Real-Time Processing of Pantograph Contact Force Algorithm

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1. Introduction

The contact force between a pantograph and the contact wire largely represents the pantograph's dynamic behavior, including loss of contact. Therefore, contact force can be used to quantitatively understand the contact performance of a pantograph. And, since the contact force varies according to the installed condition of catenaries, one can assume that contact force can be used in the assessment of the installed condition of catenaries as well. We therefore built a test system capable of real-time processing (output) of contact forces that could formerly be processed only on an off-line basis, and confirmed the system performance in running tests.

2. Measuring contact force with a pantograph

The pantograph is modeled as shown in Fig. 1. Assuming the inertial force acting upon system 1 as Fi, the aerodynamic force acting upon system 1 as Fa, and the sectional force acting upon the interface between system 1 and system 2 as Fd, contact force F can be expressed as follows.

$$F = Fa + Fi + Fd \quad \text{............... (1)}$$

Thus, contact force F can be calculated as the sum of Fi, Fd and Fa. Ordinarily, however, aerodynamic force Fa can hardly be measured. Therefore, the sum of Fi and Fd is first determined during train operation, and then the force equivalent to Fa is added to that sum to obtain the contact force.

Using a Shinkansen train pantograph as a model, we studied an algorithm for real-time output of the contact force and built a prototype data-processing system installed in a laptop computer. To correct the aerodynamic force, a table of relevant data for different train speeds in open and tunnel sections was prepared so as to permit calculating the aerodynamic force under specific conditions (train speed, etc.). Fig. 2 shows the appearance of the prototype system. This system was employed in running tests using a Shinkansen train. In the tests that lasted many hours, the system was capable of correctly outputting contact force data on a real-time basis.

3. Characteristics of contact force waveforms

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Fig. 3 shows the contact force waveform measured in a heavy compound catenary section of the Shinkansen, and Fig. 4 shows the results of a spatial frequency analysis of the contact force. From Fig. 4, it can be seen that the contact force contains three variable components ascribable to the contact wire structure—about 0.02 (l/m) support spacing cycle, about 0.08 (l/m) dropper spacing cycle, and about 0.16 (l/m) hanger spacing cycle.

Fig. 3 indicates that a slightly higher contact force—about 270N—occurred at the overlap section of contact wires. It is known that if the vertical configuration of catenaries at the overlap section is improper, the contact force increases and local wear of the contact wire tends to occur easily. The overlap section at which the higher contact force occurred was still free of local wear because the contact wire had recently been relined. However, it is considered likely that local wear due to the slightly higher contact force will occur at that point sooner or later.

Furthermore, from contact force it is also possible to predict the occurrence of a marked strain in the contact wire and a loss of contact. Thus, measuring the contact force is useful not only in understanding current-collecting performance but also in assessing the installed condition of catenaries. We are therefore now studying assessment techniques based on contact force.

4. Conclusion

By developing and testing a prototype data processing system, we confirmed that real-time processing of our contact force algorithm is possible even with a laptop computer. In the future, we intend to upgrade the method for assessing catenary conditions using contact force waveforms.

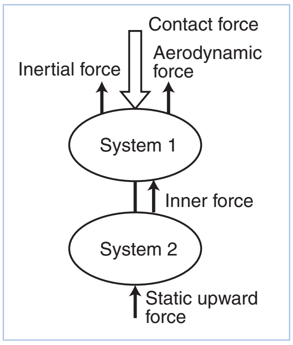

Figure 1. Forces acting on a pantograph

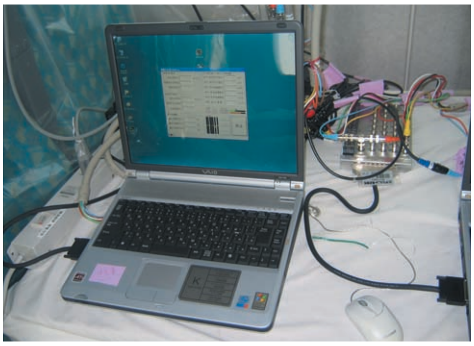

Figure 2. Contact force real time processing system

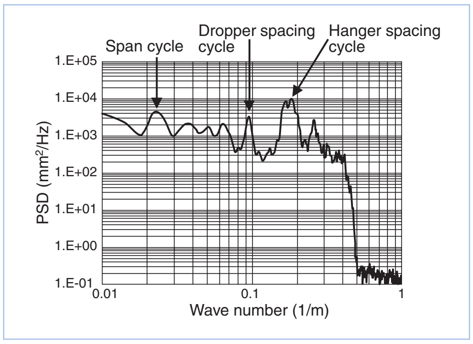

Figure 4. Frequency analysis of contact force

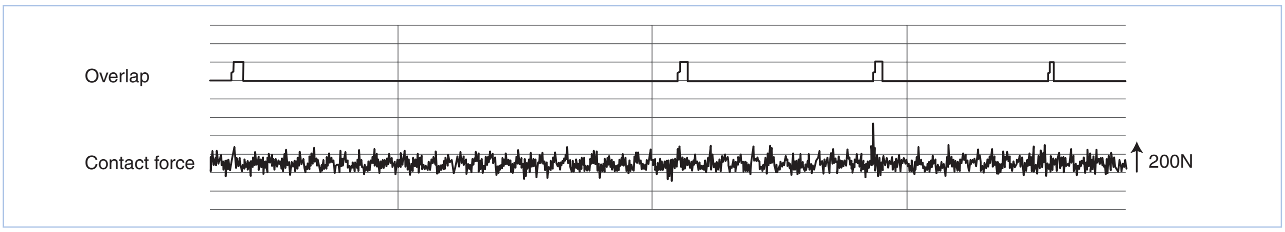

Figure 3. Contact force waveform