Vol. 5, No. 1, pp. 1-4, June 2006

INTERNATIONAL
JOURNAL OF SAFETY
www.kosos.or.kr

The Effect of Train Motion on Current Collection in High-speed Train

Jung Soo Kim*

Department of Mechanical & System Design Engineering, Hongik University
Seoul 121-791, Korea

(Received January 3, 2006; Accepted June 12, 2006)

Abstract : The safety performance of the current collection system is evaluated by conducting a test run in which accelerometer and load cell signals are analyzed. It has been found that the current collection performance is strongly influenced by the train speed, with the major frequency components arising from the train traversing the span spacing and the 8.5 Hz component originating from the panhead resonance. The train acceleration is found to have significant influence on the span passing frequency but negligible effect on the resonant response.

Key words : catenary, current collection, high speed train, pantograph, safe performance

1. Introduction

The current collection system provides the required electrical power to the train. In recent past, failure in the current collection has been a major source of train stoppage; its reliability is therefore crucial to the operational safety of the train. Two major elements of the current collection system are the catenary and the pantograph. The catenary is an overhead structure that supplies electrical energy. The pantograph transmits electrical power from the catenary to the train and must remain in physical contact with the catenary during train operation. As the train speed increases, increased fluctuation of the pantograph can adversely affect the contact between the catenary and pantograph, resulting in current collection failure. The main purpose of the present paper is to experimentally determine the relationship between the train motion and such failure.

Mathematical models and numerical simulations have been developed to analyze the response of the current collection system[1]. Apart from calculations based on simulations, experiments utilizing scale-down models can also give a more direct insight[2]. These approaches have yielded useful insights but they are limited by modeling simplifications. Thus, actual experimental tests are required to verify mathematical modeling, simulation, and scaled model. The train speed has already been established as the major factor in the current collection performance [3-5]. The effect of the train acceleration has not yet been reported, and the present work is the first to report on possible correlation between the train acceleration and current collection performance.

*Corresponding author: jungsoo@hongik.ac.kr

2. Test Run Measurement

The overall structure of the catenary is shown in Figure 1. The electrical current is supplied to the train through the contact wire connected to the messenger wire by hangers. The hangers serve to transmit the weight of the contact wire onto the messenger wire.

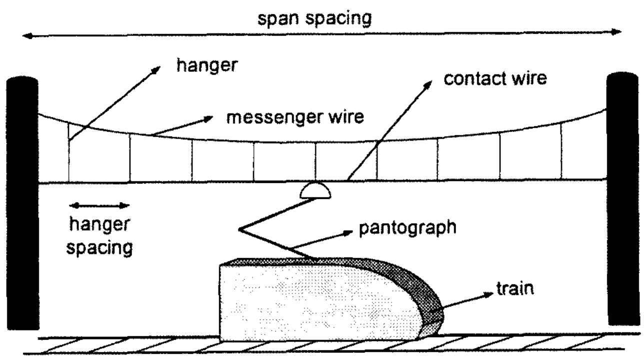

Fig. 1. Current collection in train.

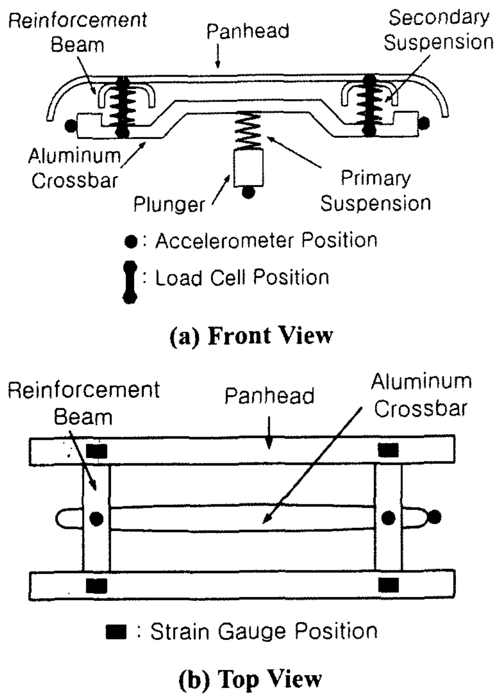

Fig. 2. Test measurement.

The steady arms are used to provide lateral adjustment needed to protect the panhead from localized wear by moving the catenary sideways.

Figures 2(a) and 2(b) describe the position of the sensors attached to the pantograph assembly during the test run. To measure the movement of the panhead that acts as contact points during current collection, two accelerometers are attached on top of the reinforcement beams that connect the front and rear panhead.

Figure 3 shows the accelerometer signal level as a function of the train speed. Since the mean value is zero only the deviation tends to increase as the train accelerates. The rate of the increase is roughly proportional to the square of the train speed. Thus, the pantograph undergoes substantially more vibration as the train gains speed.

3. Effect of Train Acceleration on Current Collection

Figure 4 shows the accelerometer signal at the train speed near 196 km/hr in the frequency domain. Several major frequency components can be observed. The first peak at 1.4 Hz is the span-passing frequency. The train speed is 196 km/hr and from the load cell data, the length of the span is found to be 40 m. The time elapsed for the train to traverse the span length is 0.73 seconds. Taking the inverse, the frequency is found to be 1.4 Hz. Also, higher harmonics of the span-passing frequency can be observed. These harmonics have the frequency of twice and three times the span-passing frequency and appear intermittently throughout the run. Since this component is the result of the interaction between the pantograph and the catenary, it is speed dependent. The span-passing frequency increases in direct proportion to the increase in the train speed.

A large peak observed at 8.5 Hz is due to the resonance of the panhead. Unlike the span-passing frequency component, this component is independent of the train speed. Previous numerical simulations corroborate this observation. Numerical simulation of the catenary and pantograph with a train speed of 200 km/hr has predicted that the resonant frequency at 8.5 Hz will be the

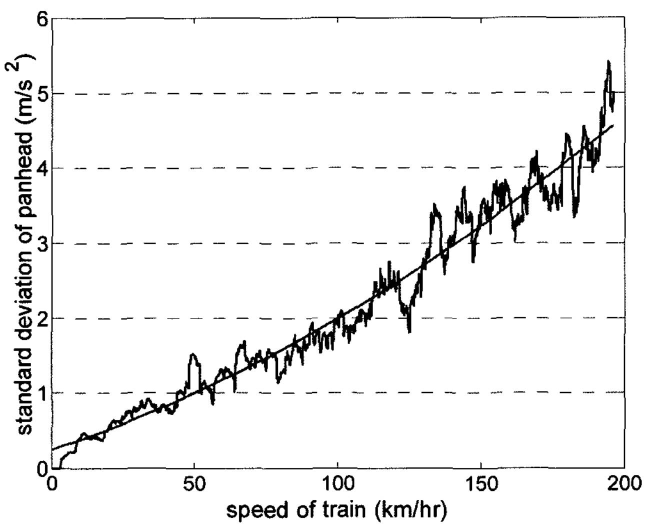

Fig. 3. Accelerometer level vs. train speed.

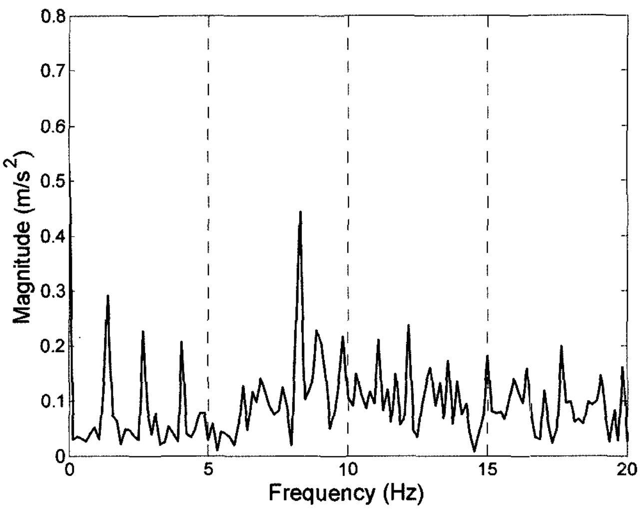

Fig. 4. Frequency components of panhead acceleration.

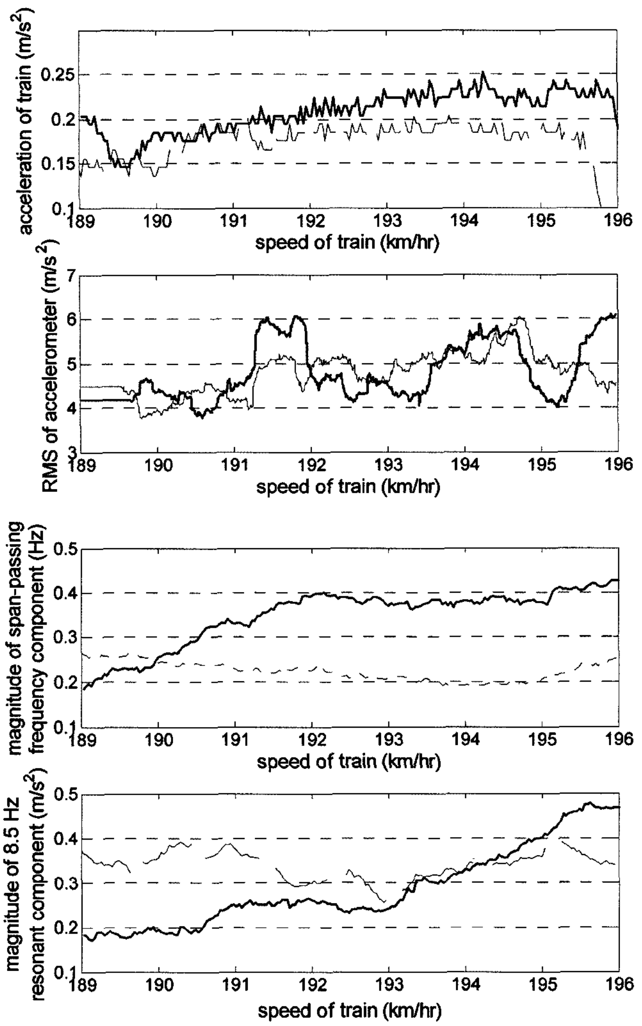

Fig. 5. Effect of train acceleration on accelerometer signal (a).

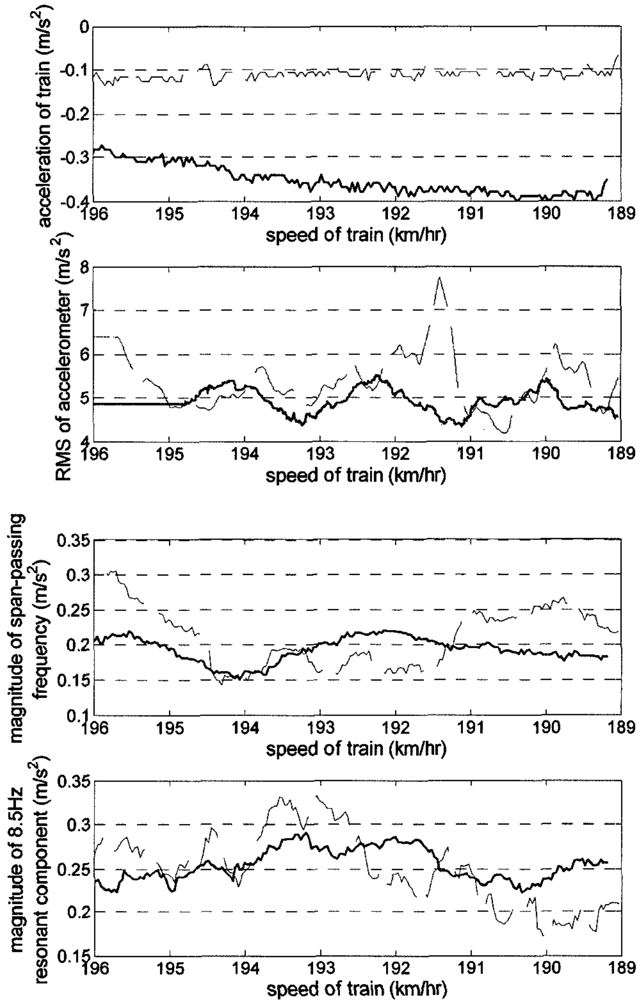

Fig. 6. Effect of train acceleration on accelerometer signal (b).

dominant component[3].

All previous investigations have focused on how high train speed affects the pantograph motion. We investigate here if the train's acceleration has any effect. The top graph of figure 5 shows two sections of the test run with the same 189 km/hr to 196 km/hr speed range but having different acceleration values. At a given train speed, the solid line sample has a higher train acceleration value than the dotted line sample. The next three graphs compare the resulting panhead acceleration signals; the root mean square values, the magnitude of the span-passing frequency component, and the magnitude of the 8.5 Hz resonant frequency component.

The span-passing frequency component is clearly influenced by the acceleration of the train. The sample with a higher train acceleration results in a higher magnitude of the span-passing frequency. However, the difference in the train acceleration has little or no effect on the 8.5 Hz resonant speed-independent component.

The top graph of Figure 6 shows two sections of the test run with the same 196 km/hr to 189 km/hr speed range but having different deceleration values. At a given train speed, the solid line sample has a higher train deceleration value than the dotted line sample. The next three graphs compare the resulting panhead acceleration signals; the root mean square values, the magnitude of the span-passing frequency, and the magnitude of the 8.5 Hz resonant frequency component. The difference in deceleration magnitude is much more distinct than the accelerating samples; the solid line having deceleration value almost three times that of the dotted line sample. However, unlike when the train is accelerating, the difference in deceleration has no visible effect in the magnitude of the span-passing frequency component.

Figure 7 shows the load cell signals from the accelerating train. The upper graph shows train acceleration and the lower graph depicts the magnitude of the span-

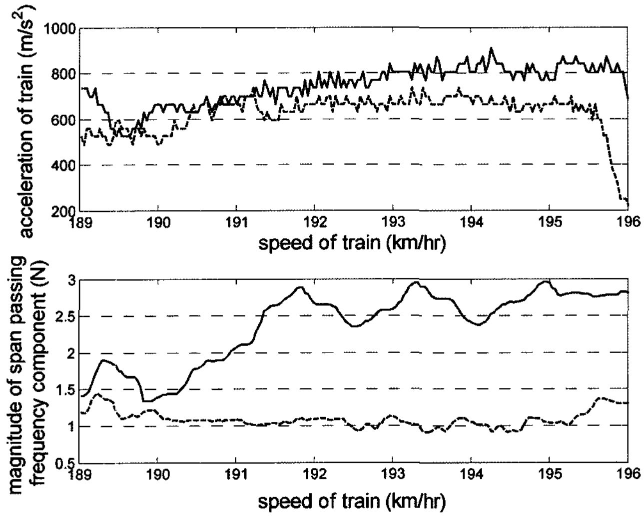

Fig. 7. Effect of train acceleration on load cell signal.

passing frequency. The magnitude of the span-passing frequency component is clearly being affected by the train acceleration and thus is higher when the train is accelerating at a higher rate. The observed dependence of the pantograph response on the train acceleration is surprising in that none of the previous works has even hinted at such dependence.

In all simulation and scale-down model investigations, the train speed is treated as a constant input variable. Although the results obtained so far are somewhat tentative, they warrant further investigation to more precisely determine the dependence of the current collection performance on the train acceleration.

4. Conclusions

Reliable performance of the current collection system is an important factor for safe operation of the high-speed train. Previous studies by the author have established that the train speed can influence the current collection performance. Frequency domain analysis of the accelerometers and the load cells has also isolated response components such as the span-passing and panhead resonance components.

In the present work, the train acceleration is found to be another important factor that determines the contact performance: The span-passing component is strongly influenced by the train acceleration, while the panhead resonant component is not.

Acknowledgment

This work was supported by 2006 Hongik University Research Fund.

References

[1] Y. S. Choi, D. H. Joung, "Numerical Analysis of Dynamic Response of Catenary/Pantograph System in High-Speed Train", SKKU J. of Science and Technology, Vol. 42, No. 2, pp. 377-390, 1991.

[2] T. A. Willetts, D. R. Edwards, "Dynamic-model studies of overhead equipment for electric railway traction", Proc. IEE., Vol. 133, No. 4, pp. 690-696, 1966.

[3] S. H. Park, J. S. Kim, S. Hur, J. H. Kyung, D. Song, "On Dynamic Characteristics of TGV-K Pantograph-Catenary System", Proc. of KSR, pp. 176-184, 1999.

[4] W. M. Kim, J. T. Kim, J. S. Kim, J. W. Lee, "A Numerical Study on Dynamic Characteristics of a Catenary", KSME Int. J., Vol. 17, No. 6, pp. 860-869, 2003,

[5] J. S. Kim, S. H. Park, "Dynamic Simulation of KTX Catenary System for Changing Design Parameter", J. KSNVE, Vol. 11, No. 2, pp. 346-353, 2001.