A Study on the Measurement of Contact Force of Pantograph on High Speed Train

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Appropriate contact force is required for the pantograph on the high speed train to collect current from the catenary system without separation. However, at high speed, large aerodynamic lifting force is generated by the contact plate and the body of pantograph, which may cause wear of the contact wire. In this study, to confirm the interface performance of the pantograph on Korea High Speed Train, a method to measure the contact force of the pantograph was proposed and the related measuring system was developed. The forces acting on the pantograph were clarified and a practical procedure to estimate the forces was proposed. A special device was invented and applied to measure the aerodynamic lifting force. Measured contact forces were displayed by the developed system and evaluated based on the criteria.

Key Words: Aerodynamic Lifting Force, Catenary System, Contact Force, High Speed Train, Pantograph

Nomenclature

\( a \) : Acceleration of contact plate
\( F_{ac} \) : Aerodynamic lifting force of contact plate
\( F_{ad} \) : Average aerodynamic lifting force of contact plate in N
\( (F_{ac})_{run} \) : Average aerodynamic lifting force of contact plate in running test
\( (F_{ac})_{wind} \) : Average aerodynamic lifting force of contact plate in wind tunnel test
\( F_{ab} \) : Aerodynamic lifting force of horn frame
\( F_c \) : Contact force of contact plate
\( F_{cp} \) : Average contact force of contact plate in N

\( F_{SP} \) : Spring force below contact plate
\( \overline{F}_{SP} \) : Average spring force below contact plate
\( k \) : Coefficient of aerodynamic lifting force
\( k_{wind} \) : Coefficient of aerodynamic lifting force from wind tunnel test
\( m_{cp} \) : Mass of contact plate
\( V \) : Train velocity in km/h

1. Introduction

KTX (Korea Train eXpress) begins commercial service on April 1, 2004. Korea becomes the fifth country to operate the high speed railway system in the world. At the same time, KHST (Korea High Speed Train) succeeded in trial running on the test track at the speed of 350 km/h. KHST shown in Fig. 1 has been constructed by home grown technologies for 7 years. All of the core systems of KHST have been developed by

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domestic research institutes and related companies. A pantograph is the one of the core systems developed by domestic technologies. The pantograph of electric power car collects current from the catenary system and supplies electric power to the transformer and the main traction system. The pantograph should follow the catenary without separation for continuous current collection. Sufficient contact force is necessary for the contact plate of pantograph not to separate from the catenary system. Separation of the contact plate causes arc generation and gives damages to the catenary system. Separation also deteriorates the quality of the collected current. On the contrary, excessive contact force causes rapid erosion of the contact wire of catenary. Since the pantograph of high speed train is in high speed air flow field, significant lifting force is added to the contact force. So, an upper limit of contact force is regulated by the standard or the guidelines. Control of the contact force is important for current collection and maintenance of the catenary system. However, unless the contact force is known correctly, control can’t be done appropriately. In the high speed train, lifting force is the major factor contributing to the contact force (Seo et al., 2002). So, to know the characteristics of the contact force and the lifting force, they should be measured in test running and analyzed correctly.

Domestic researchers studied the dynamic behavior of the pantograph and analyzed theoretically the contact force with the catenary. Measurement of the contact force on the actual track hasn’t been tried because the high voltage of the catenary was dangerous and the method and related devices were not prepared. During development of the domestic pantograph on KHST, upward force of the pantograph was measured by a special device in the wind tunnel facility, where the contact plate was fastened by a wire to the load cell on the ground (Bae et al., 2001). In this test, the flexibility of the catenary system was not taken into account and dynamic behavior of the contact plate could not be measured. So, the measured upward force can not be considered as the true contact force.

Numerical simulation of the dynamic characteristics of the pantograph has been carried out by the researchers (Park et al., 2002). However, to simulate the dynamic system of the pantograph, input data for the external forces is required. To prepare the external force data, test for the aerodynamic lifting force should be done before simulation. Therefore, numerical simulation is restricted by the test result.

In this study, to measure correctly the contact force of the pantograph on the high speed train, a practically safe and reliable testing method combined with the result from the wind tunnel test is proposed. The forces acting on the pantograph are classified into components and investigated. The components of forces are measured based on the testing method proposed in this study. A data acquisition and analysis system for measurement of forces is also developed. The proposed testing method is proved to be valid and safe by the trial running test on the high speed line.

2. Forces on Pantograph

The pantograph on KHST is of single-armed type. To reduce aerodynamic noise and weight, the structure is designed simple and the outer diameter and thickness of members are designed optimum. Fig. 2 shows the details of the pantograph on KHST. The contact plate of the pantograph is on the secondary suspension in the horn frame to follow the catenary smoothly and to prevent separation. Initial static upward force is supplied by