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Investigation on the Vibration Control of the Capsule Train through the Reduced-Scale Vehicle Model Simulating the Dynamic Characteristics

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***Abstract* - The capsule train is characterized by driving in a low-pressurized tube and magnetic levitation to reduce air drag and running friction, enabling 1,000 km/h speed. The capsule train being developed by the Korea Railroad Research Institute uses superconducting electrodynamic suspension (SC-EDS) as a magnetic levitation for large levitation gap. However, SC-EDS has the small damping characteristic, which increases vibration, resulting in ride comfort degradation. To control this vibration, active actuators should be applied in secondary suspension of the capsule train. In this study, to investigate the effects of active actuators in laboratory environment, we developed 1/10 reduced-scale vehicle model simulating the dynamic characteristics of the capsule train. Experiments by using developed testbed showed that vibration can be successfully reduced by active actuators with proposed controllers.**

Index Terms – Capsule train, Dynamic characteristic, Vibration control, Reduced-scale vehicle model

Figure 1 shows a capsule train which runs inside a low-pressurized tube using magnetic levitation [1]. As magnetic levitation, a superconducting electrodynamic suspension (SC-EDS) is used for large levitation gap [2]. However, SC-EDS has a small damping characteristic, which increases the vibration, resulting in ride comfort degradation [3]. Therefore, active actuators between bogie and carbody (secondary suspension) are necessary to control the vibration [4].

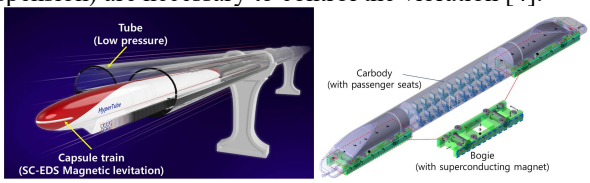

FIGURE I
CAPSULE TRAIN: CONCEPT AND FULL-SCALE DESIGN MODEL

To investigate the effect of the active actuators in laboratory environment, based on similarity law, we developed 1/10 reduced-scale vehicle model that bogie motion is generated by Stewart platform and voice coil motors are used as active actuators (Figure 2 and Table 1). And validation experiments confirmed suitability of testbed.

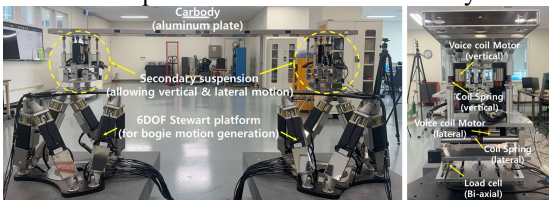

FIGURE 2
REDUCED-SCALE VEHICLE MODEL: OVERALL VIEW AND SUSPENSION UNIT

TABLE I
PARAMETERS FOR FULL-SCALE AND REDUCED-SCALE VEHICLE MODEL

Parameters	Description	Full-scale	Reduced-scale
m_c (kg)	Carbody mass	10,000	10
m_b (kg)	Bogie mass	6,000	6
$k_{air(v)}$ (N/m)	Vertical coil spring stiffness	240,000	2,400
$k_{air(L)}$ (N/m)	Lateral coil spring stiffness	240,000	2,400
k_{lev} (N/m)	Levitation stiffness	1,600,000	16,000
k_{gud} (N/m)	Guidance stiffness	900,000	9,000

For efficient vibration control, two controllers (virtual tuned mass damper (VTMD) and lag compensator) were designed and applied to active actuators. As results, figure 3 shows that carbody vibration was successfully reduced by using the active actuators with proposed controllers.

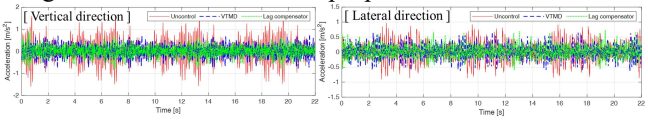

FIGURE 3
CARBODY VIBRATION REDUCTION BY USING ACTIVE ACTUATORS

Figure 4 (a) shows the effect of controller design variable (target frequency) on vibration, indicating the robustness of lag compensator is better than VTMD. Figure 4 (b) shows that active actuators also successfully reduce the vibration caused by external disturbance such as step input.

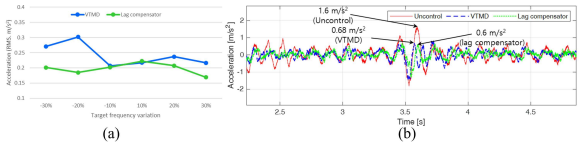

FIGURE 4
EFFECT OF CONTROLLER DESIGN VARIABLE AND EXTERNAL DISTURBANCE

Acquired knowledge from this work such as controller design method and active actuator specification will be very useful for future development of the full-scale capsule train.

ACKNOWLEDGMENT

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