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Variable Suspension Design for Active Pantograph

Seungkwon Shin*, Hyungchul Kim*, Hosung Jung*, Jongyoung Park*, Sangahm Kim*

**Korea Railroad Research Institute, Uiwang, Korea*
skshin@krri.re.kr

Abstract

There are a lot of traffic jams in the metropolitan area and the commuting time has been longer nowadays. So the urban people has been interested in the GTX(Great Train Express) project in Korea. The GTX is the train which runs at 200km/h speed in underground tunnels. If the train also operates at high speed in tunnel section, the pressure wave will happen and the uplift force of pantograph may vary abruptly. If the rigid trolley bar system is used in tunnel section, it is difficult to improve the commercial speed of train. In order to improve the train speed in tunnel section, this paper presents the new pantograph concepts which can change the suspension stiffness and deals with the dynamic behavior characteristics of pantograph according to the parameter variation.

Keywords: *Pantograph, Contact Force, Catenary System*

1. Introduction

The pantograph is an apparatus mounted on the roof of an electric train in order to collect power through contact with overhead catenary system. The pantograph and the catenary system are a dynamic coupled system and they affect each other through the contact force. The pantograph is the very important equipment that supplies the electrification devices of train with electric power from the contact wire. As the train speed increases, the contact force variation also increases. If the contact loss happens, the electric arch will happen between the pantograph and catenary system and the quality of current collection will be deteriorated. This paper presents the new pantograph concept which can change the suspension stiffness and deals with two-mass of model which is combined with the static stiffness variation of contact wire and its dynamic performance.

2. Pantograph-Catenary System

The motion equation governing the dynamic interaction between the pantograph and contact wire can be expressed as follows

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Corresponding Author: skshin@krri.re.kr
Tel: +82-31-460-5000, Fax: +82-31-460-5159
Korea Railroad Research Institute, Uiwang, Korea

$$M_1\ddot{x_1} + C_1(\dot{x_1} - \dot{x_2}) + K_1(x_1 - x_2) + K(t)x_1 = 0 \quad (1)$$
$$M_2\ddot{x_2} + C_1(\dot{x_2} - \dot{x_1}) + C_2\dot{x_2} + K_1(x_2\text{-}x_1) = F_l \quad (2)$$

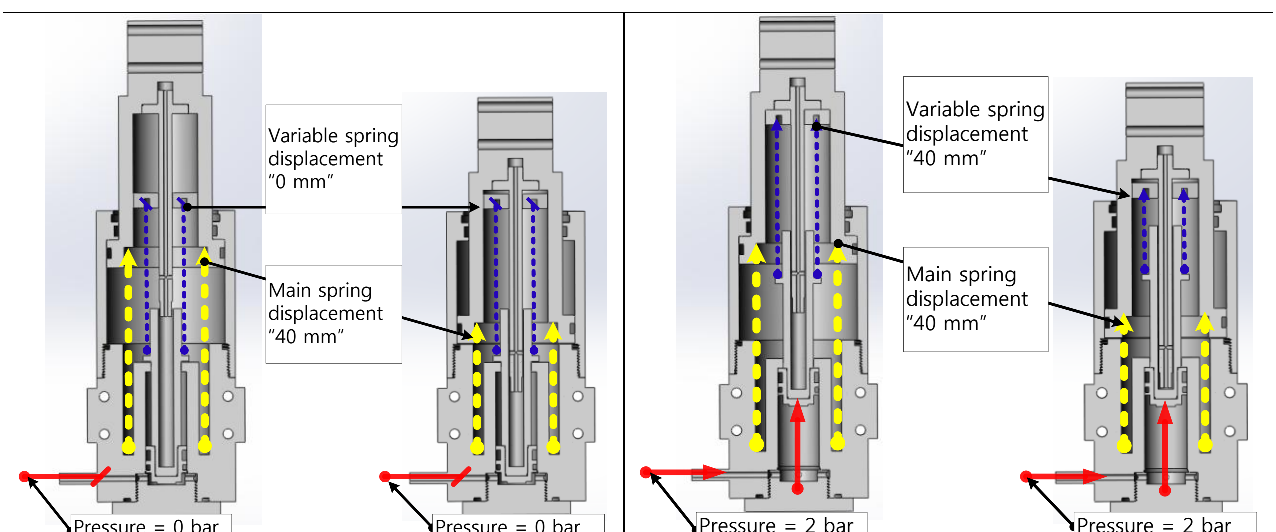
If we set state variable $x_p(t) = [x_1 \quad \dot{x}_1 \quad x_2 \quad \dot{x}_2]^T$, the state equation and output equation can be expressed as eq. (3) and (4).

$$\dot{x_P}(t) = A_P(t)x_P(t) + B_P u(t) \quad (3)$$
$$y(t) = C_P(t)x_P(t) \quad (4)$$

where, $Ap = \begin{bmatrix} 0 & 1 & 1 & 0 \\ -\frac{K(t)+K_1}{M_1} & -\frac{C_1}{M_1} & \frac{K_1}{M_1} & \frac{C_1}{M_1} \\ 0 & 0 & 0 & 1 \\ \frac{K_1}{M_2} & \frac{C_1}{M_2} & -\frac{K_1}{M_2} & -\frac{C_1+C_2}{M_2} \end{bmatrix}$, $Bp = \begin{bmatrix} 0 \\ 0 \\ 0 \\ \frac{1}{M_2} \end{bmatrix}$, $Cp = [K(t) \quad 0 \quad 0 \quad 0]$

3. Variable Suspension Design

The variable suspension was design by the combination of plunger type and piston type. This structure enable the spring constant k to be variable and the actuator will be the pneumatic system. The stiffness of spring was designed to provide the pantograph with two kinds of mode. The first mode is the general speed mode which is suitable for low speed and the second mode is the high speed mode. The maximum displacement of variable spring is 40 [mm].



a) General speed mode b) high speed mode

Figure 1. Operation Principle of Variable Suspension

3.1 Prototype Mock-up of Using 3D printer

We used the 3D printer to make the prototype mock-up of variable suspension and the used 3D printer is the OBJET24 made by Stratasys which use the VeroWhitePlus(acrylic material). The figure 2 shows the 3D printer outputs and assembly.

Figure 2. 3D printer Outputs and Assembly

4. Simulation

The simulation was carried out with the two-degree of freedom of pantograph model including the stiffness variation of the catenary system. The contact wire stiffness was used in the Honam-line of Korea. The parameters of pantograph were summarized in table 1.

Table 1. Parameters of Pantograph.

M1	5.5 [kg]
C1	0.1 [Ns/m]
M2	17.25 [kg]
C2	200 [Ns/m]

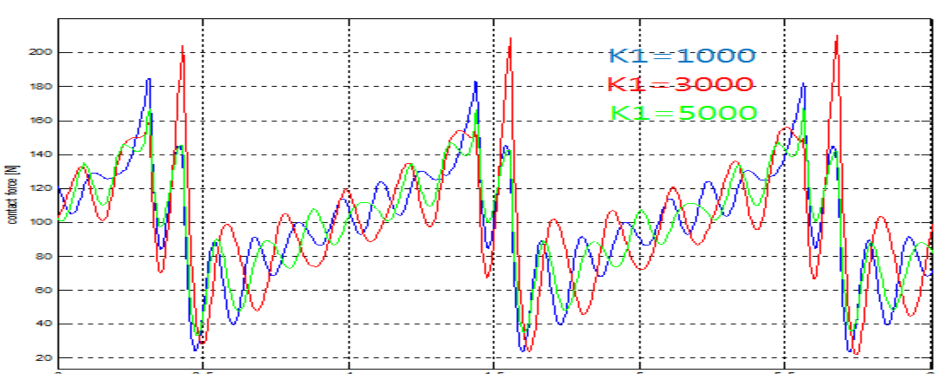


Figure 3. Contact Force with K1 Variation at V=160km/h

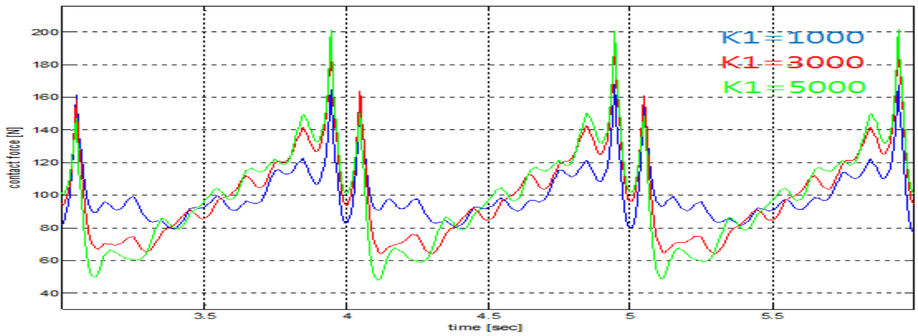


Figure 4. Contact Force with K1 Variation at V=180km/h

Figure 3 represents the contact force variation with K1=1000 [N/m], 3000 [N/m], 5000 [N/m] respectively if the train speed is 160[km/h] and Figure 4 represents the contact force variation with K1=1000 [N/m], 3000 [N/m], 5000 [N/m] respectively if the train speed is 180[km/h]

5. Conclusion

This paper deals with the variable suspension design for active pantograph and the simulations were implemented under various operational conditions to know the dynamic interactions between pantograph and catenary system. As the panhead stiffness is increased, the simulation results show that the contact force variation is increased at the train speed V=180 [km/h]. But the contact force variation is the smallest at the panhead stiffness K1=5000 [N/m] when the train speed is V=160 [km/h]. The simulation results show that the contact force can be controlled by the panhead stiffness variation.

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