NUMERICAL STUDY OF CORRELATION BETWEEN RAIL VIBRATION AND WEAR

The University of Tokyo, Student Member ○ Shi Ru Teng
The University of Tokyo, Regular Member Di Su

1. INTRODUCTION

Steel rail wear has been affecting the railway performance and increasing the maintenance costs of tracks. It also leads to several issues such as reducing traffic safety, shortening of the operational life of the rail and affects the comfort of passengers. One of the factors leading to rail corrugation wear is the wheel-rail vibration (Xiao et al, 2018). Track stiffness variation is another factor affecting the railway performance (Dahlberg, 2010). The response of the rail is highly dependent upon the track stiffness. Consequently, a plastic or rubber pad separating the rail and sleeper, as a countermeasure of environmental vibration, provides resilience and damping in the system (Carlberger, 2016). Furthermore, the track stiffness irregularities will also cause vibrations in the train and the track (Dahlberg, 2010). Therefore, the objective of this study is to obtain the correlation between rail vibration and wear by using a suitable wear model and different rail flexibility.

2. METHODLOGY

The modelling is done in SIMPACK, which the train car is represented with a cuboid of mass 25600kg as shown in Fig. 1. The car is mounted on two bogies by suspension which each bogie holds two wheelsets also by suspension in a multibody system. The simulation settings applied are velocity of 25m/s, time of 40s, and sampling frequency at 100Hz.

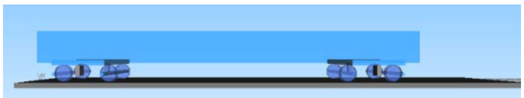

Fig. 1 Model in SIMPACK

For the modelling of the track, the rail can be modelled using either a rigid body or a flexible body with the FlexTrack module. For this module, importing the finite element model from ABAQUS is necessary, which specific nodes will be retained in SIMPACK to model the rail. Both Non-linear FlexTrack and Linear FlexTrack can be utilised, but the non-linear method is more accurate and considers non-proportional damping. In addition, the linear method only considers normal modes in a selected frequency range while non-linear method considers the track component bodies as described by the finite element substructure from the reduced elements, thereby considering the full properties of the structure. However, more time is needed for the non-linear method. Hence, the linear method is used and with sufficient modes within a targeted frequency range adopted, it should achieve the intended results at a relatively high accuracy. A flat steel cuboid is modelled to represent the flexible rails. Other components such as rail pads and sleepers are not modelled.

A case without irregularity and with rail irregularity will be implemented for both the rigid rail and the flexible rail. The rail irregularity is randomly generated from the power spectrum density (PSD) as specified by the Federal Railroad Administration (FRA)and modelled as excitation input on the assumption that the track condition is poor level.

The Archard's wear model (Carlberger, 2016) is applied to obtain the worn volume, V_{wear} as shown in Eq. (1).

$$V_{wear} = k\frac{Ns}{H} \qquad (1)$$

where, *s* is the sliding distance, *N* the normal force, *H* the hardness constant of the worn material and *k* the wear constant.

Thereafter, the wheel profile wear results element is used to calculate the wear of each wheel while the rail profile wear sum results element sums up the individual rail profile wear of multiple wheel profile wear results elements to obtain the total rail wear and worn rail profile.

3. RESULTS AND DISCUSSIONS

The total worn material volume for the rail profiles over the entire simulation run in each case are shown in Fig. 2 to Fig. 4, which the denotations for the wheel for wear are, F as front, B as back, L as left and R as right. For the left rails, the horizontal axis is positive taken from the centre of the rail at the cross section outwards while for the right rails, it is negative as the wear occurs on the inner side. Fig. 1 shows the rail wear with flexible rail and rail irregularity while Fig. 2 shows the rail wear without rail irregularity. Fig. 3 shows the rail wear with rigid rail and rail irregularity.

The worn volume for the model without rail irregularity is much smaller generally as shown from the difference between Fig. 2 and Fig. 3. The profiles between the left rail and right rail in Fig. 2 is similar, hence, if no external factors are considered, symmetry on the track can be assumed. However, there is a difference in worn volume is also observed for the front and rear bogie, which may be due to the different values of forces encountered at each point of the element. For Fig. 3, the trends in the graphs are less distinct as compared to the graphs in Fig. 2, but the peaks on the left rail are slightly different for each wheel while the peaks for the right rail are more consistent at the same point. This might be due to the different irregularity being applied on each side due to the randomness of the PSD. This can be compared with Fig. 4, which the trend is also different for both the left and right rail. However, due to the rigidity of the rail, the values are lower, and the wheel profiles seem more consistent in Fig. 4 as compared to those in Fig. 3.

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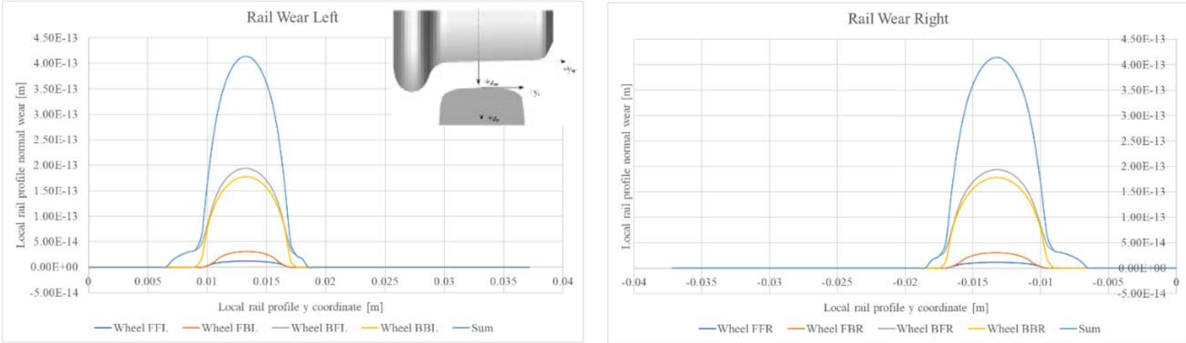
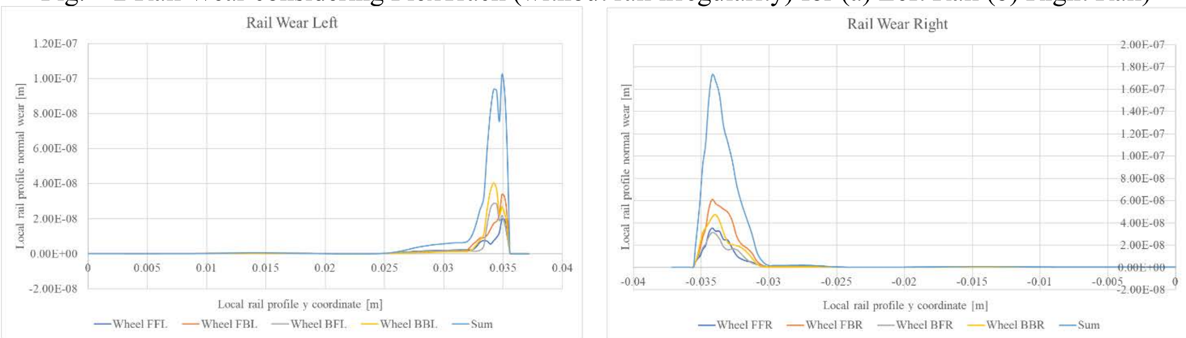
Contact address: Faculty of Engineering Bldg. #1 /, Hongo Campus, The Univ. of Tokyo
7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656 JAPAN TEL: +81-3-5841-6084



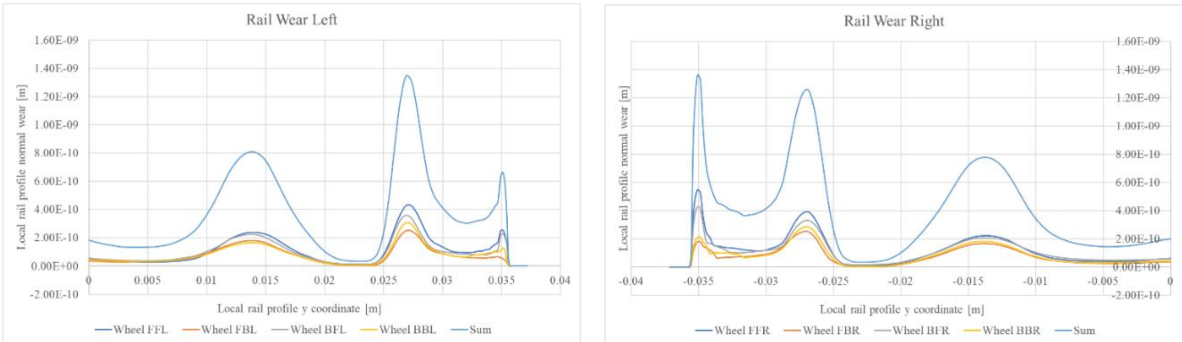
(a) (b)

Fig. 2 Rail Wear considering FlexTrack (without rail irregularity) for (a) Left Rail (b) Right Rail)



(a) (b)

Fig. 3 Rail Wear considering FlexTrack (with rail irregularity) for (a) Left Rail (b) Right Rail)



(a) (b)

Fig. 4 Rail Wear considering rigid track (with rail irregularity) for (a) Left Rail (b) Right Rail)

4. CONCLUSIONS

This study leads to a conclusion that the rail irregularity causes a huge increase in worn volume at both the wheel and the rail, and hence, the effect due to the shape of the rail may be neglected. In addition, as shown from the results, the flexibility of the rail significantly influenced the wear volume. However, more comparisons need to be done to check the effects due to other factors such as velocity and rail pad stiffnesses, etc. The rail irregularity will also have to be varied further with other degrees of randomness to check the impact on the results as well. As the model is only done for one loop, a longer simulation time and distance is required as part of the process for profile updating. Other than that, there is also a need to validate the results with site data to ensure the accuracy. With these proposed improvements, a better correlation between vibration and wear may be obtained in the future.

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