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A study on prediction of track buckling using measured lateral alignment

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Abstract

Prediction of track buckling based on the estimated lateral alignment is attempted for a numerical track model. To achieve this, the lateral alignment is estimated from 10m- or 5m-chord versine data. The buckling temperature and its location obtained from a buckling analysis with the estimated alignment are then compared with the correct values. Through numerical experiments, applicability of the 10m- and 5m-chord versine data is investigated. Moreover, the present buckling prediction is also applied to track irregularity after the realignment which is made in accordance with a 10m-chord versine criterion.

Keywords: lateral alignment, 10m-chord versine, buckling behaviour, numerical analysis

1 Introduction

Track buckling is one of inherent risks of continuous welded rail (CWR) tracks. In order to prevent this unwonted incident, constant maintenance of track conditions such as rail relative temperature, lateral alignment and track lateral resistance is important. In general, these conditions have some uncertainties. Therefore, it will be desired to assess the track buckling safety based on the probabilistic approaches [1]. In particular, the buckling temperature is very sensitive to the initial misalignment, which can be modelled as a random irregularity. In [2], [3] and [4], for Japanese ballasted tracks, the influence of the probabilistic characteristics of the initial lateral alignment and the track lateral resistance on the probability of buckling strength was discussed through the Monte Carlo Simulation. From these studies, it was found that the buckling probability is sensitive not only to the standard deviation of lateral alignment but also to its autocorrelation.

Currently, it is difficult to identify the track conditions precisely. Therefore, the probabilistic assessment can be a rational solution. However, if it becomes possible to estimate the spatial distribution of track conditions, the track buckling will be predictable deterministically by the aid of numerical simulation. Although any efficient estimation methods are not yet established for the rail neutral temperature and track lateral resistance, the lateral alignment can be measured with high accuracy and high spatial density by means of an equipment mounted on an in-service vehicle [5].

In this study, possibility of buckling prediction based on measurement data which is obtained for the lateral alignment is discussed. For the sake of simplicity, the rail relative temperature and track lateral resistance are set as deterministic values, namely only lateral alignment is treated as an unknown value. The lateral alignment is identified from 10m- or 5m-chord versine measurement data. The buckling temperature and its location obtained from the buckling simulation with the estimated lateral irregularity are then compared with the correct values. Through numerical experiments, validity of the 10m- and 5m-chord versine data is investigated. Furthermore, the buckling prediction analysis is applied to lateral irregularities after the realignment which is made in accordance with a 10m-chord versine criterion.

2 Methods

In Japan, 10m-chord versine data is obtained by the measurement [5]. Therefore, in order to simulate the track buckling, it is needed to reproduce the geometrical configuration from the observed versine data. The numerical experiments are thus conducted in accordance with the following procedure,

(1) Generation of random data as original lateral alignments using the K-L expansion
(2) Transformation of the original geometrical data to the 10m- or 5m-chord versine data with noise (It is used as a virtual measurement data.)
(3) Estimation of the original alignment from the virtual measurement data (Inversion of the original alignment)
(4) Buckling analysis using the original and estimated lateral alignment data
(5) Comparison the buckling temperature and the location of occurrence obtained from the estimated alignment with correct values

The 10m-chord versine data loses sensitivity at wave length of around 5m. This wave length may be comparable to that of the buckling mode at the bifurcation point of perfect system. From this fact, it is a concern that the accuracy of buckling prediction might be reduced. Therefore, through numerical experiments, influence of the chord length on the prediction accuracy of buckling temperature and location is investigated.

In Japan, realignment is achieved based on a 10m-chord versine criterion. It will alter the statistical properties such as the standard deviation and the autocorrelation of original geometrical configuration. Because of this, the buckling strength will also be different from that for the original alignment. Therefore, the similar numerical experiment is conducted with lateral irregularities after the realignment. To simulate this process, a realignment procedure developed in [4] is applied to the numerical track model.

3 Results

A CWR tangent track consisting of Japanese 50kgN rails and sleepers is modelled for the buckling simulation. The initial lateral alignment is generated based on the following autocorrelation,

$$R(x) = \sigma^2 e^{-(x/d)^2}, \tag{1}$$

where, σ^2 is the variance of random irregularity and d is a parameter of length. In this analysis, the variance is 5mm and d is 1.7m. Random initial alignments are then calculated by means of the K-L expansion. The buckling analysis is achieved for 100 tracks with both cases of the original alignments and the estimated irregularities identified from the 10m- or 5m-chord versine data.

Figure 1 shows the relationship between the correct and predicted values of buckling temperature, while Figure 2 shows the relationship between the correct and predicted locations of buckling occurrence. In these figures rather large scattering of predicted values is observed for 10m-chord versine data. From these results, it can be found that 5m chord length is suitable to the buckling prediction.

Similar results have been obtained for the buckling prediction after the realignment, that is, the buckling analysis with alignment estimated from 5m-chord versine data enables the buckling prediction with good accuracy.

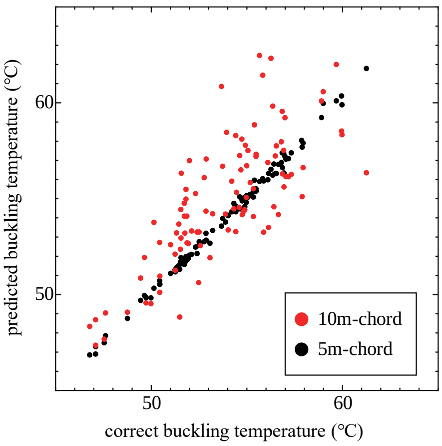

Figure 1 Prediction of buckling temperature.

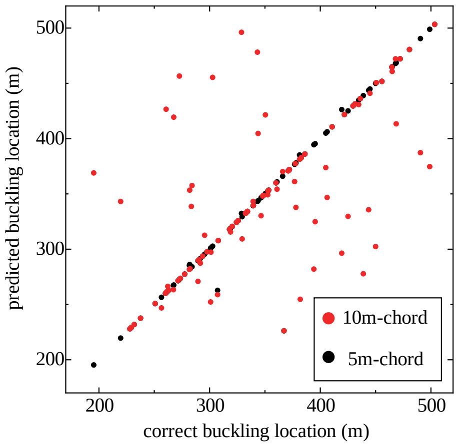

Figure 2 Prediction of buckling location.

4 Conclusions and Contributions

Prediction of track buckling based on the lateral alignment estimated from measured versine data is attempted for a numerical track model. In the current measurement method developed in Japan, 10m-chord versine data is usually obtained as the track irregularity. The 10m-chord versine cannot gain waveform components around 5m length. However, the components of about 5m wave length is important in the context of the buckling behaviour. Therefore, the lateral alignment estimated from this measurement loses information which is essential to simulate the track buckling. To cope with this inexpedience, employment of 5m-chord versine was attempted. Through numerical buckling experiments, efficiency of the 5m-chord versine has been evidenced. Furthermore, the buckling prediction by numerical analysis has been applied to irregularities after the realignment which is achieved based on a 10m-chord versine criterion. It was concluded that 5m chord length is suitable to the buckling prediction for both before and after the realignment.

In this study only the estimation of the track lateral alignment has been considered in the context of the buckling prediction. Influence of the accuracy and spatial resolution of estimation of the neutral temperature and track lateral resistance on the prediction of track buckling need to be clarified in the future.

Acknowledgements

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