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An iterative interacting method for dynamic analysis of the maglev train–guideway/foundation–soil system

Y.B. Yang [a,1], J.D. Yau [b,*]

[a] Department of Construction Eng., National Yunlin University of Science and Technology, Yunlin, 64002, Taiwan

[b] Department of Transportation Management, Tamkang University, Taipei, 25137, Taiwan

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ABSTRACT

This paper presents an *iterative interacting method* for analyzing the dynamic response of a maglev train traveling on an elevated guideway supported by piers embedded in soil. The maglev train is idealized as a row of 2D *rigid beams* each suspended by levitation forces and controlled by onboard PID controllers. The guideway is modeled as a series of simple beams supported by *rigid* piers embedded in an elastic half-space. To address the structure interactions from the train to the soil and vice versa, the entire model is decomposed into two subsystems, i.e., the maglev train–guideway and foundation–soil subsystems, each interacting with the other via the rigid piers. The procedure of analysis is as follows: First, the train–guideway subsystem is computed, and the support reactions are used as excitations to the elastic half space. Next, the ground vibrations induced by the pier excitations are computed and fed back via the supports for computing the train–guideway response. The procedure is repeated until the convergence condition is satisfied. The solution obtained for a 2-degree-of-freedom system under a harmonic force is compared with the analytical one to verify the validity of the method proposed herein. The effects of ground wave propagation on the vehicle–guideway response will be evaluated in the numerical examples.

1. Introduction

Successful operation of a commercial maglev (magnetic levitation) line in Shanghai (2002) opened up a new avenue of more efficient and environmental-friendly guided ground transportation [1]. In 2005, a low speed maglev route (Tubo Kyuryo Line) was implemented to serve the local transport of EXPO 2005 in Aichi, Japan. In 2008, an urban transit maglev system (UTM-02) started to operate between the Expo Park and National Science Museum in Daejeon, Korea [2]. Because of no physical contact for maglev vehicles levitating on a guide-rail, the maglev transport system possesses several advantages, such as low noise, less energy consumption and waste gas discharge, and environmental friendliness. In general, there are two kinds of maglev technologies developed for practical applications: (1) the electrodynamic suspension (EDS) with repulsive mode [1,3,4]; (2) the electromagnetic suspension (EMS) with attractive mode [4]. The major discrepancies between them are: (1) The EDS system takes off a running vehicle above its guide-rail with a large guideway clearance of about 10–15 cm when the moving speed exceeds a liftoff speed (100–150 km/h); (2) The EMS system can lift a vehicle up to 8–10 mm at any speed by the use of distributed magnets beneath the guide-rail.

Over the past decade, the dynamic problem of maglev vehicles interacting with a guideway has received increasing attention from researchers and railway engineers [5–15]. Considering the interaction response of a two-span guideway girder subjected to various high-speed maglev vehicle models, Cai et al. [5] pointed out that a concentrated-load vehicle model might give rise to larger response on both guideway deflection and vehicle acceleration than a distributed-load vehicle model. In addition, Cai and Chen [6] provided a literature review for various aspects of the dynamic characteristics, magnetic suspension systems, vehicle stability, suspension control laws of maglev-guideway coupling systems. To investigate the vibration behavior of a maglev vehicle moving over a flexible guideway, Zheng et al. [7,9] developed two kinds of vehicle–guideway coupling models with a controllable magnetic suspension systems to observe the stability phenomena of divergence, flutter, and collision on the dynamic system. Zhao and Zhai [8] simulated a TR06 carriage as a 10-degree-of-freedom (DOF) vehicle model with a rigid car body supported by four sets of equivalent bogie systems to investigate the vertical random response and ride quality of a maglev vehicle traveling on elevated guideway girders. Shi et al. [10] considered the random nature of guided rail irregularity in the dynamic analysis of an EMS

* Corresponding author. Tel.: +886 2 26215656 3139; fax: +886 2 23959041.
E-mail address: jdyau@mail.tku.edu.tw (J.D. Yau).

1 On leave from the National Taiwan University.

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