DYNAMIC RESPONSES OF HTS MAGLEV SYSTEM UNDER TRACK RANDOM IRREGULARITY

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Background

After the first manned HTS maglev prototype vehicle has been developed in China, researchers from Germany, Brazil, Italy and Russia have done a lot of research and developed their own HTS maglev vehicles. These shown a great prospect of HTS maglev.

Track random irregularity is the main excitations of HTS maglev system, but it has not received attention in previous studies. In this paper, a HTS maglev vehicle-bridge coupled model considering vertical-lateral coupling effect is built in UM software, it can simulate not only the vertical but lateral response of vehicles and bridges. A track random irregularity spectrum and flexible bridges with three different spans were built. The dynamical responses were calculated and the influence of different operating speeds and different spans bridge were considered and the data were analyzed.

Abstract

High-temperature superconducting (HTS) magnetic levitation (maglev), with the advantages of low-energy consumption, simple mechanical structure and environment-friendly, has the potential to become a high-speed transportation. In rail track lines, the track random irregularity is ineluctable due to the defects of permanent magnets in production and construction. And the irregularity will affect the operation stationarity. In this paper, a HTS maglev vehicle-bridge coupled model considering vertical-lateral coupling effect is built based on the Universal Mechanism (UM) software. To study the dynamical response of the maglev system, a track irregularity spectrum was built based on our group's existing guideway. Different speeds and spans were adopted in this model. The Sperling index is used to evaluate the system station-arity performance under different working conditions. The results show that HTS maglev can run very safely and smoothly on existing guideway and more flexible bridges. This study suggests the limitation of the running speed and the designs of bridges in HTS maglev under track random irregularity, as well as provides references for the engineering.

Key words: High-temperature superconducting, levitation, dynamics, vehicle-bridge coupled system, track random irregularities

DYNAMICS SIMULATION MODEL

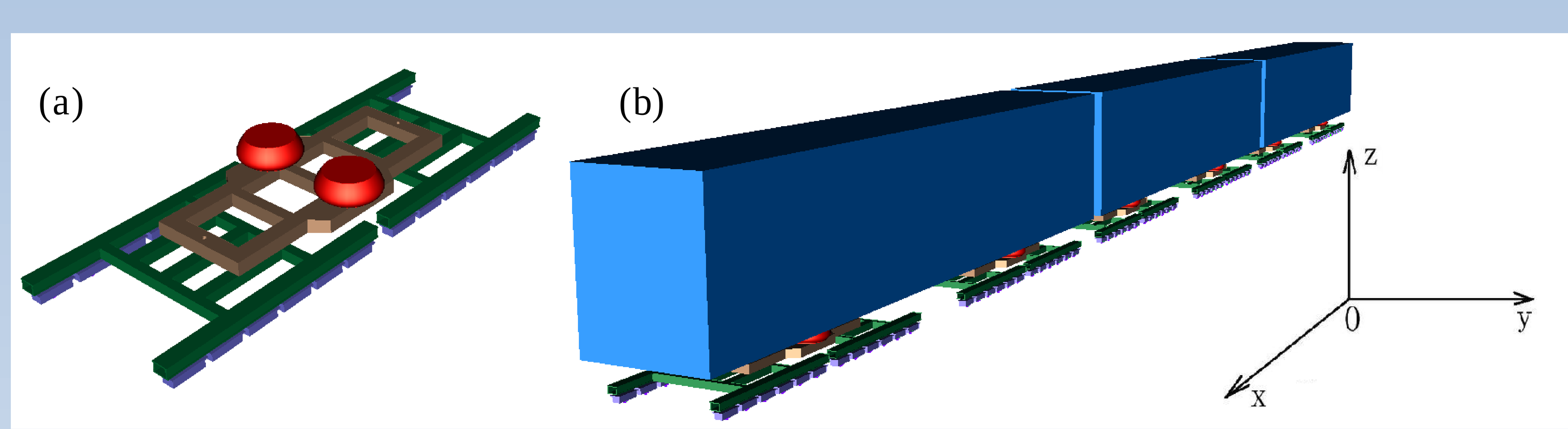
HTS force element model

$$F_z(y,z) = \mathrm{A}_1 z e^{\beta_1 z} + \mathrm{A}_2 y^{\beta_2} e^{\beta_3 z} + \mathrm{h}_1 \dot{z}$$

$$F_y(y,z) = (\mathrm{B}_1 sin(\alpha_1 y) + \mathrm{k}_1 \dot{y} + \mathrm{k}_2 \dot{y}^3) e^{\alpha_2 z}$$

By improving the existing nonlinear levitation force model and guidance force model, a two-dimensional mathematical model of track relationship for HTS maglev is established. The model takes into account the effects of levitation height, lateral displacement, vertical and lateral vibration.

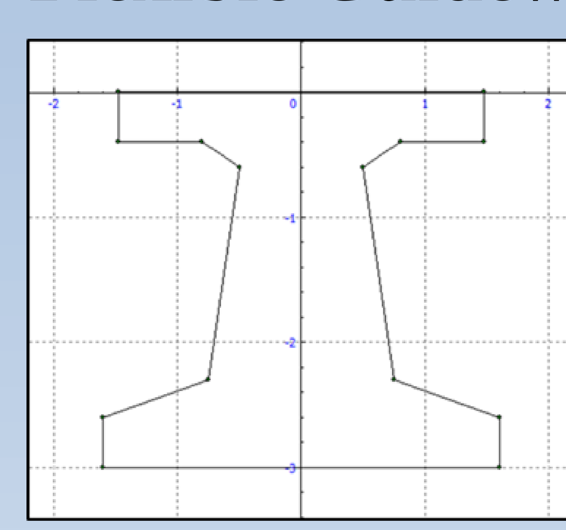
HTS Maglev Vehicle model



(a) The levitation frame model and (b) the HTS maglev train

Based on the experiment model we have developed, an HTS maglev train spatial-coupling dynamic model was built in UM. This dynamics model consists of 3 cars, and each car has 2 levitation frames. In every levitation frame, there are 24 dewars providing levitation and guidance force. And each frame contains 2 air spring supporting the carriage body. In this paper, we mainly focus on the vertical and lateral dynamics of the HTS maglev system, and the longitudinal di-rection was neglected. So, there are 5 degree of freedom (DOF) in each car body and levitation frames, and the whole model consists 45 DOF.

Flexible Guideway Model



Cross section of Shanghai TR-08

In this paper, a flexible guideway model was built by UM VBI and FEM module. This model uses a flexible concrete track, and its cross-section is in the shape of Shanghai TR-08.

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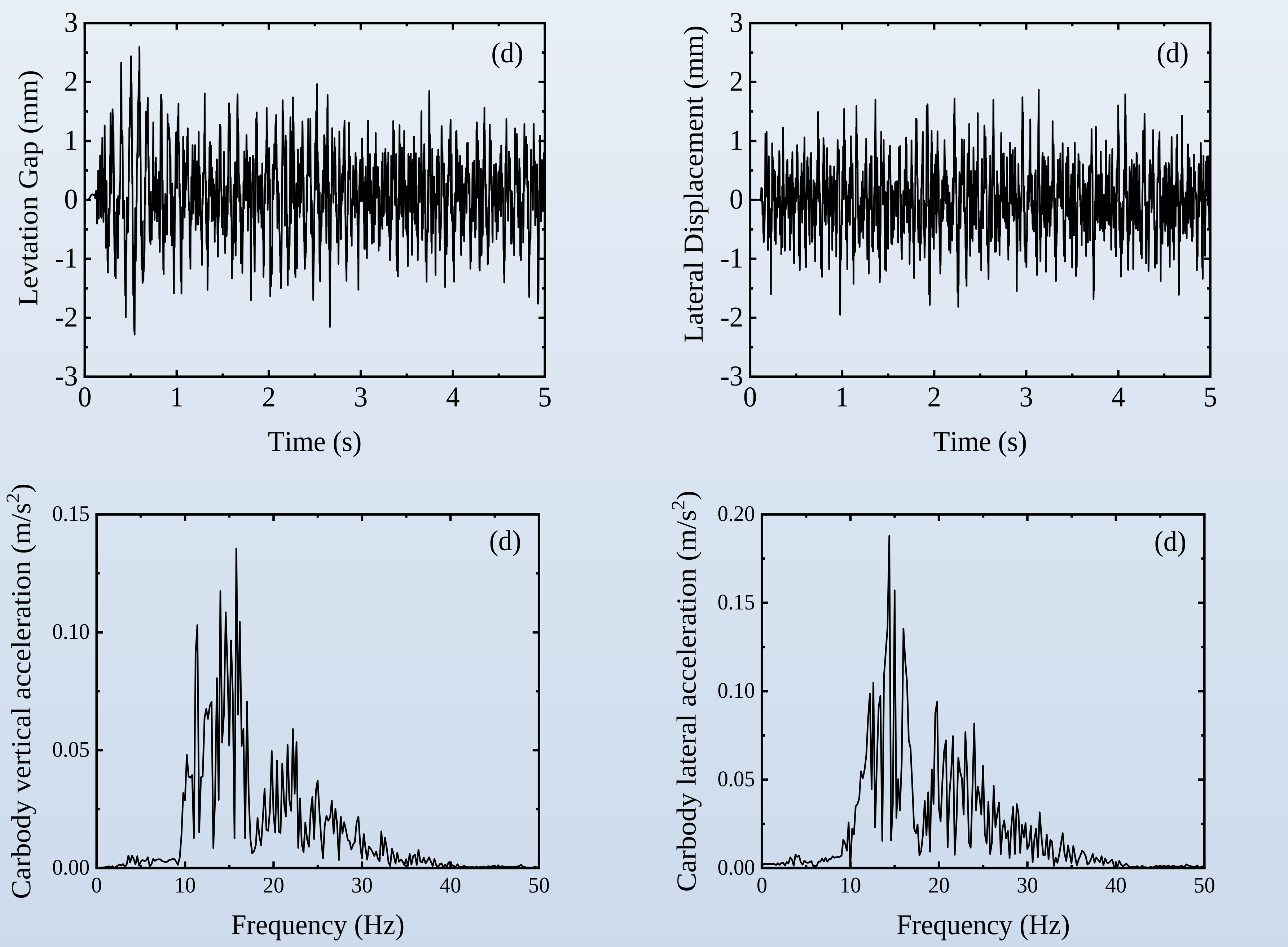
RESULTS AND ANALYSIS

Vibration Responses of Vehicle under Track Random Irregularity



Vertical and lateral displacement response of the dewars and vehicle at the speeds of 1000km/h

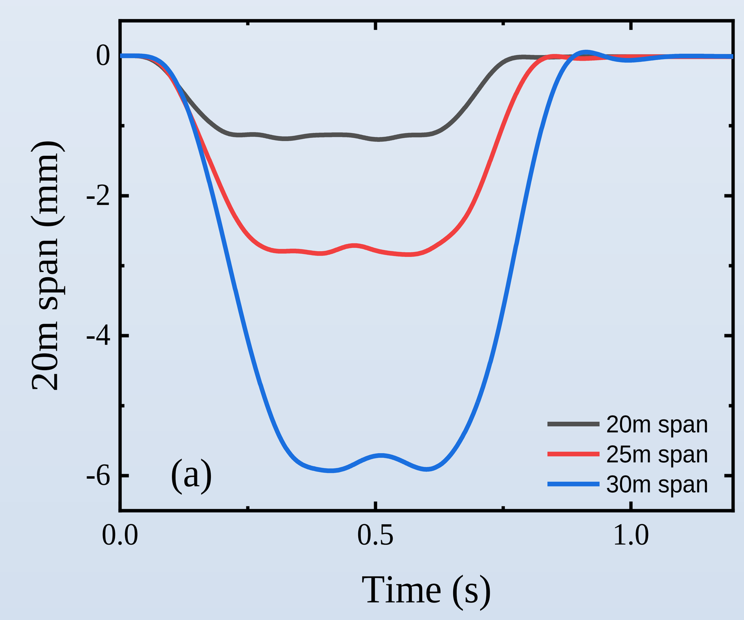
Four running speeds were tested in this simulation, which are 100km/h, 300km/h, 600km/h and 1000km/h. The irregularity spectrum is imported into the simulation model and calculated. Considering the current levitation height is at 10 mm, it can be considered that the train is safe under the excitation of track irregularity, and the risk of rail collision is very small.

In general, the maximum vertical acceleration of the car body is less than $0.15m/s^2$, and the maximum lateral acceleration is less than $0.2m/s^2$, which is much less than Based on the data from fast Fourier transform calculation, the Sperling indexes of middle car body at different speed were listed. We can see that both the vertical and lateral Spelling index of HTS maglev vehicle under track irregularity excitation are less than 2.5. It can be shown that the simulation vehicle can running very smoothly under the excitation of track irregularity.

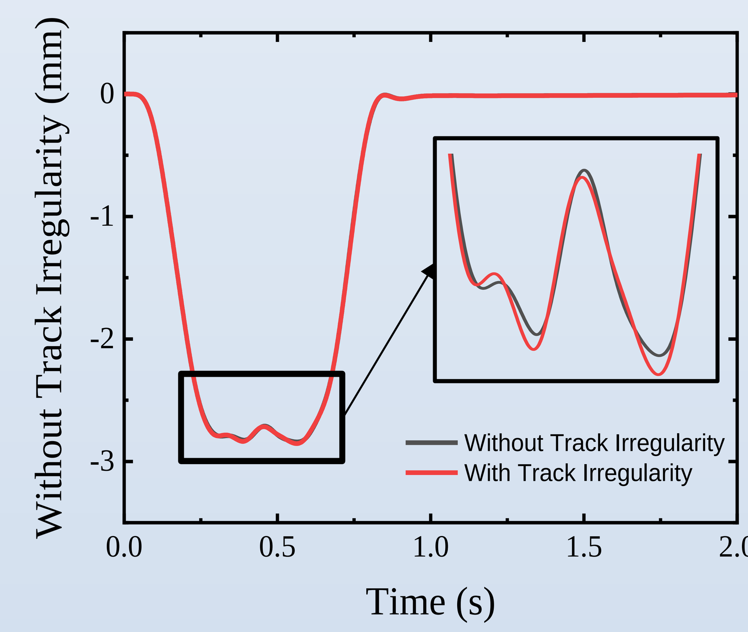
Sperling index

Speed	Vertical Sperling Index	Lateral Sperling Index
100km/h	1.37	1.49
300km/h	1.66	1.94
600km/h	1.94	2.02
1000km/h	1.94	2.17

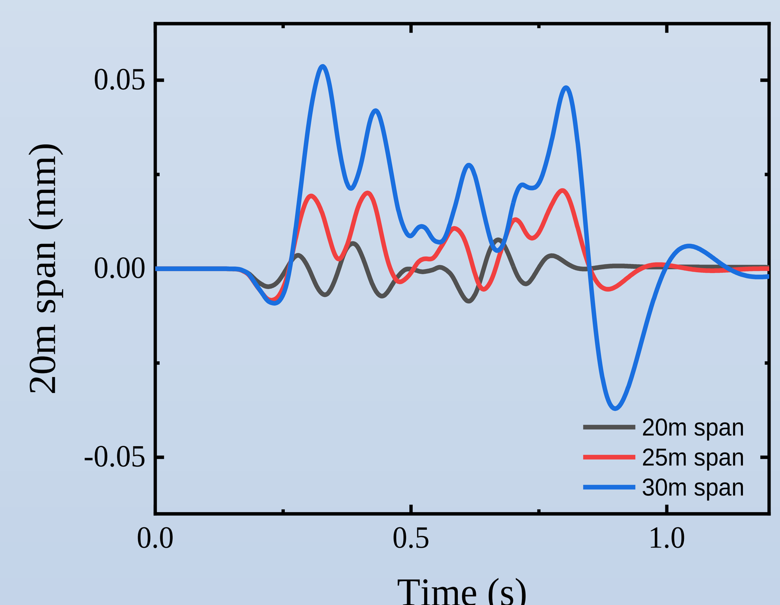
Vehicle-Track Coupling Effect



Vertical displacement response of the mid-span



Vertical displacement response of the mid-span



Lateral displacement response of the mid-span

The vertical displacement of the mid-span at speed of 300km/h is collected. The mid-span displacement of the bridges increases sharply with the increase of span length, but all meet the regulation code, and 30 m span is much close to the code. The vertical response of the bridge with track irregularity and without track irregularity are very similar, while the lateral data are very small.

The vertical Sperling index increases slightly with the vehicle-rail coupling effect, while the lateral Sperling stationarity index of the car body decreases significantly, which may be due to the vibration of the flexible bridge sharing part of the energy of irregular excitation.

Sperling index at 25 m span and 300km/h

	Rigid beam	25 m span flexible beam
Vertical Sperling index	1.66	1.74
Lateral Sperling index	1.94	1.72

CONCLUSION

This paper builds a HTS maglev vehicle-bridge coupled model considering vertical-lateral coupling effect in UM, and analyzed the response of vehicles and bridges. Through the calculation results we have learned that track irregularity is the main excitation for vehicles, but it hardly affects the response of bridges.

The responses of both vehicles and bridges of HTS maglev fit relative specifications， while the all Sperling index is excellent. The mid-span deflection of bridges increases sharply with the increase of span, and it has both good and bad influences on the vehicles.

In general, HTS maglev trains can run safely and smoothly under track random irregularity.

HTS Maglev-ETT test system

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