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Detection of high friction coefficient among sharp curves using monitoring bogie in service operation

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Abstract

When the friction coefficient of leading outside wheel of the bogie is high, it results in severe wear of flange. Therefore, the value of the friction coefficient should be well monitored in service operation. A new monitoring bogie which can measure lateral, vertical and tangential forces between wheel and rail has been developed and been introduced in some commercial lines of Tokyo Metro Company. This paper presents actual application of the estimation method of the friction coefficient between flange and rail collected by the monitoring bogie running in service operation. Using the monitoring bogie and the estimation method, a problematic curve section in terms of high friction coefficient can be detected.

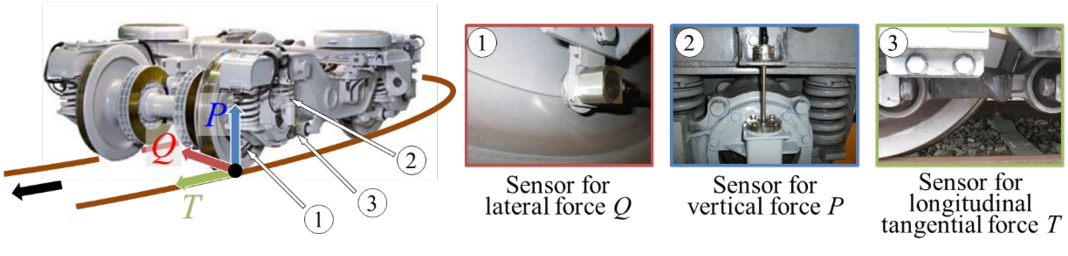
Keywords: bogie, condition monitoring, friction coefficient, curve, wear.

1 Introduction

When railway vehicles pass through sharp curves, there are some problems such as noise, corrugation on railhead and wheel/rail severe wear. On top of that, flange-climb probability should be well evaluated for sharp curves in terms of lateral and vertical forces of leading wheelset of a bogie. As for these problems, the friction coefficient between wheels and rails play important roll. When the friction coefficient of leading outside wheel of the bogie, hereafter denoted as $\mu_{1\mathrm{out}}$, is high, it results in severe wear of flange requiring frequent grinding of wheels. Therefore, the value of the friction coefficient should be well monitored in service operation. In general, the value of the friction coefficient is difficult to be measured during service operation. A new monitoring bogie which can measure lateral, vertical and tangential forces between wheel and rail has been developed and been introduced in some commercial lines of Tokyo Metro Company. Condition monitoring of the derailment coefficient has been carried out and largescale data for all curves on the line has been collected in years. Using collected data with the monitoring bogie, the estimation method of $\mu_{1\mathrm{out}}$ on certain curves has been proposed in previous works of our research team. This paper presents actual application of the estimation method of $\mu_{1\mathrm{out}}$ collected by the monitoring bogie running on service operation. Using the monitoring bogie and the estimation method of $\mu_{1\mathrm{out}}$, a problematic curve section in terms of high friction coefficient can be detected. After the detection for such curves, countermeasures using onsite lubrication devices can be considered.

2 Methods

Figure 1 shows the monitoring bogie which has magneto strictive displacement sensors for vertical force P measurement, non-contact gap sensors for lateral force Q measurement, and strain gauges attached to mono-links for tangential force T measurement [1,2]. Figure 2 shows definition of symbols: $Q_{1\mathrm{out}}/P_{1\mathrm{out}}$ in leading-outside wheel is the derailment coefficient, $Q_{1\mathrm{in}}/P_{1\mathrm{in}}$ in leading-inside wheel is called κ which is almost equivalent to the friction coefficient of the inside wheel when the vehicle runs on sharp curves. In this paper, T_1 indicates the average of the longitudinal tangential force of leading wheelset. $T_{1\mathrm{out}}$ and $T_{1\mathrm{in}}$ acting on inside and outside wheels respectively. The longitudinal force is closely related to the friction coefficient [3,4].



Sensor for lateral force Q

Sensor for vertical force P

Sensor for longitudinal tangential force T

Figure 1: Monitoring bogie for wheel/rail contact forces.

As shown in the Figure 2, if the value of κ is almost constant, small value of $\mu_{1\mathrm{out}}$ shows small T_1 and large $\mu_{1\mathrm{out}}$ shows large T_1 since the value of T_1 represents steering moment of the leading wheelset. In order to grasp relationships between the friction coefficient and contact forces, multi-body dynamics simulations are carried out and look-up tables for the estimation of $\mu_{1\mathrm{out}}$ are established in previous works.

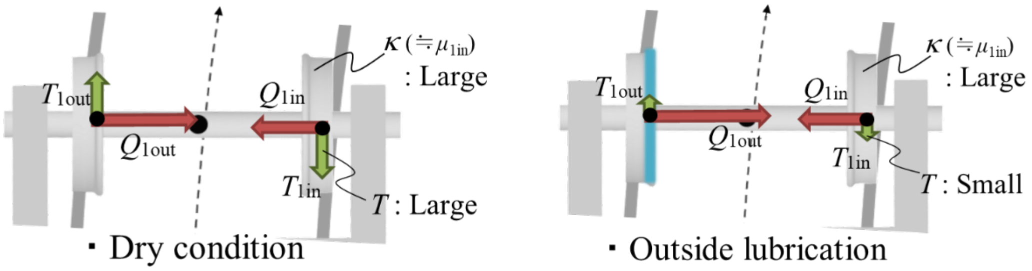


Figure 2: Relationship between friction coefficient of outside wheel and steering moment.

Figure 3 shows the flow of the estimation using regression model with multiple look-up tables. It is possible to estimate the value of $\mu_{1\mathrm{out}}$ from κ and $T_1/P_{1\mathrm{in}}$, which can be measured by the monitoring bogie. Note that the estimation of dynamical change of $\mu_{1\mathrm{out}}$ is difficult since the value of measured κ and $T_1/P_{1\mathrm{in}}$ are both affected by track irregularities. Therefore, averaged value of $\mu_{1\mathrm{out}}$ can be calculated and used in the actual application.

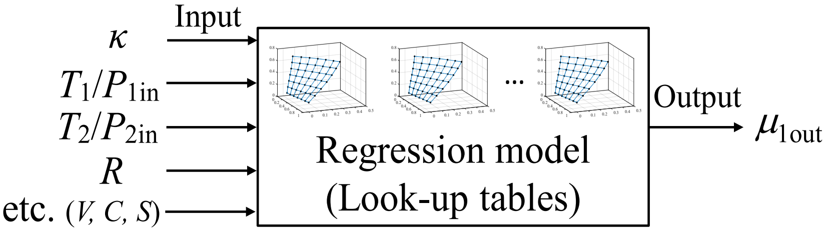
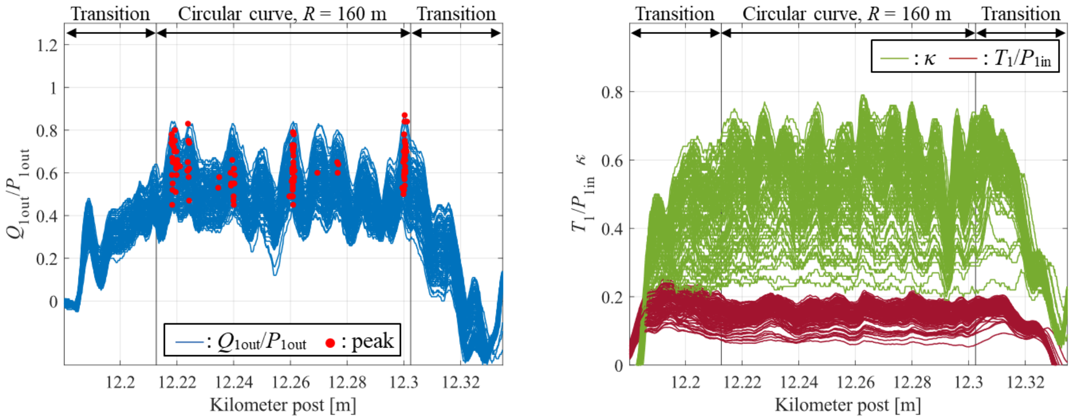


Figure 3: Flow of analysis for the friction coefficient estimation.

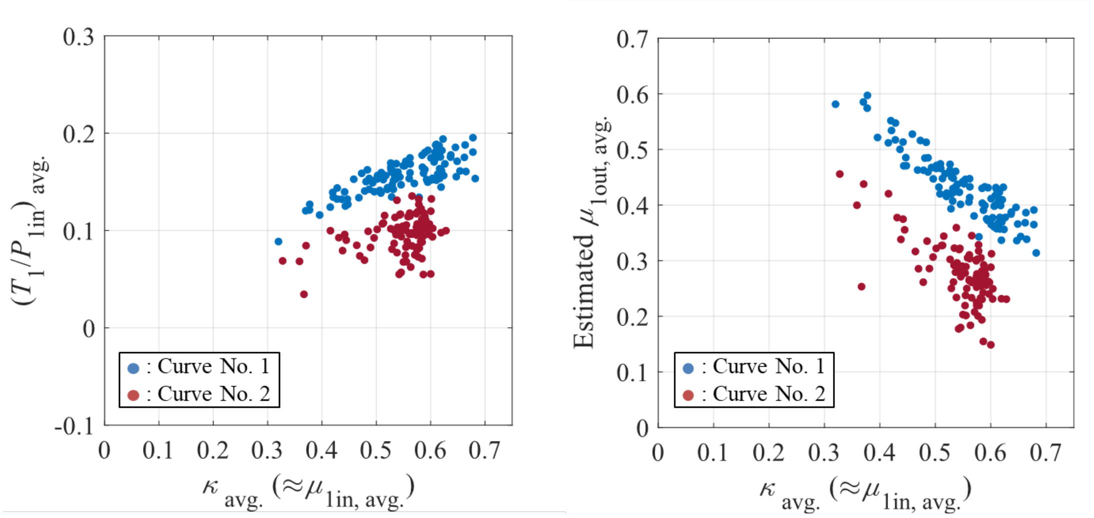
3 Results

Figure 4 shows an example of sharp curve whose radius of circular curve is 160m. The figure shows derailment coefficient $Q_{1\mathrm{out}}/P_{1\mathrm{out}}$, κ and $T_1/P_{1\mathrm{in}}$. As shown in the figure, each measured value changes in every running due to the variation of friction coefficient because the track is affected by onsite lubrication. Using these data shown in Figure 4, the averaged value of each data in circular curve are extracted for the comparison of friction coefficient. Figure 5(a) shows averaged value of $T_1/P_{1\mathrm{in}}$ vs. κ. Figure 5(b) shows averaged value of $\mu_{1\mathrm{out}}$ estimated by the regression model. In this example, two similar curves No.1 and No.2 are compared. In both examples, the value of κ is chosen over 0.3 since the case of low κ is not problematic and the estimation of $\mu_{1\mathrm{out}}$ is sensitive when the value of κ is small. As a result, the curve No.1 has a tendency of becoming high value of $T_1/P_{1\mathrm{in}}$ and it results in larger value of $\mu_{1\mathrm{out}}$. As shown in the figure(b), even though the curve No.1 and No.2 are same in geometry, the characteristics in friction coefficient are different. From these results, a certain curved track with high friction coefficient which contributes to wheel flange wear can be detected. After the detection such a curve, countermeasures of onsite lubrication can be considered as a typical method to prevent wheel flange and rail wear.



(a) Derailment coefficient (b) κ and $T_1/P_{1\text{in}}$

Figure 4: Examples of contact forces collected by monitoring bogie.



(a) Averaged value of κ and $T_1/P_{1\text{in}}$ for two curves (b) Estimated value of averaged $\mu_{1\text{out}}$

Figure 5: Comparison results for two different sharp curves with similar circular curve.

4 Conclusions and Contributions

This paper presents an actual data analysis application for the estimation of the friction coefficient between wheel and rail using the monitoring bogie. Based on the estimation method and the data collected with a monitoring bogie in service operation, high friction coefficient curve resulting severe wheel and rail wear can be detected. After the detection such curves, countermeasures of onsite lubrication can be considered as a typical method to prevent wheel flange and rail wear.

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