On the long History of MAGLEV Trains

Reinhold Meisinger[1] and Werner Schiehlen[2]

[1] *Nuremberg Institute of Technology Georg-Simon-Ohm, Reinhold.Meisinger@th-nuernberg.de*
[2] *Institute Eng. Comp. Mechanics, University Stuttgart, schiehlen@itm.uni-stuttgart.de*

Highspeed railway transportation is a branch of multibody dynamics including railway vehicles and magnetically levitated vehicles. Both technologies are competing for decades with respect to the maximum speed [1]. At the time being, the French TVG(V150) holds the speed record of 574 kmph for rail vehicles and the Japanese Shinkansen L0 made it to 603 kmph for the magnetically levitated vehicles.

The first patent for a railway vehicle [2] is due to the Englishman Richard Trevithick (1802) consisting of a steam engine mounted on a chassis. Later in 1825, George Stephenson designed and manufactured his first locomotive, called simply Locomotion, for the Stockton and Darlington Railway. The maximum speed was 39 kmph. The first patent for a MAGLEV vehicle [3] received the German Alfred Zehden (1902) devoted to the completely magnetic propulsion by a linear motor where still a mechanical suspension for the lateral and vertical motions where used, Fig.1. A second patent for MAGLEVs [4] was granted to the Frenchman Emile Bachelet (1910) regarding the magnetic levitation for the lateral and vertical guidance of a cylindrical body carrying mail and small packages with high speeds, Fig. 2. Further, a patent foe the detailed engineering MAGLEV design [5] was granted to the German Hermann Kemper (1934). These early inventions provide already the fundamental technology for MAGLEV trains. However, they haven't been used due to World War II for three decades until the nineteen-sixties.

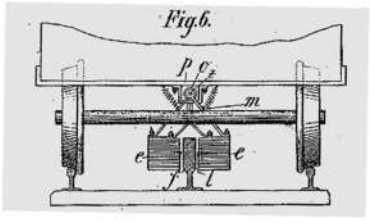

Fig. 1: US Patent by A. Zehden (1902)

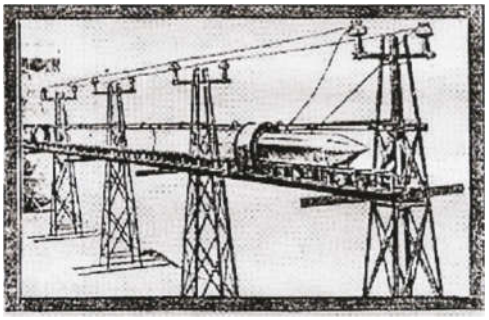

Fig. 2: US Patent by e. Bachelet (1910)

The engineering design era started 1971 when the Messerschmitt-Boelkow-Blohm (MBB) company constructed the world's first demonstration vehicle after a personal meeting of Kemper and Boelkow. On May 6, 1971 the worldwide first magnetically levitated (MAGLEV) vehicle, the MBB Demonstration Vehicle with a separate support and guidance system was presented to the public in Ottobrunn near Munich. It is the worldwide first large-scale passenger carrying proof of the feasibility of the magnetic levitation technology. In October 1971 it is followed by Krauss-Maffei Transrapid 02 with a combined support and guidance system and a speed of 164 kmph. In 1974 Krauss-Maffei and Messerschmitt-Bölkow-Blohm form the Transrapid E.M.S. joint venture company in Munich for further development of MAGLEV vehicles.

In 1975 tests started with the MBB Komet Component Testing Vehicle with a separate support and guidance system. Komet is an unmanned, magnetically supported and guided vehicle for testing components, such as electro-magnets, sensors, control systems, linear induction motors, and current collectors. Due to the short length of the test track of only 1.3 km, the MAGLEV vehicle Komet had to be accelerated by rockets. In the same year the Krauss-Maffei Transrapid 04 with a combined support and guidance system was successfully

tested with a speed of more than 250 kmph. In 1976 the MBB Komet sets up a world speed record of 401.3 kmph for MAGLEV vehicles at the straight line test track. In the same year Transrapid E.M.S. moves over from experimental MAGLEV vehicles to a transport concept and presents the Transrapid System with synchronous long-stator linear motor together with Thyssen Henschel. In 1979 at the International Transport Exhibition held in Hamburg, the public had the first opportunity to ride in the MAGLEV vehicle Transrapid 05. The separate support and guidance control system was developed by Messerschmitt-Boelkow-Blohm, and the cabin by Krauss-Maffei. The elevated steel-guideway and the longstator linear motor of this demonstration facility were built together with Thyssen Henschel.

In 1982 the 31.4 km Emsland test track is to become operational. The vehicle used was the Transrapid 06 with a speed of 355 kmph in December 1985 on the not finished guideway. In 1988 the speed attained by Transrapid 06 was 412 kmph on the finished closed loop guideway. Transrapid 07 and Transrapid 08 (similar Shanghai MAGLEV Vehicle) were designed and tested there by ThyssenKrupp Transrapid in 1992 and 1998.

Since 2002 the Shanghai MAGLEV Transportation System between Shanghai Pudong International Airport and Long Yang Road Metro Station is successfully in operation with a speed of 430 kmph and a maximum test speed of over 500 kmph on the 30 km double track guideway. It is the worldwide first MAGLEV line with commercial operation. During the first ten years it was used from 29.9 million passengers and the MAGLEV vehicles have driven already a distance of 8.97 million km.

The scientific methods include ground vehicle dynamics for the longitudinal, lateral and vertical motions, see e.g. Schiehlen and Popp [6]. For the propulsion of MAGLEV's long or short stator versions are used. For the modeling of the magnet undercarriage the method of multibody systems is most appropriate. For the control of lateral and vertical motions electromagnetic (EMS) or electrodynamic (EDS) suspensions are available where single magnet or degree of freedom control are at hand. A detailed analysis was performed by Gottzein [7] denoted as "Magnetic Wheel". Finally, the guideway is modelled as a flexible structure of simply supported Bernoulli-Euler beams. It remains a periodically time-varying system with jumping states as shown by Popp and Schiehlen [8], and Meisinger [9]. Thus, MAGLEV trains represent truly mechatronic systems.

The perspectives of MAGLEV vehicles are still very challenging. The Shanghai MAGLEV, similar to the German Transrapid TR07, is successfully operating since 2004. Recently, Incheon Airport MAGLEV began its commercial operation with EMS suspension, too. Moreover, China Railway Rolling Stock Corp. (CRRC) will develop a MAGLEV train that can reach 600 kmph as Chinadaily reported [10]. Moreover, the Maglev Board [11] promotes MAGLEV trains since 1997 internationally by annual conferences and publications.

References

[1] https://en.wikipedia.org/wiki/Maglev [2] https://en.wikipedia.org/wiki/Richard_Trevithick

[3] A. Zehden, Patent US 782312 A (1902). [4] E. Bachelet, Patent US 1020942 A (1910).

[5] H. Kemper, German Patent 643316 (1934).

[6] K. Popp and W. Schiehlen, Ground Vehicle Dynamics. Springer, Berlin 2010.

[7] E. Gottzein, Das *Magnetische Rad* als autonome Funktionseinheit modularer Trag- und Führungssysteme für Magnetbahnen. VDI-Verlag, Düsseldorf 1984. (in German)

[8] K. Popp and W.Schiehlen, „Dynamics of MAGLEV Vehicles on Flexible Guideways," in *The Dynamics of Vehicles on roads and railway tracks,* pp.479-503,August 18 -22, Delft, The Netherlands, 1975.

[9] R. Meisinger, "Beiträge zur Regelung einer Magnetschwebebahn auf elastischem Fahrweg," Munich, Ph.D.Thesis, Technical University Munich, 1977. (in German)

[10] http://shanghaiist.com/2016/10/24/faster_maglev.php

[11] http://www.maglevboard.net/en/