TECHNOLOGY

Technology

In the public imagination, "maglev" often evokes the concept of an elevated monorail track with a linear motor. Maglev systems may be monorail or dual rail and not all monorail trains are maglevs. Some railway transport systems incorporate linear motors but use electromagnetism only for *propulsion*, without levitating the vehicle. Such trains have wheels and are not maglevs.Maglev tracks, monorail or not, can also be constructed at grade (i.e. not elevated). Conversely, non-maglev tracks, monorail or not, can be elevated too. Some maglev trains do incorporate wheels and function like linear motor-propelled wheeled vehicles at slower speeds but "take off" and levitate at higher speeds.

MLX01 Maglev trainSuperconducting magnet bogie

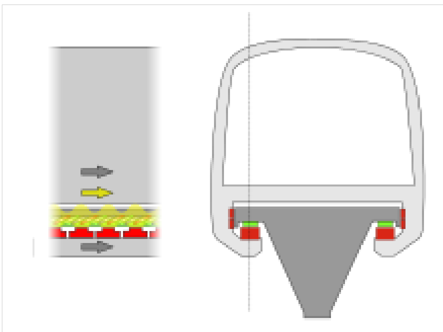
The two notable types of maglev technology are:

•Electromagnetic suspension (EMS), electronically controlled electromagnets in the train attract it to a magnetically conductive (usually steel) track.

•Electrodynamic suspension (EDS) uses superconducting electromagnets or strong permanent magnets that create a magnetic field, which induces currents in nearby metallic conductors when there is relative movement, which pushes and pulls the train towards the designed levitation position on the guide way.

Another technology, which was designed, proven mathematically, peer-reviewed, and patented, but is, as of May 2015, unbuilt, ismagnetodynamic suspension (MDS). It uses the attractive magnetic force of a permanent magnet array near a steel track to lift the train and hold it in place. Other technologies such as repulsive permanent magnets and superconducting magnets have seen some research.

Electromagnetic suspension



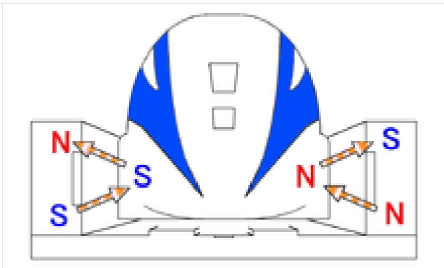
Electromagnetic suspension (EMS) is used to levitate the Transrapid on the track, so that the train can be faster than wheeled mass transit systems

In electromagnetic suspension (EMS) systems, the train levitates above a steel rail while electromagnets, attached to the train, are oriented toward the rail from below. The system is typically arranged on a series of C-shaped arms, with the upper portion of the arm attached to the vehicle, and the lower inside edge containing the magnets. The rail is situated inside the C, between the upper and lower edges.

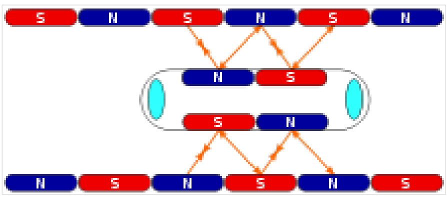
Magnetic attraction varies inversely with the cube of distance, so minor changes in distance between the magnets and the rail produce greatly varying forces. These changes in force are dynamically unstable – a slight divergence from the optimum position tends to grow, requiring sophisticated feedback systems to maintain a constant distance from the track, (approximately 15 millimetres (0.59 in)).

The major advantage to suspended maglev systems is that they work at all speeds, unlike electrodynamic systems, which only work at a minimum speed of about 30 km/h (19 mph). This eliminates the need for a separate low-speed suspension system, and can simplify track layout. On the downside, the dynamic instability demands fine track tolerances, which can offset this advantage. Eric Laithwaite was concerned that to meet required tolerances, the gap between magnets and rail would have to be increased to the point where the magnets would be unreasonably large.In practice, this problem was addressed through improved feedback systems, which support the required tolerances.

Electrodynamic suspension (EDS)



The Japanese SCMaglev's EDS suspension is powered by the magnetic fields induced either side of the vehicle by the passage of the vehicle's superconducting magnets.



EDS Maglev propulsion via propulsion coils

In electrodynamic suspension (EDS), both the guideway and the train exert a magnetic field, and the train is levitated by the repulsive and attractive force between these magnetic fields. In some configurations, the train can be levitated only by repulsive force. In the early stages of maglev development at the Miyazaki test track, a purely repulsive system was used instead of the later repulsive and attractive EDS system. The magnetic field is produced either by superconducting magnets (as in JR–Maglev) or by an array of permanent magnets (as in Inductrack). The repulsive and attractive force in the track is created by an induced magnetic field in wires or other conducting strips in the track. A major advantage of EDS maglev systems is that they are dynamically stable – changes in distance between the track and the magnets creates strong forces to return the system to its original position. In addition, the attractive force varies in the opposite manner, providing the same adjustment effects. No active feedback control is needed.

However, at slow speeds, the current induced in these coils and the resultant magnetic flux is not large enough to levitate the train. For this reason, the train must have wheels or some other form of landing gear to support the train until it reaches take-off speed. Since a train may stop at any location, due to equipment problems for instance, the entire track must be able to support both low- and high-speed operation.

Another downside is that the EDS system naturally creates a field in the track in front and to the rear of the lift magnets, which acts against the magnets and creates magnetic drag. This is generally only a concern at low speeds (This is one of the reasons why JR abandoned a purely repulsive system and adopted the sidewall levitation system.) At higher speeds other modes of drag dominate.

The drag force can be used to the electrodynamic system's advantage, however, as it creates a varying force in the rails that can be used as a reactionary system to drive the train, without the need for a separate reaction plate, as in most linear motor systems. Laithwaite led development of such "traverse-flux" systems at his Imperial College laboratory. Alternatively, propulsion coils on the guideway are used to exert a force on the magnets in the train and make the train move forward. The propulsion coils that exert a force on the train are effectively a linear motor: an alternating current through the coils generates a continuously varying magnetic field that moves forward along the track. The frequency of the alternating current is synchronized to match the speed of the train. The offset between the field exerted by magnets on the train and the applied field creates a force moving the train forward.