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Maglev Trains in China

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ABSTRACT

China is developing maglev trains that can travel at speeds of up to 1,000 km/h (621 mph). The trains make use of magnetic levitation to float above the ground, eliminating the need for wheels and brakes which could revolutionize travel in China. Some of the features are its: speed, technology, light weight, and being environmentally friendly. Some examples are: the Shanghai maglev train with the maximum cruising speed of 300 km/h (186 mph), and the Vacuum tube maglev train with the speed of 623 kph in tests. The high-speed rail (HSR) network in the People's Republic of China (PRC) is the world's longest and most extensively used. The HSR network encompasses newly built rail lines with a design speed of 200-380 km/h (120-240 mph). The benefits include shortened travel times, improved safety and better facilitation of tourism, labor and mobility, as well as reducing highway congestion, accidents and greenhouse emissions as some automobile travelers switch from car use to rail. This leads to an estimated net benefit of approximately $378 billion, with an annual return on investment of 6.5%. This paper looks at the pros, cons, and the benefits of maglev trains in China.

KEYWORDS: *Magnetic levitation technology, 5G connectivity, stability, precision, radiation, electromagnetic suspension (EMS), electrodynamic suspension (EDS), guideway*

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INTRODUCTION

Maglev (short for magnetic levitation) is a new mode of transportation that lifts and propels vehicles or trains using very powerful magnets. It is not compatible with conventional high-speed rail trucks, hence the need for a completely new infrastructure. The large initial investment cost for the construction of maglev infrastructure is a serious impediment to commercial use of maglev technology [1]. Maglev trains in China and Shanghai make use of 5G networks for broadband communication, enhanced coverage, and high-speed rail transit.

China's Maglev train (Shanghai Maglev train – SMT) is also known as the Shanghai Transrapid, is a magnetic levitation train line that operates in Shanghai, connecting Shanghai Pudong International Airport and Longyang Road station, as shown in Figures 1 and 2.

Shanghai Maglev Demonstration Operation Line is said to be a magnetic levitation train (maglev) line that operates in Shanghai, China. This line makes use of the German Transrapid technology, which is from a consortium of Siemens, ThyssenKrupp and the German government [2-4]. China is making the moves to improve railway transportation within the country by embarking on two ambitious high-speed railway lines using conventional steel wheels and rails, as shown in Figures 3 and 4. In March 2006, China approved the building of the world's first long distance commercial magnetic levitation railway (Maglev). The train has a maximum cruising speed of 300 km/h (186 mph), although it previously reached speeds of up to 431 km/h (268 mph) prior to May 2021, using the concept of magnetism to move the train at great speeds, as shown in Figures 5 and 6. This is the first time anywhere in the world that this type of technology has been used over any great distance.

HISTORY AND DEVELOPMENT

The construction of the line began on the 1st of March 2001 [5], while public commercial service commenced on 1 January 2004. The Shanghai

Transrapid project cost US$1.33 billion and took two and a half years to complete. The line is 30.5 km (18.95 mi) track and has a further separate track leading to a maintenance facility. The top operational commercial speed of the Shanghai maglev was 431 km/h (268 mph, making it the world's fastest train in regular commercial service from its opening in April 2004 until its speed reduction in May 2021) [6]. On 12 November 2003, in a non-commercial test run a maglev train achieved a Chinese record speed of 501 km/h (311 mph) [7].

The Shanghai Maglev has a length of 153 meters (502 ft 0 in), a width of 3.7 meters (12 ft 2 in), a height of 4.2 meters (13 ft 9 in) and three-classes, 574-passenger configuration (End section (ES) 1st class: 56; Middle section (MS) 2nd class: 110; End section (ES) 2nd class: 78) [8]. The train set model (Transrapid SMT) was built by a joint venture of Siemens and ThyssenKrupp from Kassel, Germany in 3 pieces (originally 4 pieces consisting of 6 wagons each were planned) and based on years of tests and improvements of their Transrapid maglev system, especially the Transrapid 08. The Shanghai Maglev track (guideway) was built by local Chinese companies who, due to the alluvial soil conditions of the Pudong area, had to deviate from the original track design of one supporting column every 50 meters (160 ft) to one column every 25 meters (82 ft), to ensure that the guideway meets the stability and precision criteria. Several thousand concrete piles were driven to depths up to 70 meters (230 ft) to attain stability for the support column foundations.

Electrification of the train was developed by Vahle, Inc. [9]. The Birmingham Maglev in the United Kingdom and the Berlin M-Bahn were the two commercial maglev systems that predated the Shanghai system. Both were low-speed operations and got closed before the opening of the Shanghai maglev train [4]. The train was inaugurated in December 2002 by the German chancellor, Gerhard Schroder, and the Chinese premier, Zhu Rongji [10] – in a demonstration of new technology which could transform modern ground transport, as shown in Figures 7 and 8. The price was 150 RMB for normal seats and 300 RMB for VIP seat, while the normal operation started on 10 October 2003.

In 2010 the fourth train of Chinese production (made by Chengdou Aircraft Industries) was added to the rolling stock, with its design slightly different from the original Transrapid-trains: separated front lights below the shortened front-windows (instead of being placed behind the windows) and interior design [4].

MAGLEV TECHNOLOGY

A charged body cannot rest in stable equilibrium when placed in a pure electromagnetic field. Current maglev systems will achieve a stable levitation using two types of maglev technology, which are [1]:

- Electromagnetic suspension (EMS)
- Electrodynamic suspension (EDS)

In EMS systems, the bottom of the vehicle is wrapped around the track like a C-shaped arm. Electromagnets are mounted in the part of the arm that is below the track. The electromagnets are attracted to the track and keep the vehicle hovering around the track. The strength of the magnetic field is continually altered by altering the current sent to the electromagnets. The distance between the train and track is approximately 15 millimeters. However, the instabilities occur with minor changes in distance between the magnets and the track. Thus, complex systems of feedback control are required to maintain stability.

In EDS systems, magnets on the train induce currents in the guideway. These currents create magnetic fields which interact with the original field of the magnets. Levitation is supported by the repulsive force between the two fields. The magnets on the train are either electromagnets or an array of permanent magnets. The advantage of EDS systems is that they are naturally stable and thus no feedback control is needed. However, EDS systems have a major disadvantage. The train must be equipped with wheels because at slow speeds the induced currents are not strong enough to support levitation.

Propulsion is typically provided by a linear motor, while the power needed for levitation is not a large percentage of the overall energy consumption of a high-speed maglev system. It is the overcoming drag that takes the most energy, The Vactrain technology is proposed as a means of overcoming this limitation [11].

"Levitation" is the process of object being suspended in the air without any physical contact or support, essentially defying gravity, which is achieved through the manipulation of magnetic fields or other forces that counteract the pull of gravity, e. g as in magnet levitation where a material like a superconductor repels a magnet, causing it to float [11].

FUTURE PLANS AND EXTENSIONS

There were various proposed plans for extensions of the Maglev train line to Shanghai Hongqiao International Airport and Hangzhou, after its approval by the central government in February 2006, work was suspended in 2008 due to public protests over radiation fears [12] despite an environmental assessment by the Shanghai Academy of

Environmental Sciences that the line was safe and would not affect air and water quality, and noise pollution could be controlled – as residents demonstrated in downtown Shanghai in January and February 2008, against the line being built close to their homes for the potential health hazards, noise, and loss of property value (Shanghai scheme buffer zone around the track will be 22.5 m (74 ft) wide, which compares unfavorably with German standards that require houses to be 300 m (980 ft) away from the line) [13].

RIDERSHIP AND REVENUE

After the opening, the ridership levels of the maglev train was a 20% of its capacity, which was attributed to limiting operating hours, the short length of the line, high ticket prices, and the termination at Longyang Road in Pudong – another 20 min by subway from the city centre [14]. The train is said to have transported over 50 million passengers since its opening, with an average annual ridership of around 3 million. Moreover, the train's revenue is generated from ticket sales, with prices ranging from US$8 or US$4.60 i. e. for passengers holding a receipt or proof of an airline ticket purchase. A round-trip return ticket costs US$12.80, while VIP tickets cost double the standard fare [4].

OPERATING COSTS

It cost $39.759 million per kilometer to build (10 billion yuan, 1.2 billion US dollars) for the line, with the balance of payments in huge deficit since it was opened. In its initial years of operation, the Shanghai Meglev Transportation Development Co. Ltd, the company that runs the line, had more than one billion RMB in losses. Transrapid USA in 2007 stated that 4 million passengers in 2006 the system was able to cover its operating costs. The ratio of costs were given as: 64% - energy, 19% - maintenance, and 17% - operations/support services; no overall amount of expenditures was given [4].

INCIDENTS

A Maglev train compartment caught fire on August 11, 2006 at 11:40 after leaving Pudong International Airport. No injuries or fatalities were recorded. Electrical problems was said to be the cause of the fire according to investigation reports [4, 15].

On 14 February 2016, the Shanghai maglev line had an equipment failure that affected operation for more than 1 hour. Due to the use of single-line operation during this time, the train interval was extended [4].

SPEED REDUCTION

At launch the Shanghai maglev had a cruising speed of 431 km/h (268 mph), which was later reduced to 300 km/h (186 mph) during most of the day, before it was then reduced to 300 km/h (186 mph) at all times [6].

CONCLUSION

The magnetic levitation (Maglev) as applied to trains offers a series of advantages in terms of speed, efficiency, sustainability, and smoothness than the conventional train. Despite all these, there is still need for continued investment and technological development to surmount the challenges of costs, and incompatibility with existing infrastructure, so as to make maglev trains a more reliable, environmentally friendly, safer and faster alternative to the conventional rail. Further information about Maglev trains in China can be found in [16, 17].

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Figure 1. Shanghai maglev train

Source:https://www.google.com/search?sca_esv=fde65a004f3df79d&sxsrf=AHTn8zpCXHuvQuUjCvbANKddDcPqt4l4zw:1740425125829&q=images+on+maglev+trains+in+china+by+wikipedia&udm=2&fbs=ABzOT_CWdhQLP1FcmU5B0fn3xuWpAdk4wpBWOGsoR7DG5zJBjLjqIC1CYKD9DDQAQS3Z5NmlRTZM9mMZwadeXOSzfMOuJ9MVOHDHVayNtOyOCEREm3RXZuZWpCKSNf1HgZ9GY_3s6mbwIMPgr4rsBKOtXrDRbh7ZTQllzMsxzAahWmrrBeh2A4_7NFFlJVSECdlabxCH&sa=X&ved=2ahUKEwi5_4frhN2LAxVZ4AIHHRzEPI0QtKgLegQIEhAB&biw=1036&bih=539&dpr=1#vhid=ZbuphKwh2AG5HM&vssid=mosaic

Figure 2. Shanghai maglev train

Source:https://www.google.com/search?sa=N&sca_esv=fde65a004f3df79d&udm=2&cs=0&sxsrf=AHTn8zqNplJQumL5khJ3O6Hc9TpS2Z7HZQ:1740429584310&q=china+maglev+train+map&stick=H4sIAAAAAAAAAFvEKpackZmXqJCbmJ6TWqZQUpSYmQfkFAAATWdHpxkAAAA&source=univ&ved=2ahUKEwjk4IO5ld2LAxVFTqQEHXHFDbI4MhCs3AJ6BAgNEAA&biw=1036&bih=539&dpr=1#vhid=B8Gxu109tD5eeM&vssid=mosaic

Figure 3. High-speed rail in China

Source: https://en.wikipedia.org/wiki/High-speed_rail_in_China

Figure 4. High-speed rail in China

Source:https://www.google.com/search?sa=N&sca_esv=fde65a004f3df79d&udm=2&cs=0&sxsrf=AHTn8zqNplJQumL5khJ3O6Hc9TpS2Z7HZQ:1740429584310&q=china+maglev+train+map&stick=H4sIAAAAAAAAAFvEKpackZmXqJCbmJ6TWqZQUpSYmQfkFAAATWdHpxkAAAA&source=univ&ved=2ahUKEwjk4IO5ld2LAxVFTqQEHXHFDbI4MhCs3AJ6BAgNEAA&biw=1036&bih=539&dpr=1#vhid=xlvUn32UuqnU-M&vssid=mosaic

Figure 5. Beijing-Guangzhou high-speed railway

Source:https://www.google.com/search?q=images+on+maglev+trains+in+china+&sca_esv=fde65a004f3df79d&udm=2&biw=1036&bih=539&sxsrf=AHTn8zpEV8rFU1aum7j05hcch7BlKckPtw%3A1740425135885&ei=r8e8Z4TcNYfzigPpN3lsAo&ved=0ahUKEwjE73vhN2LAxWHQIHHaRuGaYQ4dUDCBE&oq=images+on+maglev+trains+in+china+&gs_lp=EgNpbWciIWltYWdlcyBvbiBtYWdsZXYgdHJhaW5zIGluIGNoaW5hIDIHECMYJxjJAkjWS1CQD1jKI3ABeACQAQCYAf8HoAG_NaoBDTItMi4xLjUuMy4xLjG4AQzIAQD4AQGYAgOgApgHmAMAiAYBkgcFMS40LTKgB60f&sclient=img#vhid=6IGyvkQYX19AeM&vssid=mosaic

Figure 6. Qingyuan Maglev Tourist Line

Source:https://www.google.com/search?q=images+on+maglev+trains+in+china+&sca_esv=fde65a004f3df79d&udm=2&biw=1036&bih=539&sxsrf=AHTn8zpEV8rFU1aum7j05hcch7BlKckPtw%3A1740425135885&ei=r8e8Z4TcNYfzigPpN3lsAo&ved=0ahUKEwjE73vhN2LAxWHQIHHaRuGaYQ4dUDCBE&oq=images+on+maglev+trains+in+china+&gs_lp=EgNpbWciIWltYWdlcyBvbiBtYWdsZXYgdHJhaW5zIGluIGNoaW5hIDIHECMYJxjJAkjWS1CQD1jKI3ABeACQAQCYAf8HoAG_NaoBDTItMi4xLjUuMy4xLjG4AQzIAQD4AQGYAgOgApgHmAMAiAYBkgcFMS40LTKgB60f&sclient=img#vhid=CKu89vVHaZMpiM&vssid=mosaic

Figure 7. Urban rail transit in China

Source:https://www.google.com/search?sa=N&sca_esv=fde65a004f3df79d&udm=2&cs=0&sxsrf=AHTn8zqNplJQumL5khJ3O6Hc9TpS2Z7HZQ:1740429584310&q=china+maglev+train+map&stick=H4sIAAAAAAAAAFvEKpackZmXqJCbmJ6TWqZQUpSYmQfkFAAATWdHpxkAAAA&source=univ&ved=2ahUKEwjk4IO5ld2LAxVFTqQEHXHFDbI4MhCs3AJ6BAgNEAA&biw=1036&bih=539&dpr=1#vhid=zxmfaePDUkfg9M&vssid=mosaic

Figure 8. CRRC Maglev

Source:https://www.google.com/search?sca_esv=fde65a004f3df79d&sxsrf=AHTn8zpCXHuvQuUjCvbANKddDcPqt4l4zw:1740425125829&q=images+on+maglev+trains+in+china+by+wikipedia&udm=2&fbs=ABzOT_CWdhQLP1FcmU5B0fn3xuWpAdk4wpBWOGsoR7DG5zJBjLjqIC1CYKD9DDQAQS3Z5NmlRTZM9mMZwadeXOSzfMOuJ9MVOHDHVayNtOyOCEREm3RXZuZWpCKSNf1HgZ9GY_3s6mbwIMPgr4rsBKOtXrDRbh7ZTQllzMsxzAahWmrrBeh2A4_7NFFlJVSECdlabxCH&sa=X&ved=2ahUKEwi5_4frhN2LAxVZ4AIHHRzEPI0QtKgLegQIEhAB&biw=1036&bih=539&dpr=1#vhid=A1kxQoXSfYbLTM&vssid=mosaic