" using Model 3 are measured. A measurement result of impedance between each terminal is shown in Fig.6. When both electrodes touch the iron surface, the impedance of the sensor is very small and the impedance including the node of the electrodes touching the iron rust part is high. Therefore, the possibility of the recognition of three patterns is confirmed. In the case of Model 3, the non-uniformity of the thickness of the rust layer causes that the impedance between terminal *a* and *b* is small. Basic element "Two" is not distinguishable in all of basic elements because all impedance indicate high value in the case of basic element "Two".

As the pattern recognition of iron rust, a rust pattern model

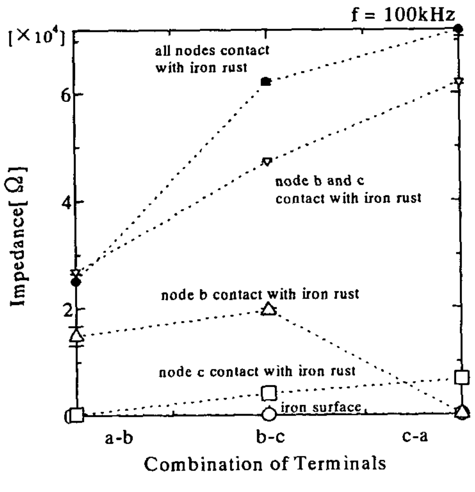

Fig.6 Measurement Result of Impedance of Sensor in Basic Elements of Touch Pattern of Sensor

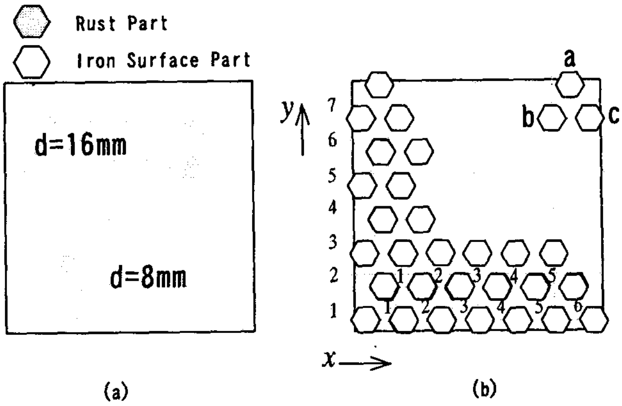

Fig.7 Model of Iron Rust Pattern and Movement of Sensor

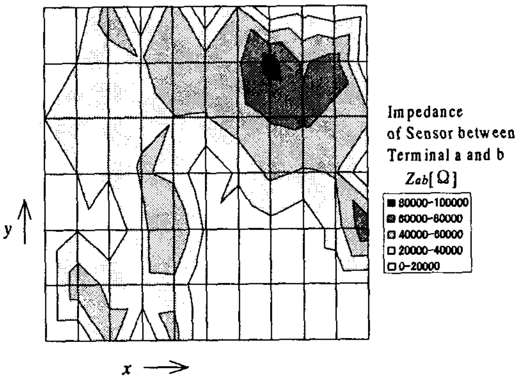

Fig.8 Measurement Result of Impedance between node a and b

shown in Fig.7(a) is prepared. The model has two patterns of thin iron rust layers, that is, a small pattern of diameter of 8mm and a large pattern of 16mm. These rust patterns are produced by putting distilled water. Scanning the sensor by 7mm that is the distance between the center of the electrode shown in Fig.7(b), the impedance of the sensor is measured. Measurement results of impedance between terminal a and b are shown in Fig. 8.

The sensor indicates high impedance near iron rust part. In other combination of terminals, the impedance of sensor is similar to this result. Therefore, it is confirmed that the sensor senses iron rust.

6. Discussion

Rules of movement of sensor for autonomous sensing are investigated. If all electrodes touch iron rust part, this situation cannot distinguished from that two electrodes touch iron rust part. To prevent this situation, a starting point of measurement is limited in the place where all electrodes touch iron surface and the sensor moves against the place where the electrode touches iron surface. When the sensor moves around iron rust part in counter clockwise, six rules of movement of the sensor is proposed as shown in Fig. 9.

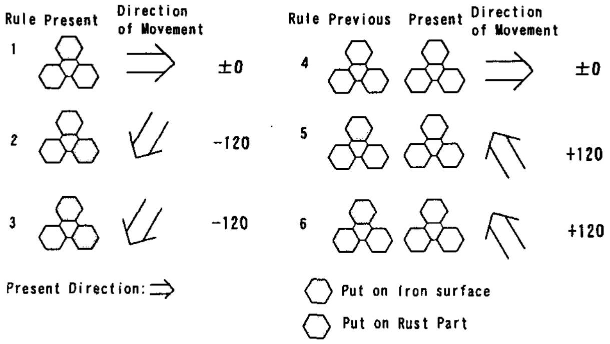

Fig.9 Six Rules of Movement of Sensor

Table 2. Rules of Recognition of Basic Elements

Data Exceeding Threshold	Basic Element
0	None
1	None
2	One
3	Two

From present state of touch pattern, the direction of movement is decided in the time when any electrodes touch iron rust part. Considering previous state and present state, the direction of movement is decided in the iron plate. When the impedance of the sensor exceeds threshold impedance, existence of iron rust under the electrode of the sensor is judged. Rules of recognition of basic elements are shown in Table2.

An experiment of edge detection of iron rust is simulated using three measurement data of the sensor. An experimental result is shown in Fig. 10.

When the threshold impedance Z_{th} is 1000, the sensor does not move correctly because of its sensitivity. In the case of 50000, the sensor moves near the edge of iron rust part. As the result, when the threshold impedance is set

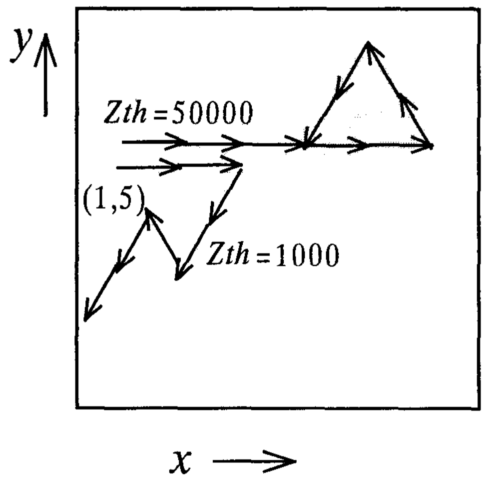

Fig.10 Simulation Result of Movement of Sensor

appropriately, the sensor moves along the edge of iron rust correctly.

7. Conclusion

In this paper, our proposed three-poles touch-type corrosion sensor with magneto-supply is presented, and the basic property and the result of simulation of the sensor are investigated. Moreover, it is shown that the sensor moves along the edge of iron rust part. As the result, this sensor is preferable for autonomous sensing system, and useful for detecting the initial state of iron rust.

Referances

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