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High-T_c Superconducting Maglev Prototype Vehicle Running at 160km/h in an Evacuated Circular Test Track

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Abstract

YBCO bulk-type high-T_c superconductor (HTS) and permanent magnetic guideway (PMG) based maglev train is intensively studied in China, Japan, Germany and Brazil, mainly through static or vibration test. Amongst these studies, only a few of reports are available for the direct and effective assessment on the dynamic performance of the HTS maglev vehicle by running on a straight or circular PMG track. The highest running speed of these experiments was lower than 50 km/h due to a short length in a straight test tract or weak guiding force in a circular tract. In this paper, we report that a side-suspended HTS permanent magnetic guideway maglev system is constructed, which shows a highly stable suspension beside the permanent guideway even in a high running speed. A speed up to 160 km/h in a circular test track with 6.5 m in diameter is achieved for the first time for this type of maglev prototype system. Theoretical analyses and experimental results reveal that the dynamical stability of this type of side-suspended HTS-PMG maglev system relies on configuration of YBCO bulks above the permanent guideway. A increasing pressure between the superconducting bulks and the permanent guideway in this side-suspended circular tract system also provides an interesting platform for studying the dynamics of HTS-PMG maglev system with a varying load and a high running speed.

Introduction

Dynamic behavior of the Maglev system is an important aspect in characterizing the properties of the system. So far, most of the researches on the dynamic operation of the HTS maglev vehicle is performed mainly by testing on a short-distance linear tract or small-radius circular track.

The test speed was not high due to a limited length of the driving motor and short radius of the circular track. In order to investigate the dynamical properties of the HTS maglev system in a high running speed, it is necessary to design and constructor HTS maglev system which can reach a much higher speed than what was achieved previously. In this paper, we report the design and construction of a side-suspended-HTS maglev circular track system, in which the PMG track was laid on the wall to allow the vehicle to operate at a high speed.

Design and Construction

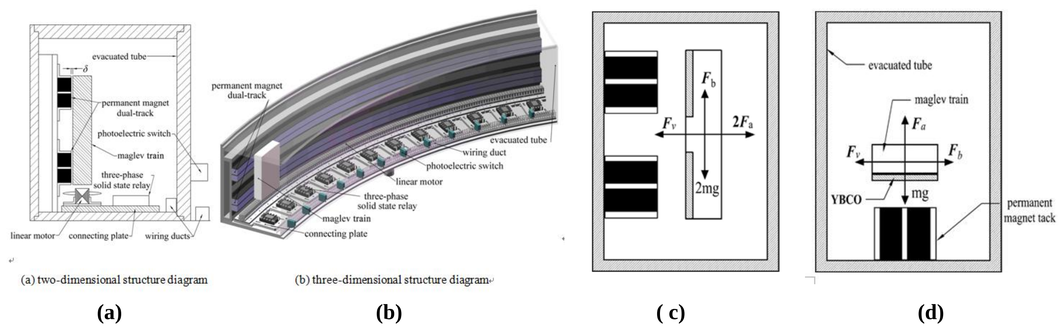


Fig. 1. Part of the schematic of high-T_c maglev track in an evacuated tube. (c) and (d) show the side suspension and up-down levitation.

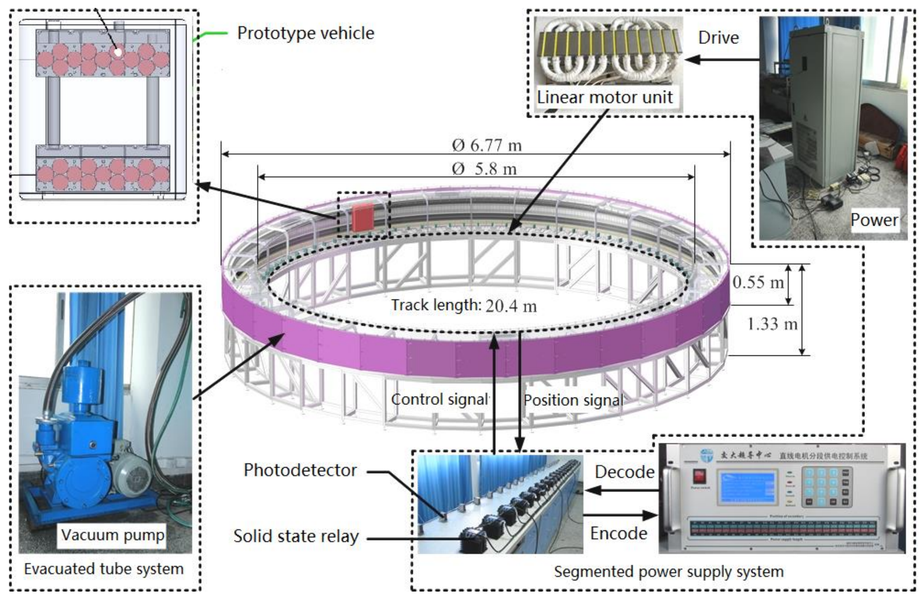


Fig. 2. Structure of SS-HTS maglev test circular track system with an evacuated tube, which is consist of SS-HTS maglev system, Evacuated tube system, and the segmented power supply control system.

Results and Discussion

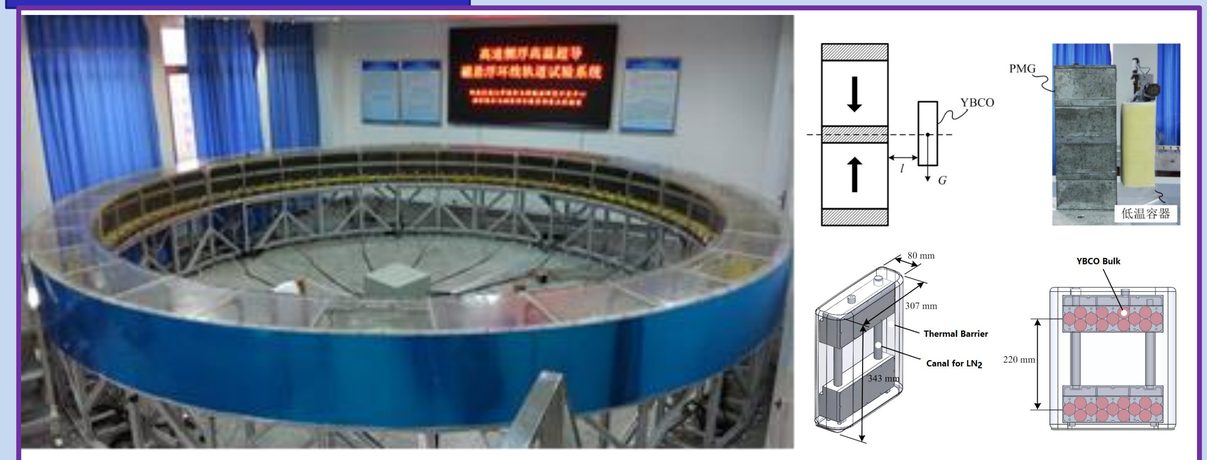
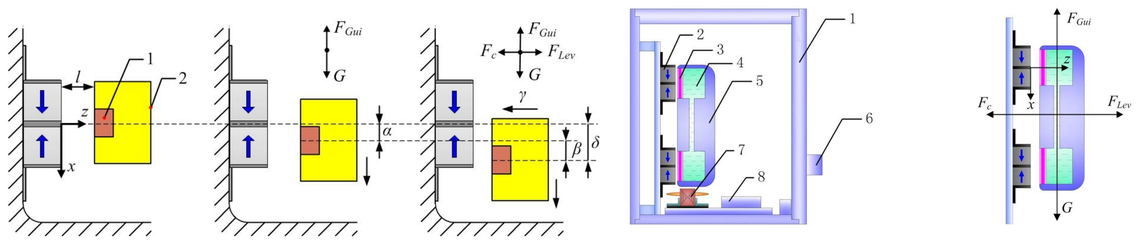


Fig. 3. The practical system for the high-T_c maglev track in an evacuated tube. The side-suspension is graphically presented.



$$F_x = -a\int_0^h dz\int_{-b}^{b} dx\left[\Delta M(x,z)G(x,z) + M(x,z)\Delta G(x,z)\right]$$
$$= -a\int_0^h dz\left(\int_0^b dx\left(-\frac{p}{\mu_0}\left[G(x,z)\right]^2\delta\right) - \int_{-b}^{b} dx\left(M_s\left[G(x,z)'\delta\right]\right)\right)$$
$$= a\int_0^h dz\left(\frac{p}{\mu_0}\int_0^b dx\left[G(x,z)\right]^2 + M_s\int_{-b}^{b} dx G(x,z)'\right)\delta$$
$$= a\int_0^h dz\left(\frac{p}{\mu_0}\int_0^b dx\left[G(x,z)\right]^2 - 2M_s\left|G(b,z)\right|\right)\delta$$

$$F_x = \left(k_1(l) - k_2(l)\right)\delta$$
$$k_1(l) = \frac{ap}{\mu_0}\int_0^h dz\int_0^b \left[G(x,z)\right]^2 dx$$
$$k_2(l) = 2aM_s\int_0^h \left|G(b,z)\right| dz$$

Fig. 4. The mechanical analyses for the side-suspension system. The guiding-force was calculated, which reveals that a complicated relation between the guiding force and the position deviation.

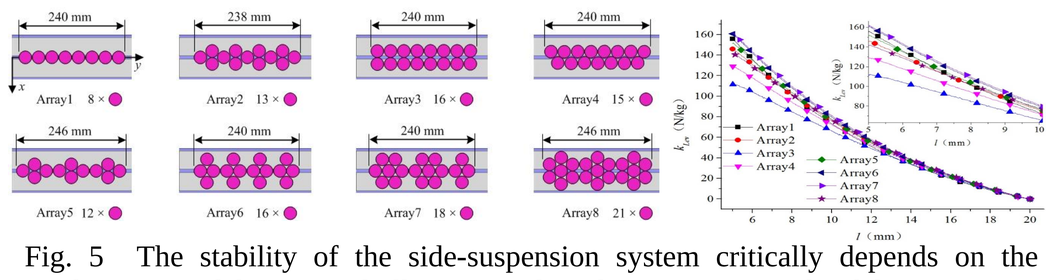


Fig. 5 The stability of the side-suspension system critically depends on the configuration of the YBCO bulks surrounding the symmetric axils of the PMG.

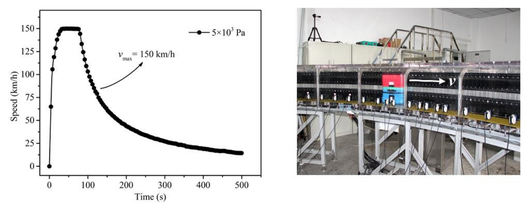


Fig. 6. The evolution of the velocity of the prototype maglev vehicle in the evacuated tube.

Conclusion

The experimental results have demonstrated that the side-suspension high-T_c superconducting maglev system is a good solution for achieving a high running speed in a circular track with a small diameter. It is also revealed that the stability of the side-suspension system critically depends on the configuration of the YBCO bulks surrounding the symmetry axils of the PMG. A triangle arrangement of the YBCO bulks surrounding the symmetry axils of the PMG provides the best stability for the side-suspension high-Tc superconducting maglev system.