Reproducing the 3D Behavior of Overhead Contact Lines and Pantographs

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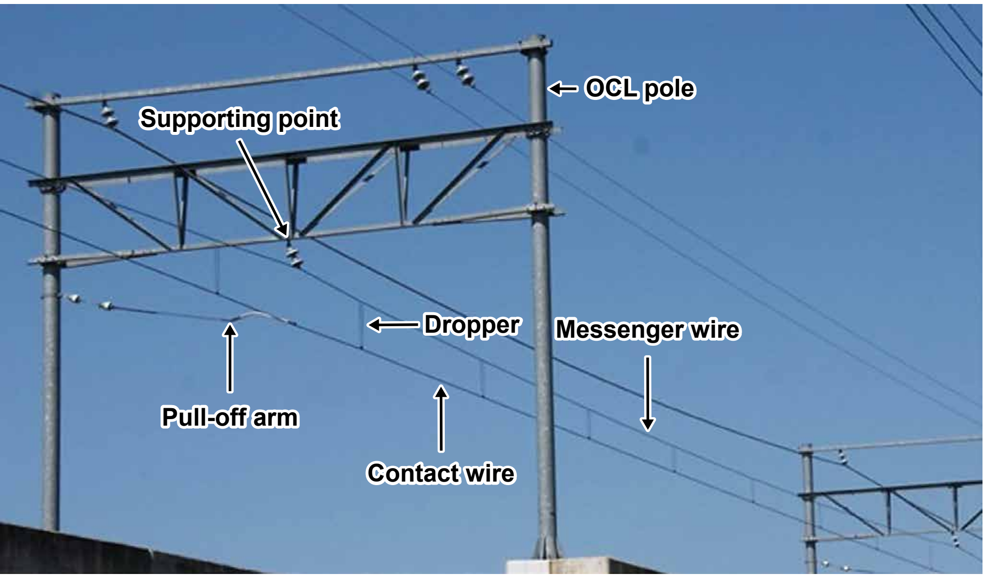
Current Collection

Facilities unique to electric railways include overhead contact lines (OCLs, Example of OCL (simple OCL)), which supply electric power to rolling stock, and pantographs (Pantograph example (single arm pantograph)), which take electricity into rolling stock. The pantographs contact with OCLs to take in electricity. Simulations are used to develop OCLs and pantographs, and to consider increasing the speed of trains. Recently, it has become increasingly difficult to adequately evaluate the performance of OCLs and pantographs in conventional 2D simulations (Conventional 2D simulation constructed by modeling with the OCL and pantograph as lumped mass). Thus, we have developed a simulation to understand 3D behaviors of OCLs and pantographs. This paper outlines the solution.

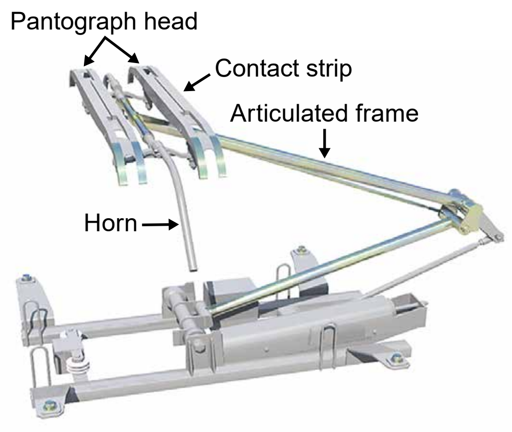


Example of OCL (simple OCL)

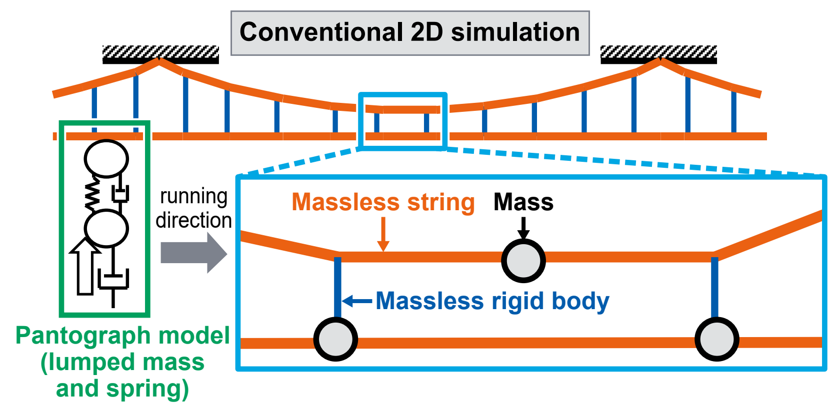
Introduction

The pantograph contains contact strips that are in direct contact with the contact wire, a pantograph head that holds the contact strips, and an articulated frame for moving the pantograph up and down to follow changes in the height of the contact wire. In addition, a horn is provided on each end of the pantograph head in order for the pantograph to safely slide on the OCL even when a vehicle negotiates a meeting or branching point (detailed later).

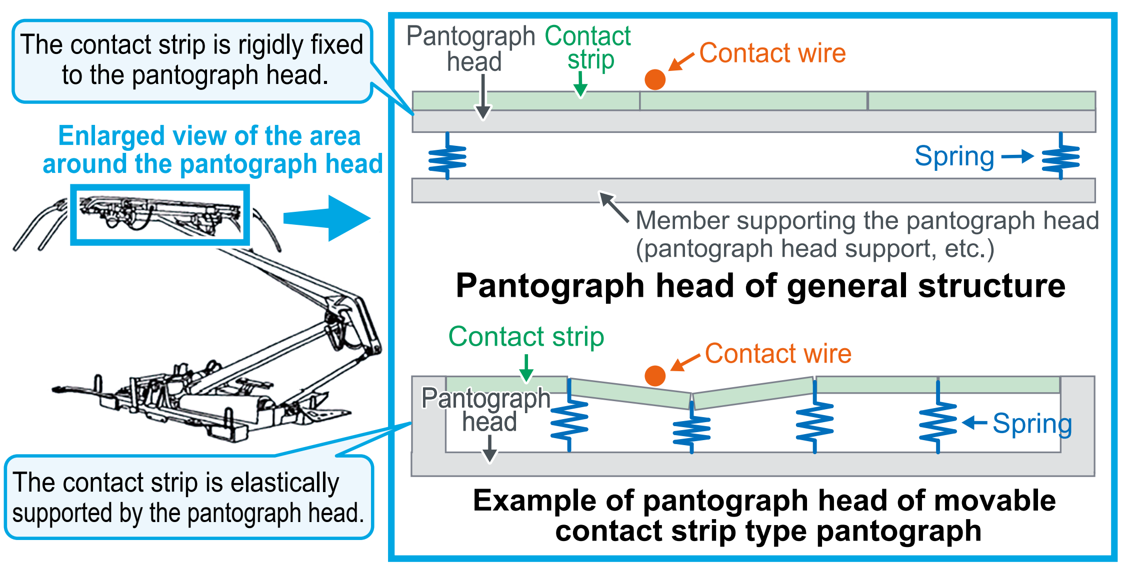
The pantograph performs current collection to take electricity from the contact wire into the vehicle. The force acting between the OCL and the pantograph is called the contact



Pantograph example (single arm pantograph)



Conventional 2D simulation constructed by modeling with the OCL and pantograph as lumped mass



Pantograph head structure

force. While the vehicle is at a standstill, the pantograph is in contact with the contact wire with a nearly constant contact force (50 to 60 N). However, during running, the contact force fluctuates due to the effect of, for example, the height difference of the contact line between the supporting points and the middle part of them. Excessive contact force may cause breakage of the contact wire, damage to various metal fittings, or increase in the amount of wear of the contact wire. On the contrary, when the contact force goes to zero, the pantograph may move away from the OCL (contact loss). In that case, an arc generated between the contact wire and contact strips may increase both wear of them.

In order to develop an OCL or current collector, or to increase the train speed, we should make sure that the above issues will not occur. However, fluctuations in contact force are caused by various factors, such as vibrations of the OCL and pantograph, changes in the height of the OCL, and waves propagated through the OCL. Therefore, it is not easy to understand the interaction between the OCL and pantograph. Thus, a computer simulation is used that includes modeled OCLs and pantographs.

Overview of 3D Simulation

To understand the interaction between the OCL and pantograph, we have developed a simulator using 3D models of these system (Pantograph head structure and 3D model of OCL and pantograph). This simulator models the OCL and pantograph by combining multiple finite elements for each of them. With these models, we can consider the following: (i) for the OCL, the 3D layout including the lateral deviation, and (ii) for the pantograph, the layouts of the members along the track and those perpendicular to the track. Each of these models is used to reproduce the behavior of the OCL and pantograph during train running.

Force exchange occurs between the pantograph and OCL by contacting each other, which is called dynamic interaction. As shown in Contact point and contact force, the simulation models dynamic interaction by applying forces of the same magnitude and opposite directions at the contact point between OCL and pantograph.

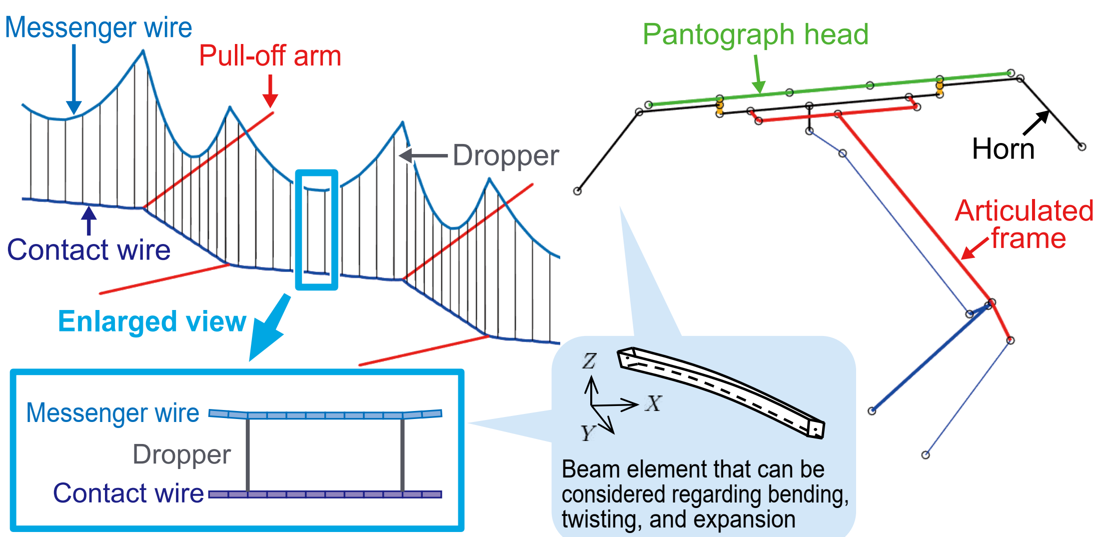
The simulator uses the penalty method to calculate the contact force. Specifically, a virtual spring (Contact point and contact force) is inserted between the OCL and pantograph, and if they are in contact, the force corresponding to the amount of contraction of the spring is defined as the contact force.

The following are two examples that use this simulation for the calculations.

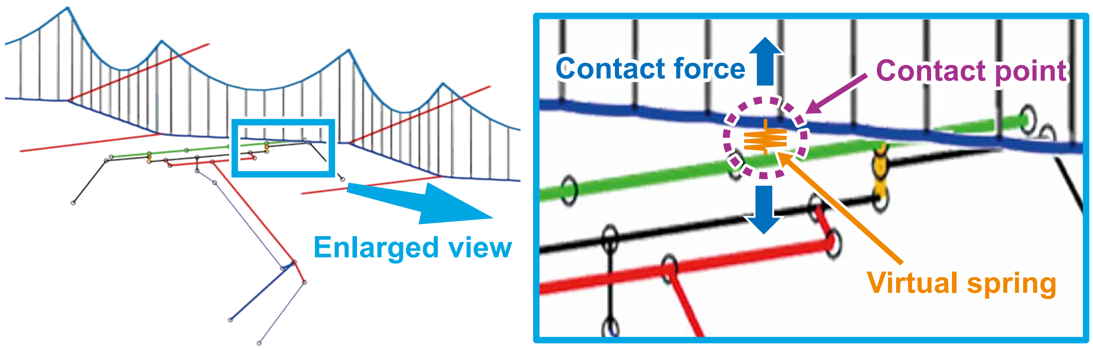
Pantograph Behavior Analysis

Computation results of movable contact strip type pantograph shows the analysis results of the movable contact strip type pantograph described above as an example of analyzing the 3D behavior of the members that make up the pantograph. In Computation results of movable contact strip type pantograph, the pantograph is moving from the front to the rear of the view. Also, in a pantograph with such a structure, it can be seen that the moving contact strips are only those near the contact point with the contact wire, and those away from that point are not moving.

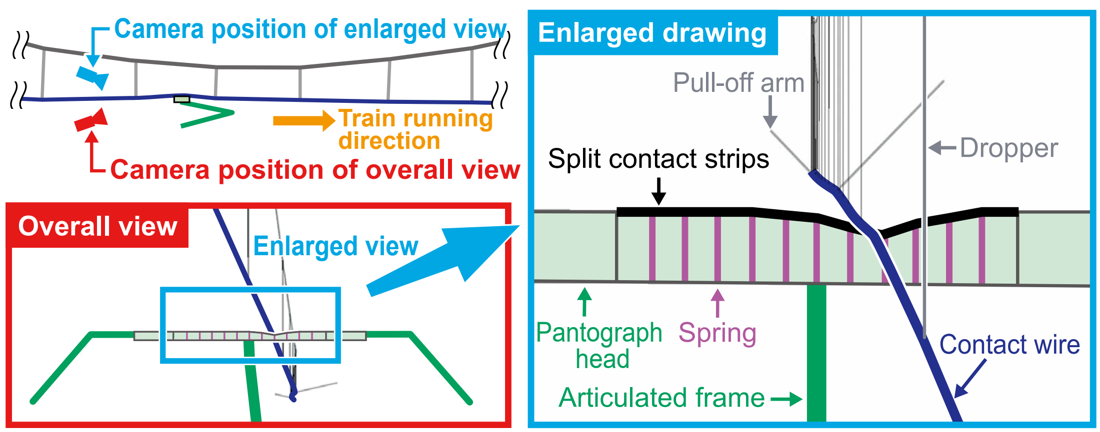
By constructing such a new computational model, it would be possible to evaluate the performance of pantographs with complicated structures , these were previously difficult, and it will be thought



3D model of OCL and pantograph



Contact point and contact force



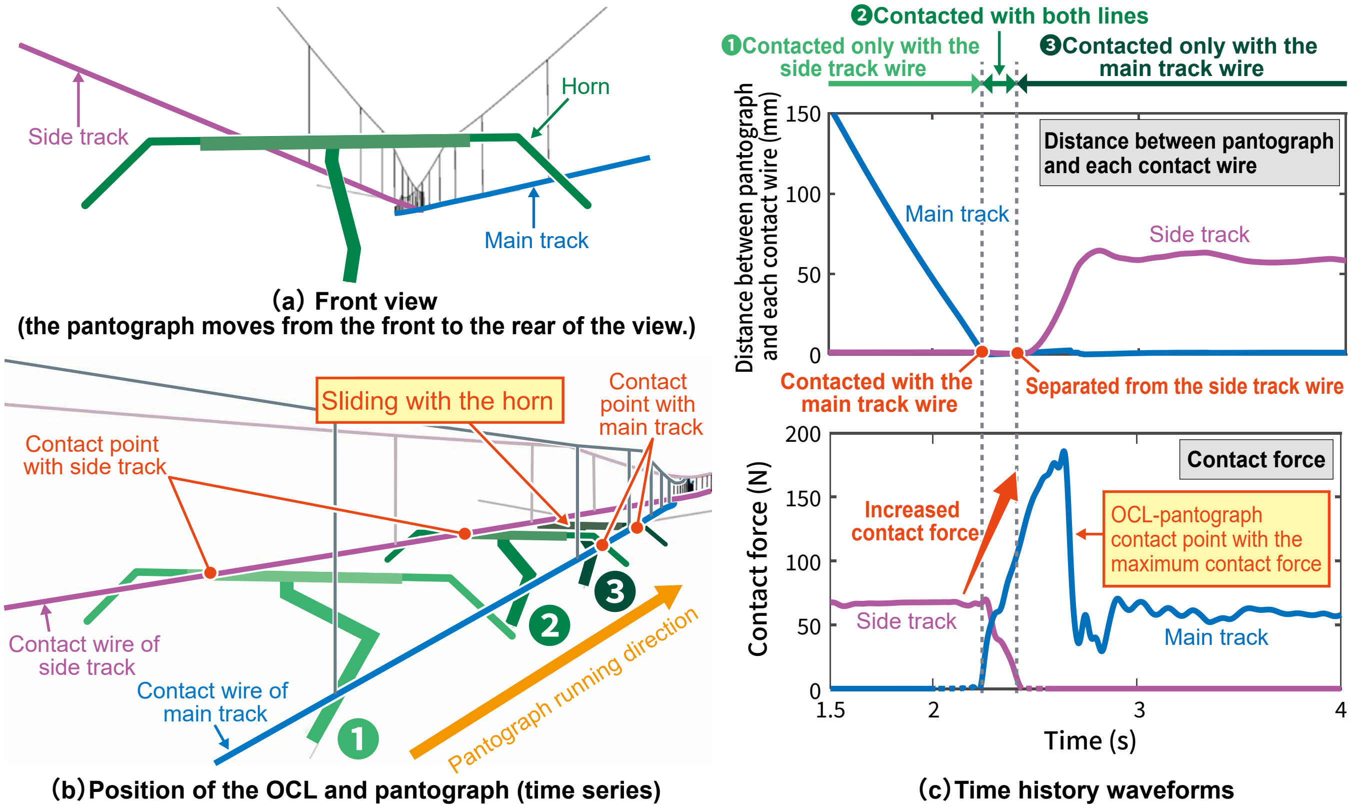
Computation results of movable contact strip type pantograph

that the model can be used for the development and improvement of pantographs with more complicated and sophisticated mechanism in recent years.

Analyzing where the Tracks Meet

To show an analysis that considers 3D OCL placement, Results of analyzing where the tracks meet shows an example of analysis targeting the points where tracks meet. At such a location, a total of two sets of OCLs, one above each track, are installed in an intersecting manner or nearby each other. When a vehicle is running on the main track, the pantograph of this vehicle only contacts the contact wire of the main track which is lower than that of the side track. On the other hand, as in Results of analyzing where the tracks meet (a), when a vehicle is entering the main track from the side track, the pantograph of this vehicle should make a smooth transition from the contact wire of the side track to that of the main track.

Results of analyzing where the tracks meet (b) shows the position of the pantograph and the contact point with the OCL at each point when the vehicle enters the main track from the side track. At point ①, the pantograph is in contact with only OCL of the side track, whereas at point ②, while the pantograph contacts OCL



Results of analyzing where the tracks meet

of the side track, OCL of the main track is pushed up with the horn. Beyond point ③ further advanced, the pantograph would move away from OCL of the side track and contact only OCL of the main track.Results of analyzing where the tracks meet (c) shows the results obtained in this analysis. The upper graph shows the change in the distance between the pantograph and each contact wire, and the lower graph shows the change in the magnitude of the contact force between the pantograph and each contact wire. From these figures, it can be seen how the pantograph moves away from the contact wire of the side track to that of the main track before and after point ② .

Conclusion

This paper explained a simulation that reproduces the 3D behavior of the OCL and pantograph. Utilizing a 3D simulation as described above example would make us to improve the development efficiency of OCL and pantograph development, understand 3D behaviors, and investigate the cause of accidents between OCL and pantograph. In the future, we will utilize this simulation to solve various issues with OCLs and pantographs.

References

1) Koyama, T., Nagao, K., Ikeda, M., "Three-dimensional Simulation of Catenary/Pantograph Dynamic Interaction," Quarterly Report of RTRI, Vol.62, No.2, pp.104-109, 2021