Maglev Trains - Поезда на магнитной подушке

The need for fast and reliable transportation is increasing throughout the world. High-speed rail has been the solution for many countries. Trains are fast, comfortable, and energy-efficient. The United States is years behind European countries in high-speed rail research and development. Meanwhile, in Germany and Japan, magnetic levitation may be an even better solution.

Maglev research and development began in Germany and Japan during the early 1970′s. After laboratory tests in both countries, a test track was constructed in Japan during the mid-1970′s and in Germany during the mid-1980′s.

The construction of a 7-km test track began in Miyazaki Prefecture in Japan in 1975 and was completed in April of 1977. Test runs of the ML-500 began on the Miyazaki Test Track in July of 1977 and a 517 km/hour run was attained in December 1979. Two-car train sets began testing in 1981 and three-car train sets in 1986. The manned two-vehicle train MLU001 reached a speed of 400.8 km/hour in 1987. In 1990, the Minister of Transport of Japan authorized construction of the Yamanashi Maglev Test Line. It was to be the final test to confirm the practicality of maglev. The 42.8 km line between Sakaigawa and Akiyama of Yamanashi Prefecture opened in 1996 and the first running test of the MLX01 was in April of 1997.

Germany was testing their Transrapid 07 maglev at the TV (Transrapid Versuchsanlage in Emsland) test track between Nordschleife and Sudschleife. Both test vehicles have traveled more than 400,000 km on the test track as of December 1996. The longest nonstop test has been 1,674 km in May of 1993. In June of the same year, the Transrapid 07 set a new maglev speed record of 450 km/hour. In 1991, Germany’s government certified the operation of the first maglev train for the public. A maglev route was to be constructed between Hamburg and Berlin.

In the United States, scientists James R. Powell and Gordan T. Danby patented the first design for magnetic levitation trains in 1969. In 1970, the United States Federal Railroad Administration studied high-speed ground transportation. Little maglev research was accomplished in the United States and in 1986, the government stopped all funding toward maglev technology. Four years later, the United States Federal Government and the Federal Railroad Administration began to officially support maglev technology. (Lotti-Chun, On-line) They began the National Maglev Initiative in 1990, a cooperative effort of the U.S. Department of Transportation, the U.S. Army Corps of Engineers, and the U.S. Department of Energy. The purpose of the initiative was to evaluate possible improvements for intercity transportation with magnetic levitation. The tasks included «planning, analyzing, and assessing maglev technology» to make it a viable option for future transportation. The initiative should also determine the role that the Federal Government should have in the development of maglev systems. Significant effort has been devoted to the understanding of maglev’s technical and market potential, however, the key issue is whether such research and development warrant the federal investment. The

Intermodal Surface Transportation Efficiency Act of 1991 offered more support by recognizing the goals of future transportation systems. Section 1036 of the Act established a Maglev Prototype Development Program which specified the requirements for the design and construction of a U.S. maglev system. (the University of Alabama in Huntsville, On-line)

The support and guidance systems of German magnetic levitation are based on the attractive powers between electromagnets on the vehicle and reaction plate rails on the underside of the guideway. (Lotti-Chun, On-line) The levitation and guidance magnets are controlled individually. An electronic control system keeps the vehicle levitating at a constant distance of 10 mm from its guideway. The propulsion and braking systems are based on a rotating electric motor with a split stationary core (stator). The vehicle is then propelled by the traveling magnetic field which is created with support magnets serving as the exciters. The energy flow is reversed to break the vehicle without any contact to the guideway. This method of propulsion requires the motor to be installed on the guideway rather than on the vehicle. Unlike conventional transportation systems in which a vehicle has to carry the total power needed for the most demanding sections, the power of the maglev motor is dependent on the local conditions such as flat or uphill grades. The linear induction motor installed in the guideway is divided into sections. Power is only supplied to sections where a vehicle is currently located.

This method conserves energy and prevents safety concerns because all vehicles in a section of track must be traveling at the same speed in the same direction. The power for the German Transrapid is supplied from Germany’s 110 kV national grid system. Separate substations provide the power independently to each side of the guideway motor. The placement of these substations is dependent on local route conditions. The support and guidance systems and the onboard power is supplied via linear generators in the support magnets resulting in entirely contactless technology. If the national grid power supply fails, onboard batteries which are powered during the journey will provide power to levitate the vehicle until it reaches the next terminal. If the next terminal is too far away, the vehicle is stopped at the next power station. Braking is supplied by the onboard batteries to slow the vehicle to 10 km/hour. The vehicle is then lowered onto skids and stops after a few meters. The skids are coated with a special material to create low friction while sliding on a steel surface. There is no reason to leave the vehicle for such a motor failure.

The heat generated by the friction will melt a thin layer of ice when running in winter conditions. The materials used to construct maglev vehicles are non-combustible, poor transmitters of heat, and able to withstand fire penetration. In the unlikely event that a fire and power loss occurred simultaneously, the vehicle is automatically slowed down so that it stops at a predefined emergency power station. Research has shown that the German Transrapid is about 20 times safer than airplanes, 250 times safer than conventional railroads, and 700 times safer than automobile travel. Despite the speeds up to 500 km/hour, passengers can move about freely in the vehicles at all times. Maglev vehicles cannot be derailed because they surround the guideway. The collision is impossible because there will be no intersections and other transportation systems will cross at different levels. A collision between two maglev trains is nearly impossible because the linear induction motors prevent trains running in opposite directions or different speeds within the same power section. There is not a solution against all vandalism and sabotage, however many precautions have been taken. (Thyssen, On-line)

Japanese maglev development is similar to the German Transrapid in many ways but uses a different principle of levitation, guidance, and propulsion. Instead of surrounding the guideway as the German Transrapid does, Japan's maglev vehicles are enclosed by the guideway on the bottom and part way up the sides. (RTRI, On-line) They start on pneumatic wheels until reaching a speed of about 100 km/hour before the electromagnetic force levitates the vehicle. (China Daily, On-line) Levitation coils are installed on the sidewalls of the guideway. Superconducting magnets are installed on the vehicles several centimeters below the center of these guideway coils. When the onboard magnets pass the coils at high-speed, an electric current is induced in the coils and they serve as electromagnets. The forces then push the superconducting magnet upwards and levitate the vehicle. The coils on either sidewall of the guideway face each other and are connected under the guideway to create a loop. The electric current changes in the loop result in attracting and repulsive forces that keep the vehicle in the center of the guideway. The propulsion coils on the sidewalls of the guideway are energized by a three-phase alternating current from a local substation. The shifting magnetic field which is created attracts and pushes the onboard superconducting magnets. The maglev vehicle is then propelled along the guideway. (RTRI, On-line)

The guideway, or track, that the maglev trains run on can be raised above the ground or be at ground level. The elevated guideway for Germany's Transrapid is normally 31 meters tall and the ground level guideway is normally six meters tall. This flexibility plus the ability for substantially sharper turns and steeper grades than railroads allow maglev guideways to be located in many different conditions. As with conventional railroads, trains are made up of several individual vehicles coupled together. The smallest train requires two vehicles and the maximum length is only determined by the length of station platforms, approximately ten sections. This enables trains to be constructed depending upon demand and the frequency increased when needed. Germany's proposal for the Berlin to Hamburg route is to use six section trains with trains every ten to fifteen minutes. The end sections of a maglev train can contain between 56 and 110 seats depending upon the density of the seating layout. Center sections can contain between 64 and 140 seats. Neither the number of seats per section nor the number of sections comprising a train affects the performance of a maglev train. The high speeds of a maglev system make it suitable for transporting urgent goods with container sections. These container sections can form their own trains or be coupled with passenger sections to form «mixed-traffic» trains. During peak hours, freight trains sharing a passenger route will have long journey times because they will often have to wait in sidings for passenger trains to pass. Because of this problem, German maglev research is investigating the possibility of exclusive passenger routes and exclusive freight routes. (Thyssen, On-line)

Conventional railroads have achieved speeds above 500 km/hour during special laboratory speed tests, yet their normal operating speed is below 300 km/hour. Maglev vehicles are designed for operating speeds of up to 500 km/hour. Besides the speed improvements over other methods of transportation, maglev trains have many benefits at slower speeds too. Maglev trains experience lower energy consumption, less wear, lower noise levels, and much faster acceleration without affecting passenger comfort. Maglev trains can accelerate from 0 to 300 km/hour within 5 km compared to the German ICE high-speed train which requires about 30 km to reach the same speed. Because of these advantages, maglev trains are planned for three areas of transportation: local connections such as airport links; medium-distance inter-city connections; and long-distance national and international connections. (Thyssen, On-line)

Even with much faster journey times, comfort was a key consideration during maglev development. There are no jolts during acceleration, braking, or passing at any speed. High-pressure fluctuations occur in tunnels and when passing opposing traffic. Extensive measurements, computer models, and experience from high-speed rail have resulted in advanced technology for keeping the vehicles pressure-tight. A variety of business services and entertainment provide passengers with even greater comfort than high-speed rail travel.

A major advantage of conventional rail systems versus other methods of transportation is their ability to operate in almost all weather conditions. Maglev systems are even better prepared for icy conditions because they do not require overhead power lines nor pantographs — parts that are subject to freezing on conventional railroads. The guidance and propulsion components are mounted below the guideway where they are protected from ice and driving snow. Snow will rarely accumulate on the guideway because of the frequency of trains and the wind that will easily remove it from elevated sections. The gap of 150 mm between the bottom of the vehicle and the top of the guideway allows operation even if snow builds upon the guideway. In especially poor weather conditions, snow clearance vehicles can be deployed to clear the guideway. (Thyssen, On-line)

As well as the many other positive effects of maglev, maglev trains are more environmentally-friendly than alternative forms of transportation. They operate at lower noise levels, consume less energy, require little land for the guideway, and release low magnetic fields. Noise is reduced by the contactless technology used and air pollution is reduced because of no emissions of exhaust gasses. A maglev train at a distance of 25 m and speed of 250 km/hour results in vibrations, or oscillations, below the «human threshold of perception» (KB value of 0.1). At a distance of one meter from the side of a maglev train running at 350 km/hour, the wind speed is only 8 km/hour. Less land is required for both the ground-level and elevated guideway and leaves the ground beneath the elevated guideway suitable for other purposes such as agriculture and traffic. In areas utilizing a ground-level guideway, there is still enough clearance for small animals and microorganisms to pass underneath so there will be little effect on the environment. This guideway construction also eliminates animal collisions that frequently occur with roadways. Unlike conventional railroads, a maglev guideway does not dissect the landscape.

The landscape requires fewer changes and does not have to be free of all natural growth as they do for conventional railroads. Maglev trains release no pollution into the ground they run above nor do they affect local water. Raft foundations will be used for most guideway supports which are not even as deep as the basement of normal houses. A well-developed construction plan will result in less damaging effects during construction than during that of conventional railroads and roads. Maglev routes will be grouped with existing transportation wherever possible. The German Transrapid releases an extremely low magnetic field. The magnetic field, even inside a passenger compartment, is considerably less than that of a hair dryer, toaster, or electric sewing machine. It will, therefore, have no negative influence on cardiac pacemakers or magnetic cards such as credit cards. (Thyssen, On-line)

The cost of making the guideway is a high percentage of the total investment for a maglev system. These costs are no higher than those of other high-speed rail systems and the comparison looks even better for maglev when the terrain becomes difficult. Many of the tunnels, embankments, and cuttings necessary for roads and railroads are avoided because maglev guideways can be easily adapted to the topography. (Thyssen, On-line)

The operating costs of a maglev system are approximately half that of conventional long-distance railroads. There is no friction because of the contactless technology, resulting in very little mechanical wear. The guideway receives little pressure because the weight of each maglev vehicle is not transferred to the guideway at specific points like the axles of conventional trains. Energy consumption is lower per seat than other comparable means of transportation and faster turnaround times mean fewer vehicles and operating staff are required. (Thyssen, On-line)

Germany is the furthest into their development efforts and closest to beginning construction of a commercial maglev route. Planning permission for an initial section of the Berlin to Hamburg line is expected by the end of 1998. Construction will then begin immediately and the final section should be approved by the end of 1999. After five years of construction, the route should be completed in 2004. The Transrapid can then begin operation over the 292-km route in 2005. The journey time from Lehrter Station in Berlin to Hamburg Central Station will be a maximum of 60 minutes. Transrapid trains will run in both directions every 10 to 15 minutes during peak times. The two terminals will be closely integrated with other intercity services and local transportation. Nearly two-thirds of the route will follow roadways with other parts following existing railroads and power lines. More than half of the route, 161 km, will run at ground level. This maglev proposal is half-owned by the Federal Government and half-owned by private industry. (Thyssen, On-line)

In Japan, the Central Japan Railway Company (JR Tokai) is leading their maglev project. They believe that conventional railroad technology has reached its peak performance. Japan currently has research and development into many applications of superconductors including the Superconducting Generator (Super GM), superconducting storage devices, and the magnetic levitating train. Their government's budget for superconductivity research in 1996 was 20 trillion yen (approximately $180 billion US). Early reports propose a maglev route from Tokyo to Osaka to be completed by 2005.

The United States, which was once a leader in transportation including railroads, has spent years debating the possibility of high-speed rail and maglev. Much of the research and proposals have been done by organizations such as the High-Speed Rail/Maglev Association. Some airlines including USAir have a positive interest in the development of maglev. The U.S. government has supported airlines but ignored most proposals for high-speed rail and maglev until the past couple of years. The poor condition of Amtrak has created a public feeling that railroads cannot be successful in the United States. High-speed rail supporters believe the contrary is true because of the metropolises that are spread across the United States. There has also been a public idea that the airline industry is a private enterprise and receives no government subsidy. In reality, the airline industry receives billions of dollars of subsidies each year. In the process, Amtrak has lost much of its funding and service cutbacks have been the result. There has been little improvement in U.S. rail travel during the past couple of decades. Many European countries have profitable national railroad networks with millions of dollars in profits each year.

Few will argue that high-speed rail and maglev can alleviate many of America’s transportation problems. The operational costs are cheaper than the current rail system. The main issue is now the investment costs to build such a transportation network. Private funding from investors is plentiful for high-speed rail and maglev development. The Channel Tunnel became the largest privately financed engineering project in history with an expense of $14 billion. As America’s transportation problems grow worse every year, the public realization of the importance of high-speed rail and maglev will grow. Amtrak’s testing of European high-speed rail technology is the furthest that actual testing has gotten in the United States. Many see the high-speed rail plans developed by Amtrak to be a very limited success, and some high-speed rail advocates see its current drawbacks. Because of the poor state of current railroad track, the new high-speed rail that Amtrak is investigating will result in minimal performance improvements. The public may view this as the limit to high-speed rail’s capability.

In conclusion, while America appears to be many years from the first maglev demonstration, this practical form of high-speed transportation will soon be a reality in Germany and Japan. High-speed rail and maglev advocates hope that Germany’s Transrapid maglev system will set the stage for new maglev development projects around the world.