Creating of STEM – Equipment: MagLev Train

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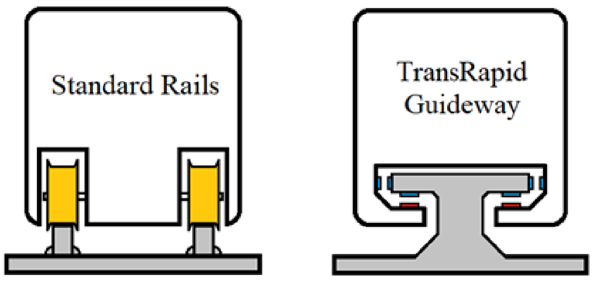
1. How Does It Work?

Maglev trains have no wheels or rails. As shown in Figure 1, they have guides, and they float along these guides without even touching them.



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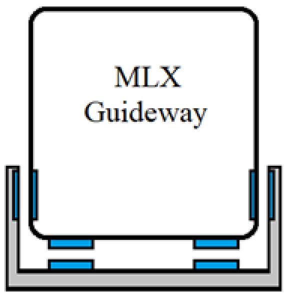

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Figure 1. Comparison of Wheel-Rail versus Guideways

There are three important and necessary forces for achieving MagLev functionality: levitation, movement, and direction (Fig. 2).

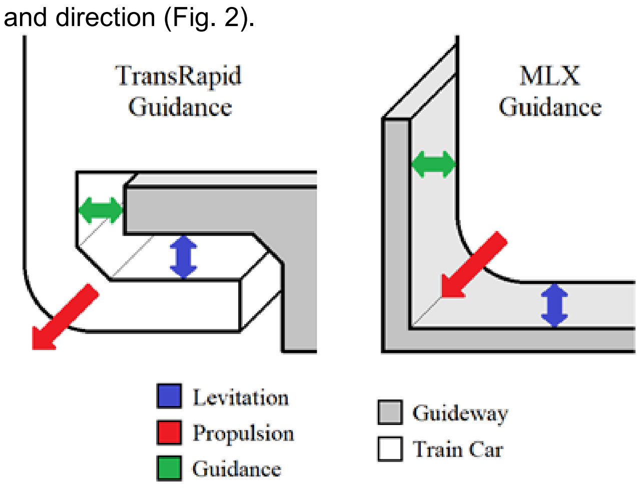

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Figure 2. Levitation, propulsion, and guidance in MagLev

1.1 Levitation

Levitation is the ability of a train to stay suspended over a rail. There are two important types of levitation technology.

Electromagnetic Suspension (EMS) uses the attractive force of electromagnets located on the rail and in the train to achieve levitation (Fig. 3a). The advantages of this method are that it is easier to implement than electrodynamic suspension, and that it supports levitation at zero speed. The disadvantages are that the system is inherently unstable. At high speeds, it becomes difficult to maintain the correct distance between the train and the guide. If this distance cannot be maintained, the train will not be able to levitate and stop. To take this into account, EMS requires sophisticated feedback control systems to ensure that the train is always stable.

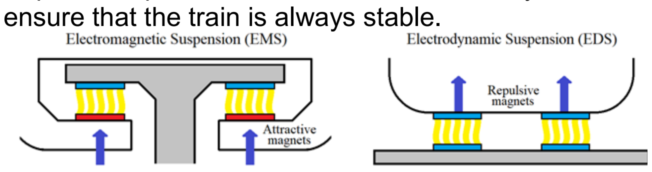

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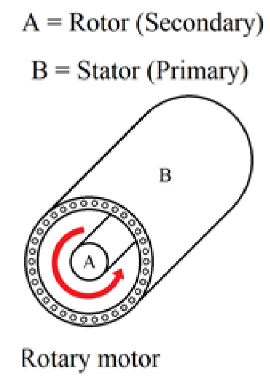
Figure 3. Electromagnetic suspension (uses attractive magnetic forces) (a) and electrodynamic suspension (uses repulsive magnetic forces) (b)

Electrodynamic Suspension (EDS) uses the repulsive force of the (superconducting) magnets located on the rail and on the train to achieve levitation (Fig. 3b). The magnets move past each other while the train is moving and generate a repulsive force. The advantages of this method are that it is incredibly stable at high speeds. Maintaining the correct distance between the train and the guide is not a problem. The disadvantages are that it is necessary to gain enough speed so that the train can even levitate. In addition, this system is much more complicated and more expensive to implement.

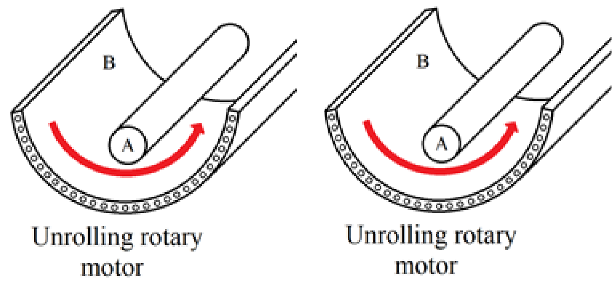
1.2 Propulsion

Propulsion is the force that propels the train forward. MagLev uses an electric linear motor for traction. A conventional electric rotary motor uses magnetism to create torque and axis rotation. It has a fixed element - a stator, which surrounds a rotating element - a rotor. A stator is used to generate a rotating magnetic field. This field causes a rotational force on the rotor, which makes it rotate. A linear motor is simply an expanded version of a conventional motor (Fig. 4). The stator lies in the plane, and the rotor lies above it. Instead of a rotating magnetic field, the stator generates a field that moves along its length. Similarly, instead of a rotational force, the rotor experiences a linear force that pulls it along the stator. Thus, the electric linear motor directly produces movement in a straight line. However, this motor can only exert force when the rotor is above the stator. As soon as the rotor reaches the end, it stops.



a)

Figure 4. Rotary motor versus linear motor



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When describing a linear motor, the standard is to use the term "primary" instead of "stator" and "secondary" instead of "rotor". On MagLev trains, secondary is attached to the bottom of the wagons, while primary is in the rail. Thus, the magnetic field is directed along the guide, and it pulls the train. The entire MagLev track can be considered part of the train engine. The system that has been described to date is the Linear Induction Motor (LIM). It is called that because the magnetic field in primary induces a magnetic field in secondary. It is the interaction between the initial field and the induced field that creates traction.

However, in this configuration, the secondary device is always slightly behind the moving field in the primary. This lag is a source of energy and speed loss. In Linear Synchronous Motor (LSM), lag is eliminated by attaching permanent magnets to the secondary device. Since the secondary device now creates its own stationary magnetic field, it moves along the primary element synchronously with the moving field - hence the name of this version of the engine [4]. Because LSMs are faster and more efficient, they are the preferred engine on MagLev high-speed trains .

1.3 Guidance

Guidance is what keeps the train in the center of the rail. For high-speed MagLev, repulsive magnetic forces are used for this (Fig. 5). In TransRapid, on a train located on either side of the rail, two electromagnetic rails are installed.

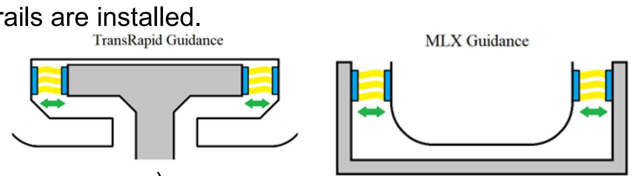

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Figure 5. Guidance system of TransRapid and MLX (both use repulsive magnets)

In MLX guidance, it is associated with a levitation system. Levitation rails on both sides of the train are connected to each other. Thanks to this connection, when the train moves closer to one side, a force arises that pushes it back to the center. Thus, MLX simultaneously levitates and guides.

1.4 Benefits of Maglev

The most obvious appeal of MagLev trains is that they can travel faster than traditional rail trains. The only commercial MagLev expressway, Shanghai MagLev, is currently the fastest train available. It travels at 50 mph (80 km/h) faster than the fastest high-speed Rail Train. And this is only the main advantage. The lack of friction between the train and the rail eliminates many of the limitations that traditional trains have. It follows that in the future MagLev will only be faster.

2. How to do it?

Based on several introductory classes, an independent analysis by the project participants of the available information and the principles of maximum simplification of the design, we came to the following design (Fig. 6), which we propose to use in the future.

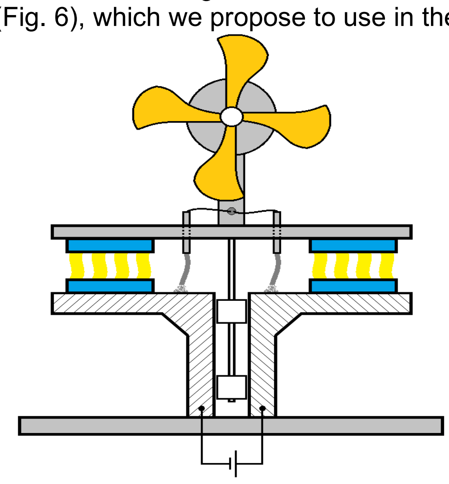

Figure 6. Our simple MagLev system

Regarding the three necessary forces discussed earlier and necessary for the functioning of MagLev, they are implemented as follows.

Levitation in our project is provided by permanent magnets, which makes MagLev non-volatile. Primary magnets are located along the entire line, thereby providing the necessary repulsive force throughout the route. Secondary magnets are located directly on the moving part - the train.

Guidance is provided according to a simplified scheme through the use of vertical guide axes moving along a horizontal groove along the entire route. The main objective of the implementation is to reduce the coefficient of friction of the guide, which is ensured either by using a material with a low coefficient of friction, or by using rolling elements.

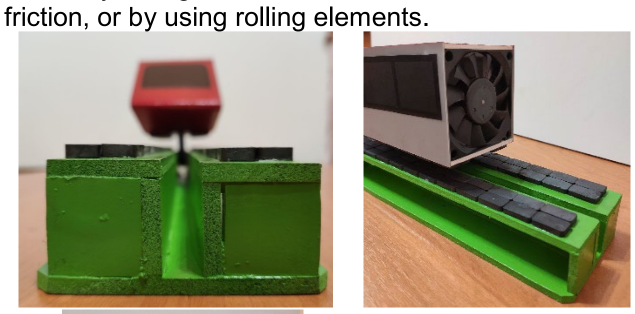

Figure 7. Example of simple MagLev train for school

The train comes into motion due to the rotation of the propeller on the moving part. However, the use of classic AA batteries on the moving part was unacceptable based on their mass, which exceeded the permissible load. It was decided to power the propeller through the feed rails. The basis of the route design was made on the basis of aluminum corners, which were both a strong structural material and electrical conductive sliding contacts. A voltage was applied to the corners from the battery, which was removed by the sliding contacts of the train (Fig. 6) along the entire route.

Using the proposed solutions, a working MagLev train layout was created, examples of which are shown in Figure 7.