Review of Coupled Vibration Problems in EMS Maglev Vehicles

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(Received 14 April 2009; revised 28 January 2010; accepted 5 November 2009)

The maglev train is a new type of guideway transportation for both long distance and urban applications in the 21st century. Recent progress in maglev technology indicates a probability of widespread commercial application of maglev systems in the near future. However, some economic and technical issues remain to be solved before the commercial application, and the vehicle-guideway coupled vibration problem is the most urgent technical problem that needs to be solved. In this article, the maglev vehicle-guideway coupled vibration problem, especially for the EMS system, is presented and divided into three main areas: the stationary vehicle-guideway, self-excited vibration; the moving vehicle-bridge coupled vibration; and the vehicle-guideway interaction caused by track irregularity. The available literature relevant to all the three coupled vibration problems is reviewed here, and the methodologies and main conclusions corresponding to each coupled vibration problem are compared and generalized as a reference for future work. The solutions proposed in the literature aiming to solve the coupled vibration problems are also enumerated, and their feasibility is discussed. Finally, work still required to solve the remaining problems is identified, and some suggestions for future research aimed at solving these remaining problems are provided.

1. INTRODUCTION

1.1. The Development of Maglev Systems

The maglev vehicle is a new type of guideway transportation for the 21st century. Compared with conventional railway systems, it has advantages of low noise, high speed, and the ability to climb steep slopes.[1] Research on maglev vehicles can be traced back to the 1960s.[1,3] The first-high speed commercial demonstration line around the world, 30 km long, was constructed in Shanghai, China, in 2003, using German Transrapid technology. The operating speed of this demonstration line is 430 km/h, and a maximum speed of 501 km/h has been achieved.[1] In Japan, a maximum manned-speed record of 581.7 km/h was achieved by the MLX01 maglev system in 2003;[2,4] in November 2004, a relative speed of 1026 km/h was reached when two vehicles were passing each other.[5] In 2005, the first low-speed commercial line, the Tubo-kyuryo Line (TKL), adopting HSST-100L technology, was established in Japan, demonstrating that the low-speed maglev system had reached the commercial application phase.[2,6,7] Countries such as Korea,[9–15] the United States,[16–23] and the United Kingdom[2,24,25] have also started their own maglev programs. Recently, it has been reported that Korea's Urban Maglev Program is planning to construct a 6.1 km urban maglev demonstration line at Incheon International Airport by 2011.[26] In China, a 1.5 km low-speed maglev test line was established in Tangshan in 2008; in 2009, the CMS04 vehicles began their test runs in this test line. In addition, the possibility of constructing a 170 km Shanghai-Hangzhou high-speed maglev line in China is also under discussion.[27] The progress in maglev technology indicates a high probability of widespread commercial application of maglev systems in the future.[2]

Generally, maglev systems can be divided into two categories: the EMS (Electromagnetic Levitation System) and the EDS (Electrodynamics Levitation System).[3] The EMS system uses electromagnetic attraction force as its suspending force, while the EDS system generally uses magnetic repulsive force. The German Transrapid system, the Japanese HSST system, the Chinese CMS system, and the Korean UTM system are EMS type, while the MLU system is a typical EDS system. The EDS system can also be divided into two subclasses: the PM (Permanent Magnet) type and the SCM (Superconducting Magnet) type. Compared with the EMS system, the EDS system enables a larger suspension gap (up to 100 mm) and is inherently stable; therefore, it is unnecessary to control the air gap between the vehicle and the track during the operation. However, the SCM type EDS system, such as the MLX system, needs sufficiently high speed to obtain enough induced current for levitation. Therefore, this system is suitable for long-distance and high-speed transport. The EMS system, although inherently unstable and requiring constant control, is able to levitate at a standstill and is commercially available.

Recently, during the development of the study on the EM-PM (Electromagnet-Permanent magnet) hybrid levitation system,[28,86] some researchers[3,28] have suggested that the EM-PM hybrid levitation system be independently categorized as