Development of System for Supporting Lock Position Adjustment Work for Electric Point Machine

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This paper presents a method which makes use of data collected in the monitoring devices fitted to electric point machines. First, a model was built to detect the lock position of the point machine. Then, an algorithm was devised to predict variations in the lock position, by employing meteorological data, air temperature and humidity. A study was then conducted to investigate how the predicted lock position data could be utilized. Second, we have proposed how to provide supporting information for planning the work of the lock position adjustment. Finally, a method was developed to enable visualization of the predicted position data.

Keywords: electric point machine, locking error, lock position, multivariable analysis

1. Introduction

Various studies have been conducted over the past few years using sensors, in order to build systems which can detect the state of equipment. These systems are called condition-based monitoring systems, and have already been applied and introduced in many fields. Condition-based monitoring systems for various applications are also used in railways, creating an environment where big data can be utilized [1]. In the future, it will be important to be able to extract this data in order to improve the efficacy of equipment maintenance. In the case of electric point machines, which form part of the signaling system, monitoring devices to guarantee safety, have been installed [2,3]. However, the large amounts of data being collected by these lock-monitoring devices are still not being used to their full potential for preventive maintenance [4,5]. This paper therefore describes a technique which makes use of data stored in lock-monitoring devices, which should contribute to more effective maintenance. The paper also reports on a method for visualizing the lock position prediction results alongside actual values.

2. Background

Turnouts change the course of trains at bisections on the track. Electric point machines move the turnout from side to side. When the turnout is switched, the lock piece of the electric point machine is inserted into the notch of the lock rod (Fig. 1). The purpose of this locking is to prevent the turnout from switching as a train passes over it, thus ensuring safe operation. The lock position, which is defined as the relative position of the center of the lock piece in relation to the center of the lock rod notch, varies according to various factors, such as a temperature (Fig. 2). If the lock position is greater than a certain value, the lock piece will not fit properly into the notch on the lock rod. This causes a “locking error”, and switching the turnout becomes impossible, often leading to traffic delays and congestion. The position of the lock piece therefore needs to be adjusted at times, in order to ensure that it is always within the lockable range. Lock monitors are used in practice to achieve this, which monitor and store lock positions. These devices monitor the lock position by detecting displacement of the lock rod with a sensor installed in the point machine. If the lock position exceeds the threshold value, the lock-monitoring device triggers an alarm so that the lock position can be adjusted before switching becomes impossible. This helps prevent switches becoming inoperable due to locking error. If an alarm sounds during train operating hours and the lock position requires adjustment immediately, train operations may be affected. To prevent this, it is important to adjust the lock position appropriately in advance. To date however, no method exists to predict lock position...
position variation.

Investigations were carried out therefore to solve this problem, to increase the efficacy of maintenance work by offering support at the long term maintenance planning stage, and enable lock position adjustment.

3. Considering how to provide the information to support lock position adjustment work

3.1 Examination of information needed to support lock position adjustment work

As described above, adjusting lock positions requires advance information about the position of the lock piece. In order to achieve this, it had to be determined which type of information would be needed to ensure lock positions were adjusted correctly.

The ideal position of a switch is when the center of lock position in the course of its daily movement matches the notch center. If daily movements of the lock position are obtained, it is possible to calculate the required adjustment of the lock position. For example, Fig. 3 shows the predicted lock position will vary between -0.8 and 0 millimeters. In this case, the center of the movement is about -0.4 millimeters, so we adjust lock position to 0.4 millimeters. This estimated adjustment amount is the information required to support lock positioning. Thus, if this information can be provided, lock positioning efficiency will increase which in turn to reduce the number of triggered alarms.

3.2 Method for predicting lock position variation [6]

This section describes the method for predicting variations in daily lock positions with a view to gathering the necessary information mentioned in the previous section. This method predicts the lock position variation for the next day based on accumulated lock position data. Figure 4 illustrates the method. First, it models lock positions by the following equation (1) [7]. Next, by this model formula, lock positions are calculated for the next day including temperature and humidity for the next as input.

\[ R_t = a_0 + a_1 [R_{t-1}, T_{t-1}, H_{t-1}]^T + \ldots + a_n [R_{t-n}, T_{t-n}, H_{t-n}]^T \]  

(1)

Fig. 3 Lock position adjustment amount

![Fig. 3 Lock position adjustment amount](image)

Fig. 4 Method for predicting the lock position variation

\[ a_0 : \text{parameter}, R_t : \text{lock position at } k \text{ time}, \]
\[ T_t : \text{temperature at } k \text{ time}, H_t : \text{humidity at } k \text{ time} \]

This method can calculate predicted lock position values for the next day, which means that the lock position can be adjusted during track working hours. In turn, this should avoid alarms being raised, and thus prevent the need to go onto the track to move the lock position during train operating hours. It should be noted that accuracy of the prediction of the lock position is affected by accuracy of the weather forecast.

3.3 Consideration of the explanatory variables of the proposed method

Under the method described in the previous section, lock positions are predicted for the next day using data stored in the lock positions, temperature and humidity. However, rail temperature also needs to be taken into account since it also strongly influences lock position. Therefore, in the modeling of the lock position movement, it is necessary to select explanatory variables that reflect rail temperature. Below are the results of attempts to see if rail temperature can be adequately determined with meteorological data.

In general, it is not desirable to select two variables which have a high correlation with each other as explanatory variables. It was decided therefore to first of all confirm the correlation between meteorological data and rail temperature.

First, the following items were measured.

Measurement location: Maintenance depot (Fig. 5),
Measured data: Rail temperature, temperature and humidity in the hut, temperature, humidity, and solar radiation amount on the roof,
Measurement interval: 10 minutes,
Measurement period: July 19, 2013 - November 6, 2013

In addition to the above measurements, temperature and humidity data were used from the Japan Meteorological Agency (JMA) observed at a meteorological station about 7 kilometers away from the measurement location.
The correlation between meteorological data and rail temperature was confirmed. Table 1 shows the correlation coefficient between rail temperature and the data. A high correlation was confirmed between rail temperature and temperature. Therefore, rail temperature and temperature cannot be used as explanatory variables.

Next, it was verified whether temperature or humidity could be used as an alternative to rail temperature. A single regression analysis was made of weather data with rail temperature as the objective variable. Table 2 shows the resulting determination coefficient which indicates the high contribution rate of temperature. This signifies that rail temperature can be estimated to a high degree of accuracy by using temperature.

Based on the above results, the use of temperature as an explanatory variable in the lock position prediction method was considered to be appropriate. However, it is necessary to predict the temperature as input data under the prediction method described in the previous section. Therefore, it was necessary to measure the temperature and make a prediction in the vicinity of the prediction target equipment. In consideration of the availability and reliability of the prediction data of the JMA, it was considered reasonable to select JMA temperature data as the explanatory variable. Therefore, it is necessary to select temperature data from a JMA meteorological observatory near the electric point machine.

4. Consideration of supporting information on long term preventive maintenance planning

In order to reduce the number of alarms set off every day at electric points, it is not only necessary to adjust the lock positions on a daily basis, it is also important to have effective monthly and yearly preventive maintenance plans. This chapter describes results of a study into how the acquired information can contribute to effective medium to long term maintenance planning.

4.1 Examination of supporting information necessary for long term preventive maintenance plans

To formulate a proper maintenance plan, it is necessary to determine when and how often to perform lock position adjustment. Figure 6 represents an example of the information used to determine when to perform lock position adjustment. The lock position should be adjusted before the center of the variation in the lock position reaches the alarm threshold. Furthermore, early action is encouraged by giving a fluctuation range, which should increase maintenance efficacy. Figure 7 shows an example of the type of information used to how often the lock position needs to be adjusted. The example shows action to be taken on a monthly basis. Figure 7 shows that the lock position on electric point machine B tends vary more than on electric point machine A. This means that in the maintenance plan, electric point machine B requires special attention. For point machines which show significant variation, it is possible to apply specific measures such as the increasing frequency of lock position adjustments. The proposed method therefore shows that it is possible to determine the frequency of lock adjustment by using predicted lock position movement values, and that it is possible to use these values to time and plan maintenance more efficiently.
4.2 Trend analysis of the long term variation in lock position

The prediction method uses temperature and humidity data and given the importance of weather forecasting accuracy on the result the method can only be applied for predictions over a few days. This section discusses a method to assist long term preventive maintenance planning, considered in the previous section.

Detecting long term trends in lock position variation requires lock position data over a long period. It is important when processing the data accumulated over a certain amount of time, to take into consideration lock adjustments which were made over the same period. Before explaining the method used to determine long term lock position trends, the section below first describes how input data was handled.

The lock position data under consideration includes artificial variations due to adjustment work. These variations must be removed in order to get a clearer picture of the trend in lock position movement. One way to eliminate manual adjustments of the lock position from the data could be to use work records. However, many of these are paper based, and inputting this data into the system manually would be too time-consuming. This led to the idea of finding a way to eliminate data automatically using only the lock position data. The dotted line in Fig. 8 (a) shows the night-work time zone. The lock position of the electric point machine changed over 10 times during the night shift period. Based on the fact that this variation in lock position occurred during this night period, it was considered that these movements showed that the lock position was being adjusted. Once this was established however, it was difficult to know by how much the lock position had been displaced on these occasions. To solve this problem, data for the first lock positions detected after adjustment were matched with the data of the last known detected lock positions before adjustment (Fig 8 (b)). This translation seems to be reasonable judging from the fact that on days when no lock position adjustment work is done there is only a small change in data collected during the night periods.

The blue solid line in Fig. 9 shows two-months of data for July and August, processed according to the method described above. The trend in lock position variation differs between July and August. Below is an explanation of how to use these trends in lock position variation for monthly maintenance planning. The method involves looking at the trend from a monthly point of view, and from the point of view of average behavior on a particular data in the month.

First, the movement trend is examined across one month. Average values were examined, representing movement characteristics in a day. Figure 9 shows the trend in average values. In Fig. 9, the standard deviation (σ) was used to represent the mean ± 2σ as the variation width. As described above, the variation range is used as the indicator to show when the lock position needs to be adjusted. Then variation over one day in the month is examined based on the mean values. Figure 10 shows the trend in monthly averages. In this example, it is clear that variation of the lock position on this point is greater in August than in July. This information can therefore be used to plan maintenance more efficiently.

![Fig. 7 Monthly average variation of the lock position](image)

![Fig. 8 Influence of removal of lock adjustment data](image)
5. Visualization system for predicting locked position variation

It was considered that being able to visualize predicted values obtained with the method described in Chapter 3 would be useful to gain a rough idea of lock position adjustment. To this end, a system was designed to view lock position movement forecasts. Figure 11 shows an example of the system’s screen display. In order to be able to compare predicted and observed values, both are indicated on the screen. Data on lock position, temperature and humidity for the day leading up to the target day are also indicated on the screen so that the user can check if the data is correct or not by comparing data for two consecutive days, because the output of the prediction model is not always correct. Future work on this system aims to improve the method, and modify the user interface to suit user needs.

6. Conclusions

This paper describes a method for predicting locked position variation on electric points, utilizing data stored in lock-monitoring devices and long term lock position fluctuations. It was shown that it is possible to determine by what margin the lock position was adjusted, by predicting variation of the locked position, thus making allowing information to be provided to support maintenance work, such as frequency of lock position adjustment required by obtaining and examining long term variations. In addition, a system was designed to visualize the electric point ma...
chine incorporating the abovementioned lock position prediction method. Future work aims to improve the method itself and the user interface in the system for visualizing its output.

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