Improvement of Pantograph Performance by Use of a Variable Stiffness Spring

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The contact performance of a pantograph is often evaluated in terms of compliance characteristics. The compliance characteristics specify, when a pantograph runs along an overhead rigid conductor having sinusoidal irregularities, the maximum amplitude of overhead rigid conductor irregularities with which the pantograph can run without causing a control loss. The compliance characteristics is a frequency response, wherein there is generally a plurality of frequencies at which the compliance characteristics show a peak and a valley. These frequencies are determined primarily by the mass of a movable part of the pantograph and/or the stiffness of a spring element. Fig. 1 shows how the compliance characteristics vary when the stiffness of a pan spring that supports the panhead of the pantograph is varied.
The Railway Technical Research Institute has proposed a technique, whereby the contact performance is improved by matching a principal disturbance frequency acting on a pantograph with the peak frequency of the compliance characteristics curve by allowing the stiffness of the pan spring of the pantograph to be varied and altering the peak frequency as shown in Fig. 1.
The contact performance was investigated by numerical simulation using a simple control to vary the stiffness of a variable stiffness spring in response to the running speed. It was assumed that the dominant disturbance frequency acting on the pantograph would be determined by the running speed and the interval between items of hardware along the wire such as the hangers and supporting points. Then, the stiffness of the variable stiffness spring was controlled so that this frequency agreed with the peak frequency of the compliance characteristics of the pantograph. As a result, it was revealed that there is less fluctuation of the contact force when the stiffness is varied in response to the running speed than when the stiffness is constant regardless of the running speed, and it was confirmed that this technique of improving the contact performance is effective for the catenary-type contact wire (Fig. 2).
Figure 3 shows the variable stiffness spring that was developed and prototyped to implement the proposed technique of improving contact performance. This variable stiffness spring has two air springs arranged so that they are opposite to each other, whereby the stiffness of the variable stiffness spring can be varied by altering the air pressures of both air springs. The change in stiffness is possible in the range of approximately 15 kN/m to 36 kN/m.
The variable stiffness spring shown in Fig. 3 was mounted on a pantograph, whereby the variation in a dynamic characteristic associated with the change in stiffness was confirmed. Figure 4 shows the variations in the dynamic characteristic (compliance=compliance characteristics/static upward force) of the pantograph due to differences in the air pressures of the variable stiffness spring. The air pressures shown in the graph are differential pressures from the atmospheric pressure. As shown in Fig. 4, it is confirmed that the compliance peak frequency varies with the alteration of the stiffness, and it has been shown that the pantograph compliance characteristics can be controlled by the variable stiffness spring.
In the future, pantographs fitted with a variable stiffness spring are scheduled to be run under an actual overhead line to confirm the enhanced effect of the contact performance.

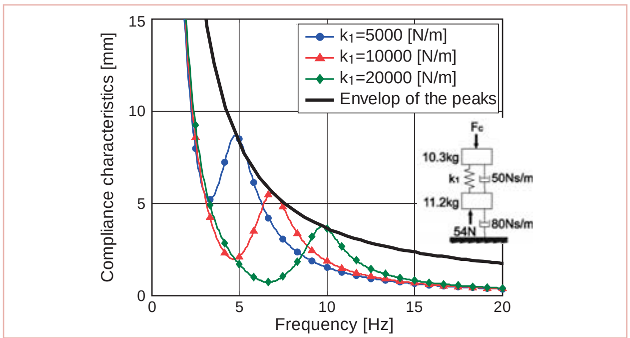

Fig. 1 Variations of compliance amplitude due to differences of pantograph stiffness

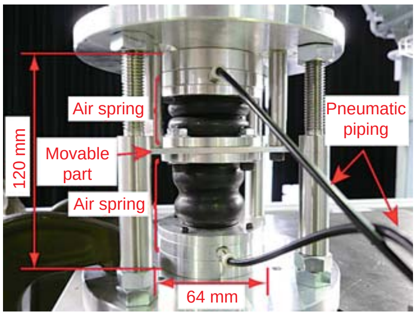

Fig. 3 Prototype of the variable stiffness spring

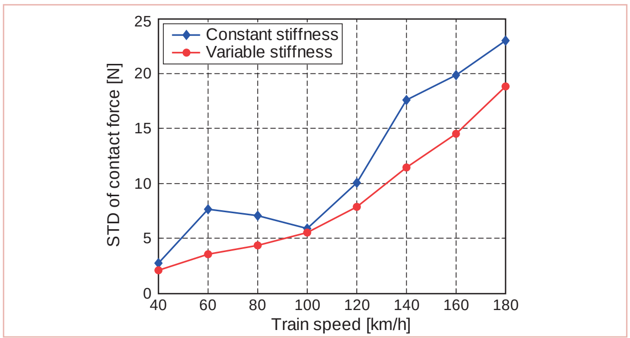

Fig. 2 Difference in the contact performance between the pantograph with a variable and a pantograph with a spring of constant stiffness (Numerical simulation results)

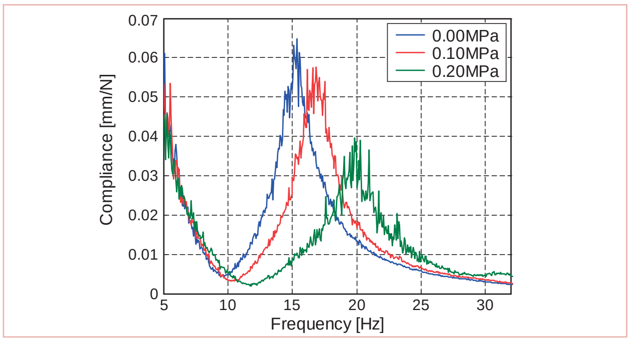

Fig. 4 Dynamic characteristic control of a pantograph with the variable stiffness spring