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Analysis of Dynamic Response for HTS MagLev Vehicle Model

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The paper deals with dynamic response of a HTS Maglev vehicle model. Evaluation of dynamic characteristics is required in mechanical design of Maglev vehicle system. Based on the mechanism of levitation and actual structure of the vehicle, a simplified vibration model is presented and analyzed with random vibration theory. The transient response at each DOF is measured. The analytical results show excellent agreement with the measurement results.

1. INTRODUCTION

In order to explore the application HTS bulk in Maglev vehicle, a HTS Maglev vehicle model has been developed, which consists of levitation and drive system. Its structure is shown schematically as Fig.1. It comprises two containers filled with liquid nitrogen, including nine pieces of YBCO HTS bulk. The levitation system is a repulse-type, self-stable system due to flux pinning effect. However, it is shown by operation that there exists vibration of the vehicle at each degree-of-freedom (DOF). The vibration analysis is very important for safety, ride quality and system costs. To investigate the dynamic characteristics of the system, dynamic testing was carried out. According to the theory of HTS levitation, a simplified vibration model is presented and researched with random vibration theory. The analytical result shows very good agreement with the measurement result.

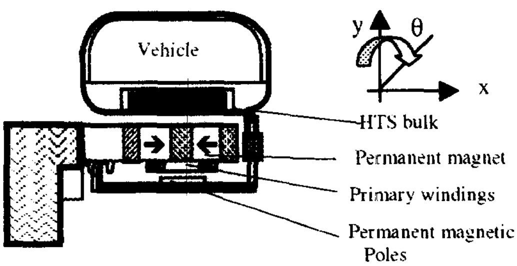

Fig.1 The structure of HTS Maglev model vehicle

2. MEASUREMENT OF RANDOM VIBRATION

The vibration signals received by accelerators are put into charge amplifiers BK2635, which can output voltage signal proportional to acceleration, velocity or displacement signals. The vibration displacement signals and power source signals of the linear motor stator are recorded by magnetic tape recorder RTP510A. Frequency spectrum is observed by dynamic analyzer HP3560A. According to the frequency spectral analysis on the wave, the natural frequency at each DOF can be achieved.

3. ANALYSIS OF RANDOM VIBRATION

Based on the structure of vehicle model, the model can be treated as a rigid body. A simplified dynamic model is obtained as following:

$$[M]\{\ddot{Z}\}+[C]\{\dot{Z}\}+[K]\{Z\}=\{F(t)\} \quad (1)$$

Here $\{Z\}^T$: Position vector matrix; $\{\dot{Z}\}$: Velocity vector matrix; $\{\ddot{Z}\}$: Acceleration vector matrix; $\{F(t)\}$: Excitation vector matrix; $[M]$: mass matrix; $[C]$: Damping coefficient matrix; $[K]$: stiffness matrix. Based on the theory of random vibration, autocorrelation

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function matrix with transient response can be written as,

$$[\Phi_{ZZ}(t_1,t_2)] = \int [\overline{H(\omega,t_1)}][S_{FF}(\omega)][H(\omega,t_2)]^T e^{i\omega(t_2-t_1)}d\omega \quad (2)$$

Then, with Eq.(2),the mean-square values of transient response at each DOF are:

$$[E[Z^2]] = \int [\overline{H(\omega)}][S_{FF}(\omega)][H(\omega)]^T d\omega \quad (3)$$

Here

$$\begin{cases} \overline{H_n(\omega,t)} = \int_0^t h_n(\tau)e^{i\omega\tau}d\tau \\ H_n(\omega,t) = \int_0^t h_n(\tau)e^{-i\omega\tau}d\tau \end{cases} \quad (4)$$

In Eq. (4), $h_n(\tau)$ is the pulse response function at nth (n=1,2,3) DOF, if $\xi_n < 1$, the function of pulse response can be written as:

$$h_n(t) = \frac{e^{-\xi_n \omega_{0n} t}}{\sqrt{1-\xi_n^2}\, m\omega_{0n}} \sin(\sqrt{1-\xi_n^2}\, m\omega_{0n} t) \quad (5)$$

According to the structure of the vehicle and the result of model-analysis, the parameters of Eq. (1) and power spectrum density (PSD) of excitation are given in table 1.

From the table 1, the mean-square values in transient response at each DOF can be obtained, as shown in Fig.2, Because the magnitude of the mean-square values

Table1. Structure parameters of model vehicle

L_1(m)		3.75×10^{-2}	Natural frequency (rad/s)	ω_{01}	5.89
m(kg)		10		ω_{02}	11.39
$I_{\theta 1}$(kg.m^2)		0.149		ω_{03}	11.39
P	S_{f1f1}(N^2/Hz)	1.313×10^{-5}	Damping coefficient	ξ_1	0.01
S	S_{f2f2}(N^2/Hz)	4.803×10^{-5}		ξ_2	0.011
D	S_{f3f3}(N^2.m^4/Hz)	3.8667×10^{-7}		ξ_3	0.01

indicates that of the vibration displacement, Fig.2 shows that the damping of the vehicle at each DOF is relatively small, transition time relatively long and the amplitude of lateral slide and roll relatively high. It can be concluded that the guidance force needs to be increased in order to decrease the amplitude of slide and roll vibration.

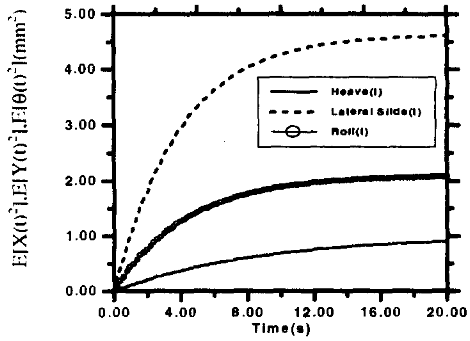

Fig.2 The mean-square values in transient response

4.CONCLUSION

Although HTS Maglev vehicle is developed recently, it has many advantages compared with other levitation schemes due to its simplicity and reliability of levitation and guidance scheme. The following results can be get from above measurement and analysis.

- The HTS Maglev vehicle model is stable in the direction of levitation and guidance.
- The transition time of vibration is relatively long.
- The amplitude of vibration in lateral side and roll are relatively higher than that in heave.

REFERENCES

1. Zhang Yong, Xu Shangang, "Measurement and Analysis of a HTSC Maglev Model vehicle", *Proceedings of MT-15th*, Beijing, China, October, (1997)763~766.
2. Zhang Yong, Xu Shangang, "Research of High Temperature Superconductor MAGLEV Vehicle" Proceedings of the Symposium on MAGLEV Train in China, October, 1997, Hangzhou, China.
3. H. Weh, "Possible Applications of HTSC Material in Energy Conversion and Magnetic Support Technique", *Proceedings of the SPEEDAM*, Taormina (Italy), June, 1994.