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Evaluation of Field Calibration Test on Rail for Train Wheel Force Measurement

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Abstract

An accurate measurement of the train-track interaction forces is important for track performance evaluation. In the field calibration test as a wheel load measurement process, the calibration system creates a different boundary condition in comparison with that in the train wheel passage. This study aims to evaluate a reliability of the field calibration test in the process of wheel load measurement. Finite element models were developed to compare the deformed shapes, bending moment and shear force profiles on the rail section. The analysis results revealed that the deformed shapes and their associated bending moment profiles on the rail are significantly different in two numerical simulations of the calibration test and the train wheel load passage. However, the shear stress profile on the rail section of the strain gauge installation in the field was almost identical, which may imply that the current calibration test is sufficiently reliable.

Keywords: *Wheel load, rail, Strain gauge, Calibration factor, Train-track interaction force, Shear strain*

1. Introduction

The train-track interaction forces such as vertical wheel force, lateral force, and longitudinal force during train passage can be measured in many different ways. The accurate measurement of those interaction forces applied by the running train wheels on the rail is important for track performance evaluation [2, 4].

One common measurement method for vertical wheel force involves the shear strain measurement on the rail neutral axis in two rail sections. The calibration test in the field by using a hydraulic jack and its steel support is also conducted to identify a calibration factor between the applied vertical force and the measured rail shear strain by linear regression analysis. This paper aims to evaluate the field calibration test in the process of train wheel force measurement [3, 5].

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2. Measurement Method of Wheel Force

2.1 Measurement principle

The measurement procedure of wheel force is described as below. Strain gauges are first installed on the rail neutral axis with 45^o, eliminating the effect of bending moment, to measure the shear strains at two sections (see Fig. 1). Each section of strain gauge attachment is located 100-mm away from the rail center between two adjacent sleepers [2].

Fig. 2 shows the structural models and the associated shear force diagrams in order to explain the principle of wheel load measurement. When a point load (P) is applied between Sleeper 2 and section A, the resultant shear forces (V_A and V_B) on the two sections A and B are identical (see Fig. 2(a)). When the point load moves to a location

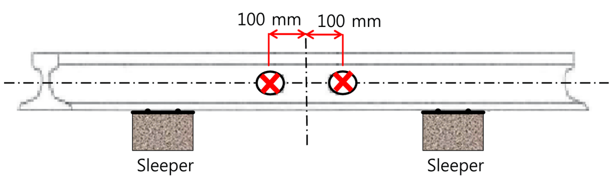
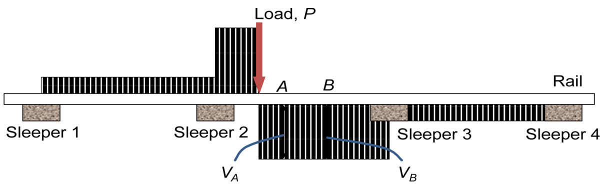
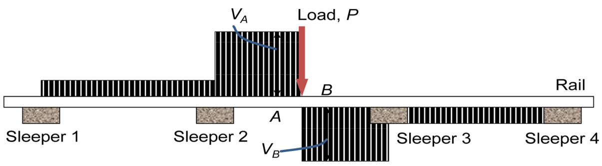


Fig. 1 Installation location of strain gauge



(a) Case 1 : Load between Sleeper 2 and Section *A*



(b) Case 2 : Load between Sections *A* and *B*

Fig. 2 Structural model and associated shear force diagram

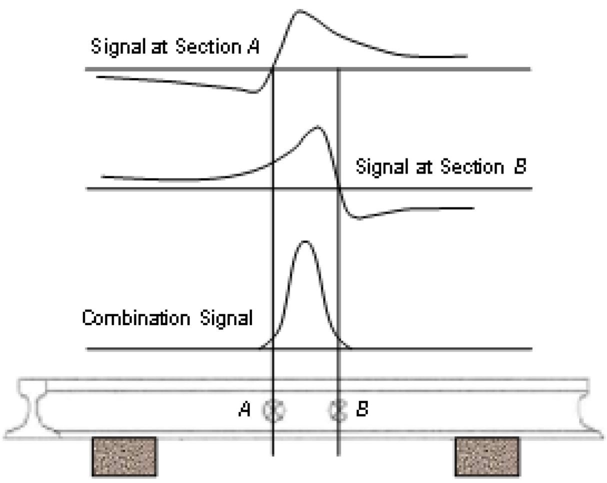
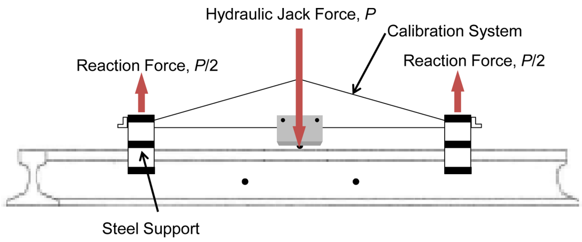


Fig. 3 Signals of measurement

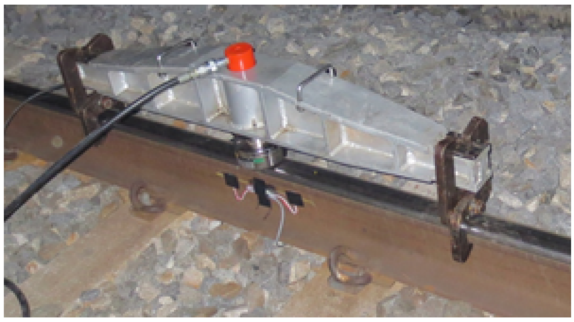
between the sections *A* and *B* (see Fig. 2(b)), the shear force difference (i.e., V_A - V_B) would be proportional to the applied load *P*. Therefore, from the measurement of shear force difference the applied vertical load can be calculated based on the resultant signals of measurement at the sections (see Fig. 3).

2.2 Field calibration test

In the field, a calibration test using a hydraulic jack and its steel support is conducted to calculate a calibration factor between the applied vertical force and the measured shear strain by linear regression analysis as well as for verification of the installed strain gauge performance. The applied jack force gradually increases by a level of 10 kN, and this loading procedure is usually repeated at least three times [2, 3].



(a) Schematic view



(b) Photo view

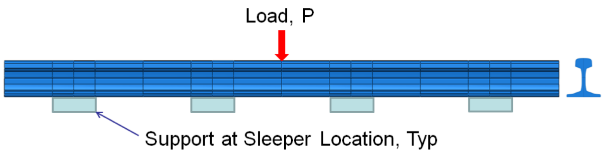
Fig. 4 Calibration test

Fig. 4 shows the schematic and photo views of the field calibration test. As can be seen, two steel supports at each end of the calibration system are used to stabilize the hydraulic jack. Fig. 4(a) shows the equilibrium condition during loading by the jack in the calibration test. As shown, the upward reaction force at each end should be developed to satisfy the self-equilibrium of the system. This boundary condition in the calibration test is different from that in the actual train wheel passage.

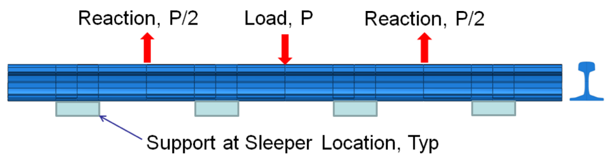
3. Finite Element Analysis

3.1 Model

As previously mentioned, the boundary conditions in the field calibration test and the actual train passage are different, which might have an effect on the shear strain measured on the rail web. Finite element models were developed to evaluate the accuracy of the calibration test for wheel load measurement. Fig. 5 shows the models using the finite element analysis software ABAQUS [1]. 2600-mm long UIC60 rail with four supports at the sleeper locations was modeled by using linear elastic 3-D solid elements. A Young's modulus of 200 GPa and a Poisson's ratio of 0.3 were assigned to the elastic material properties. The downward stiffness of 50 kN/mm at the sleeper support was assumed; the upward stiffness of the ballast track was neglected.

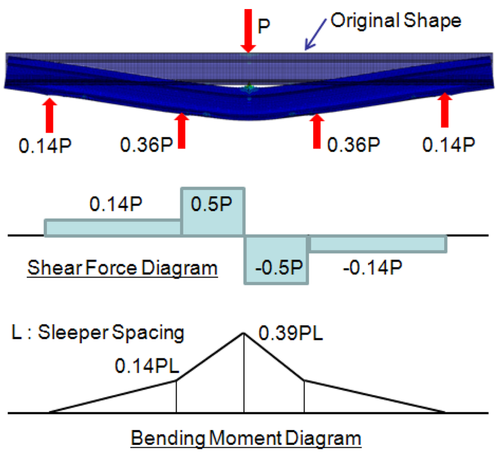


(a) Model 1

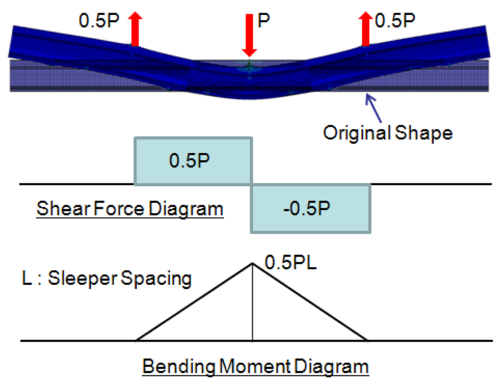


(b) Model 2

Fig. 5 Finite element models



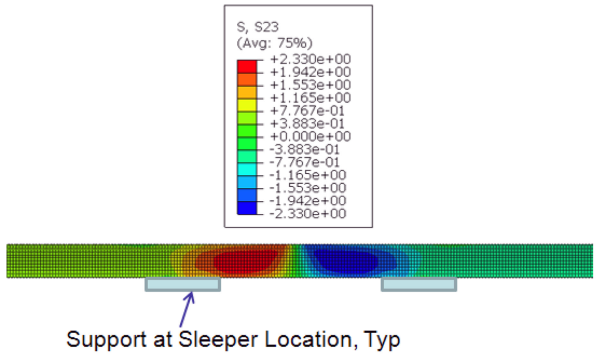
(a) Model 1



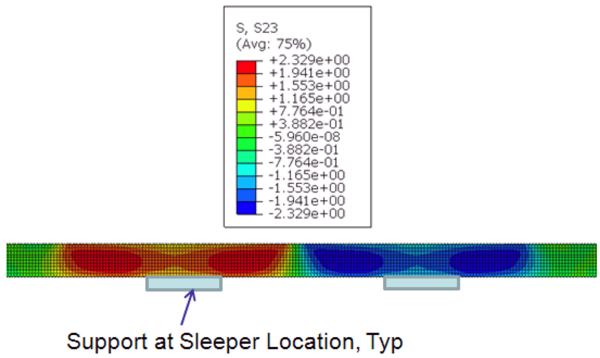
(b) Model 2

Fig. 6 Comparison of deformed shapes (amplification factor = 2,000) and shear force / bending moment diagrams

Two different finite element models, designated as Model 1 and Model 2, were developed for comparison purposes. Model 1, shown in Fig. 5(a), simulated the loading and boundary conditions during a train wheel passage in the field. A one-ton unit force was applied to the center of the rail between two adjacent sleeper supports. Model 2, shown in Fig. 5(b) simulated the loading and boundary conditions as used in the field calibration test using a hydraulic jack and its end supports. To simulate the self-equilibrium condition of the calibration system, a 0.5-ton reaction force was applied to each end support.



(a) Model 1



(b) Model 2

Fig. 7 Shear stress contours of rail web

3.2 Global response

Fig. 6 compares the global responses of Model 1 and Model 2. As can be seen in the figure, the deformed shapes are significantly different, particularly in bending. Based on the applied load and reactions, the shear and bending moment diagrams are also compared in Fig. 6. As shown, although the bending moment distribution along the rail between Model 1 and Model 2 are significantly different, the shear force (0.5P) of the rail section between the two middle sleepers is identical in the two models.

3.3 Comparison of shear stresses

As previously mentioned, the field calibration test for wheel load measurement purpose involves the shear strain measurement on the rail section at a distance of 100 mm from the rail center. To further evaluate the shear stress distribution at the measurement section where the strain gauges are installed in the field, Fig. 7 compares the shear stress contours along the rail web. As shown, the shear stress distribution in Model 1 and Model 2 are almost identical. This may indicate that the calibration test, commonly used in the field for wheel load measurement purpose, is sufficiently accurate without any significant boundary effects.

4. Conclusion

The field calibration test on rail for train wheel load measurement purpose was studied to evaluate any boundary effect on the shear strain profile of the rail web. Finite element models were developed to compare the shear stress profiles on the rail for this study. The analysis results revealed that the deformed shapes and their associated bending moment profiles on the rail section are significantly different in the two numerical simulations of the calibration test and the train wheel load passage. However, the shear stress profile on the rail section at the strain gauge installation in the field was almost identical, which may imply that the current calibration test in the field is sufficiently reliable. In the future, a similar study may be needed to evaluate any boundary effect on the shear stresses for lateral force measurement purpose.

Acknowledgments

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