

Analysis and comparison of operation principle of two ways of running maglev trains

Gurong Wu*

Qibaodwight high school, Shanghai, 201101, China

* Corresponding Author Email: grwu_grant@qibaodwight.org

Abstract. With the continuous development of rail transportation, people have put forward higher requirements for high-speed train and ride comfort. At present, the world's most advanced and fast rail transportation is the maglev train. Its development will surely bring more convenience to people's production and life. This paper describes two common operating modes of maglev train and their respective advantages and disadvantages. At the same time, their structure and principle are analysed. In this paper, the whole development process of maglev is introduced, and it is divided into different major countries. Finally, it gives some constructive suggestions on the future development direction of maglev, and puts forward the direction of vacuum passage, supplemented by practical research examples.

Keywords: Magnetic levitation train, electromagnetic levitation system, electric levitation system, vacuum tube.

1. Introduction

People's travel methods continue to improve, maglev train is now the representative of efficient land travel. However, it works in two ways, and the two fit in different places. At present, the design of suspension system can be divided into two directions: normal conductance type and superconducting type. The normal conduction type is also known as the normal magnetic absorption type. It uses the principle of electromagnetic suction of ordinary DC electromagnet to suspend the train, and the suspended air gap is small, generally about 10 mm. The speed of the normal maglev is 400~500km/h [1]. Superconducting type, also known as superconducting magnetic repulsion type, makes use of the strong magnetic field generated by superconducting magnets to interact with the coils arranged on the ground during train operation, generating electric repulsive force to levitate the train. The suspended air gap is large, generally about 100mm, and the speed can reach more than 500km/h. The levitation technology is electromagnetic levitation system (EMS) and electric levitation system (EDS). In this paper, the two methods are compared and the scenarios suitable for each other are obtained to provide help for the planning of the local government. Civilian adoption of the maglev is more likely.

2. History and development

2.1. In the early development

Japan, due to its geographical position, was in urgent need of a medium and long-distance transportation suitable for inland areas, so it was the first country to begin research on permanent maglev trains, starting in 1962. And with the continuous progress of science and technology, gradually turn to superconducting maglev train technology research. It was not until the 1970s that japan successfully developed a super-high speed maglev train with a speed greater than 500km/h, and it ran safely with passengers on board. In 1995, a manned maglev train was tested at speeds of up to 411km/h. In December 1997, he set the world's highest speed of 550km/h on a test line in Yamanashi Prefecture [2].

Germany began to do research on maglev trains in 1968. At the beginning, the normal conductor and superconductor were paid equal attention to. After comparing the cost, durability and safety of ordinary conductor and superconductor test trains, Germany, different from Japan, chooses to focus

on the development of permanent maglev trains and continuously makes technological breakthroughs in them. At present, Germany has become the most mature country in the research of permanent magnet maglev train technology in the world, and has become the reference object of most countries in northern Europe.

In the early 1980s, China began to conduct research on low-speed normal maglev trains. In October 1994, Southwest Jiao tong University completed the first test line of maglev railway, and carried out the manned test of maglev train at the same time, successfully carried out the test of the maglev train with 4 seats, the dead weight is 4T, the suspension height is 8mm, the speed is 30km/h, which passed the expert appraisal organized by the Ministry of Railways in January 1996. Then, in the Institute of Iron Research ring test line gauge 2M, 36m long, designed for a speed of 100km indoor maglev test line successfully on the length of 6.5m, 3M wide, weight 4T, 15 seats, designed for a speed of 100km/h of the low-speed normal 6T single bogie maglev test car In November 1998, it passed the appraisal of scientific and technological achievements of the Ministry of Railways, which filled the gap in the field of maglev train technology in China [3].

2.2. Current situation of the development

The L0 maglev train is the latest type of maglev train in Japan. The model is made up of five carriages and has a commercial speed of 500 km/h. A test run with a total distance of 4,064 km was conducted on 14 April 2015, updating the previous record of 2,876 km in 24 hours in 2003. On April 16, 2003, the seven-car train reached a maximum speed of 590 km/h, surpassing the world record of 581 kilometres per hour set by the MLX01-2 high-speed train on December 2, 2003. The current world record, 603km/h, is held by the L0 high-speed train, which was set in 2015 [4].

In 2016, Changsha Maglev Express train with a speed of 100 km per hour was put into operation under the lead of CRRC Zhujiang Machinery Corporation, which was called the 1.0 version of China's commercial Maglev train in the industry. Commercial Maglev version 1.0 is more suitable for urban areas. In June 2018, China's first commercial maglev 2.0 train rolled off the production line at CRRC Zhuzhou Electric Locomotive Co LTD. The 2.0 version of the train is designed to run at 160 kilometres per hour and has three compartments with a maximum capacity of 500 passengers. In addition, the vehicle's traction power is increased by 30% and its suspension capacity is increased by 6 tons. The commercial Maglev 2.0 train is suitable for transportation between central cities and satellite cities [5]. At 10:50 on May 23, 2019, China's 600km/h high-speed maglev test vehicle rolled off the assembly line in Qingdao. This marks a breakthrough in China's high-speed maglev technology.

3. EMS and EDS technology

3.1. EMS technology

3.1.1. Principle

More traditional EMS-style maglev trains work by using the attraction of magnets on the train and on the track to levitate the train. In the actual operation process, it is necessary to fine adjust the suspension distance of the vehicle and the suction generated by the electromagnet, so as to generate enough and appropriate lift force, so that the train can be suspended. And when the vehicle is running, the wheel also needs to keep a certain lateral distance with the track, so that the friction force is further reduced. At the same time, in the process of train operation, it is necessary to carry out horizontal and vertical direction guidance to ensure the safe operation of the train [6]. The structure of EMS was shown in figure 1.

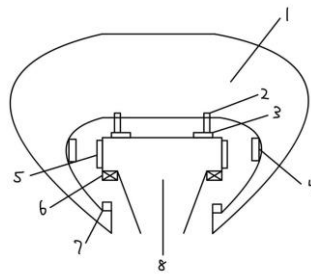


Figure 1. The structure of EMS.

1: Vehicle 2: slider 3: slide way 4: guide and brake magnet 5: guide and brake track 6: long stator core armature winding 7: suspension and propulsion magnet 8: T-beam

3.1.2. Advantage and disadvantage

The suspension air gap of the normal maglev is small, and it is still in suspension at low speed and parking. And the magnetic field inside and outside the car is relatively weak, no harm to the human body. Also, the load on the line is continuously dispersed, reduce the pressure of trails.

However, the guidance of normal maglev requires closed-loop control. At the same time, the normal conductance electromagnet has safety redundancy, and the vehicle weight is relatively large. Crucially, it is relatively slow.

3.2. EDS technology

3.2.1. Principle

Different from EMS operating principle, EDS adds current to the train track, resulting in electromagnetic induction repulsion between the track and the bottom of the train. The smaller the gap, the stronger the repulsive force, which makes the train levitate in the air. However, in the actual running process, when the train runs at a slow speed, the lift force provided by it is no longer enough to support the train levitating. Therefore, the train will be equipped with wheels at the bottom to ensure safety during the start and stop stages. Low temperature superconductivity technology has further developed EDS system. The main characteristic of superconducting maglev train is that its superconducting elements have complete conductivity and diamagnetism. The electric suspension system can be explained by Lenz's law [7]. According to the principle of "magnetic generation of electricity", the movement of on-board magnets will generate time-varying magnetic field in space, which in turn will generate induced eddy current inside the conductor, and the induced magnetic field will be generated by the "electrogenerated magnetism" and the source magnetic field to generate electromagnetic force. The structure of EDS was shown in figure 2.

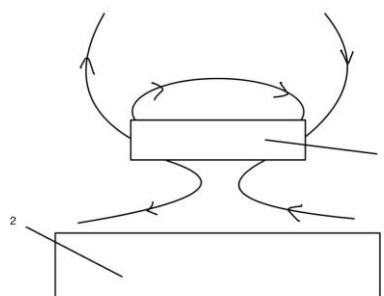


Figure 2. The structure of EDS.

1. Ferromagnetic 2. Superconducting disk

3.2.2. Advantage and disadvantage

Since the superconducting magnets of the Japanese superconducting maglev system are not redundant, in order to ensure the efficiency of the maglev train, the superconducting magnets are required to have high reliability. The failure of superconducting magnet is a key problem affecting

the normal and safe operation of the vehicle. After nearly ten years of research, the cause of the failure of the system has been found, and it has been studied and confirmed under laboratory conditions, and the possibility of the failure of the system has been fundamentally eliminated. The average fault-free time of superconducting magnets has reached more than 100,000 hours. Superconducting magnets provided by three companies have been used on the Yamanashi test line maglev train, and so far, no out-of-voltage phenomenon has been found. In addition, superconducting maglev vehicles weigh less and travel faster. At the same time, the hover guidance does not need control, has stability.

However, at low speed, the vehicle needs to be supported and guided by wheels, and the load of the vehicle on the line is relatively concentrated, and the pressure on the line is large. Finally, its magnetic field is relatively strong, making it unsuitable for patients who need pacemakers.

4. Technical challenges and future development

4.1. Challenge

4.1.1. Challenge 1 Emergency braking strategy and implementation

With the increase of speed, the safety braking ability of trains is also one of the core problems. For a train traveling at 600 kilometers per hour, it is very difficult to stop it in time. Because this is magnetic levitation, it is obviously not realistic to adopt normal friction braking. Therefore, I need to consider the combination of eddy current braking and friction braking, and realize the joint effect of different braking means through reasonable control strategy adjustment, so as to ensure high-speed and accurate parking under emergency braking [8].

4.1.2. Challenge 2 High-speed vehicle-ground communication technology

The safe and efficient operation of high-speed maglev train cannot be separated from the support of wireless communication system. Facing the 600 km/h train, the communication stability and reliability requirements between the car and the ground become higher. High speed movement will cause frequent switching and Doppler Effect [9]. The traction and levitation control system generally requires the transmission delay of train position information within 5 ms, which poses a challenge to the wireless communication system. If the vacuum pipe transmission is adopted, there will be waveguide phenomenon in the metal closed pipe, which leads to the difficulty of wireless coverage in the pipe. Therefore, it is necessary to carry out prospective research on vehicle-ground integrated communication system, and form a system solution by wireless access to 5G technology under the mode of leakage cable or leakage waveguide coverage.

4.1.3. Challenge 3 Aerodynamic noise problem

Another obvious challenge is the aerodynamic noise generated by high-speed maglev trains. Due to its very fast running speed, huge aerodynamic noise will be generated during the train operation, which will affect the surrounding environment. The aerodynamic noise generation mechanism of train running on open line can be summarized as the noise generated by turbulent flow and the noise generated by air flowing through the surface of the structure parts. Therefore, for high-speed operation, it is necessary to optimize the shape of the high-speed maglev train head and body exterior. In addition, it is necessary to increase the sound insulation performance of the body and tunnel structure.

4.2. Development direction

The energy required to pull a train is determined by the interaction between the train and the environment, and is mainly used to overcome friction and air resistance. When the train runs at high speed under air conditions, the aerodynamic drag is the main part, which is proportional to the square of the speed. The experimental data show that when the train speed exceeds 400 km/h, the aerodynamic drag takes up at least 80% of the total drag [10]. Therefore, in order to reduce the energy required to pull the train and further improve the running speed, it is very important to reduce the

aerodynamic resistance which is dominant when the train runs at high speed. One technical solution is to run maglev trains inside low-pressure pipes and optimize their shape. Under such conditions, the train can reach subsonic or even supersonic speed. In July 2019, the TUM Hyperloop team created a test speed of 463 km/h on a 1.6-km long vacuum tube test line. But the technology is still very immature and a long way from being used. Even though the technology has great future potential, the system is still in its early stages, so further research is necessary to address a number of technical issues.

5. Conclusion

Maglev transportation system is a non-contact transportation technology that uses electromagnetic force to realize levitation, guidance, and traction. Maglev trains are one of the key research and development directions in the railway industry due to their superior high speed and environmental potential. In this paper, the PRINCIPLES of two different modes of magLEV operation are systematically described, the technical difficulties in their application are briefly sorted out, and the development status and research and development activities of magLEV transportation system and vacuum pipeline maglev transportation in the world in recent years are reviewed. Maglev transportation has excellent high-speed potential and environmental advantages, and researchers need to carry out further research in different aspects for the application of 600 km/h. In order to pursue higher speed, several research institutions have combined vacuum pipeline and maglev technology to carry out theoretical analysis and experimental exploration. For engineering applications, it is necessary to carry out continuous and in-depth research.

References

- [1] Qadir, Z., Munir, A., Ashfaq, T., Munawar, H. S., Khan, M. A., & Le, K. (2021, October). A prototype of an energy-efficient MAGLEV train: A step towards cleaner train transport. *Cleaner Engineering and Technology*, 4, 100217.
- [2] Wang, D., Li, X., Liang, L., & Qiu, X. (2020, February 26). Dynamic interaction analysis of bridges induced by a low-to-medium-speed maglev train. *Journal of Vibration and Control*, 26(21–22), 2013–2025.
- [3] Jeon, K. W., Shin, K. B., & Kim, J. S. (2013, August). A study on evaluation of fatigue strength of a GFRP composite bogie frame for urban subway vehicles. *Advanced Composite Materials*, 22(4), 213–225.
- [4] Lai, Q., Liu, J., Haghani, A., Meng, L., & Wang, Y. (2020, September). Energy-efficient speed profile optimization for medium-speed maglev trains. *Transportation Research Part E: Logistics and Transportation Review*, 141, 102007.
- [5] Guang Yang, & Zhenmin Tang. (2005). The analysis of high-speed wheel-rail train and high-speed maglev train safety systems. *Proceedings of ICSSSM '05. 2005 International Conference on Services Systems and Services Management*, 2005.
- [6] He, Y., Wu, J., Xie, G., Hong, X., & Zhang, Y. (2021, August). Data-driven relative position detection technology for high-speed maglev train. *Measurement*, 180, 109468.
- [7] Fujii, N., Ogawa, K., & Chida, M. (1997). Three-Dimensional Force of Magnet Wheel with Revolving Permanent Magnets. *1997 IEEE International Magnetics Conference (INTERMAG'97)*.
- [8] Krüger, K., & Schumann, R. D. (1993, January 12). Effects of Dimilin, an insect growth regulator, on behaviour, fertility and development of a non-target organism, *Leptothorax acervorum* (Hym., Formicidae). *Journal of Applied Entomology*, 115(1–5), 526–531.
- [9] Hyung-Woo Lee, Ki-Chan Kim, & Ju Lee. (2006, July). Review of maglev train technologies. *IEEE Transactions on Magnetics*, 42(7), 1917–1925.
- [10] Ma, D., Song, M., Yu, P., & Li, J. (2020, October 27). Research of RBF-PID Control in Maglev System. *Symmetry*, 12(11), 1780.