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MAGLEV: A TECHNOLOGY TO PROPEL VEHICLES AND FUTURE OF TRAVELING

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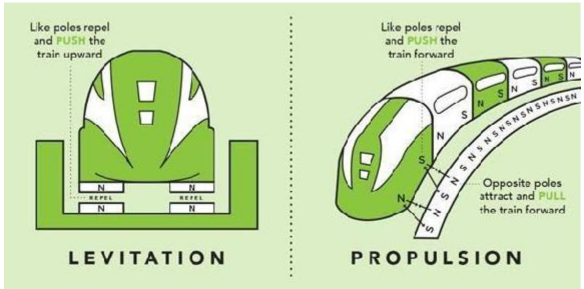
***ABSTRACT** The term "Levitation" refers to a class of technologies that uses magnetic levitation to propel vehicles with magnets rather than with wheels, axles and bearings. Maglev (derived from magnetic levitation) uses magnetic levitation to propel vehicles with maglev, a vehicle is levitated a short distance away from a "guide way" using magnets to create both lift and thrust. MAGLEV can be the future of travelling as we have seen in China, South Korea and Japan they have been using maglev trains for decades. Maglev trains move more smoothly and somewhat more quietly than wheeled mass transit systems. Maglev trains come out to be fastest in the trains as they are elevated from the ground due to the magnetic field which results in frictionless movement. Now the travel is faster due to the Hyperloop maglev trains. In simple words Hyperloop is a maglev train track which is built in a vacuum tube to eliminate the air resistance in order to achieve highest speed. Hyperloop can be a promising future train to travel from country to country in a few hours*

1. INTRODUCTION

Magnetic levitation is the process of levitating an object by exploiting magnetic fields. If the magnetic force of attraction is used, it is known as magnetic suspension. If magnetic repulsion is used, it is known as magnetic levitation.

Electromagnetic levitation works via the magnetic force of repulsion. Using repulsion though makes a much more difficult control problem. The levitating object is now able to move in any direction, meaning that the control problem has shifted from one dimension to three. There is much interest in levitation due to its possible applications in high speed transport technology. These applications can be broadly referred to as MagLev, which stands for magnetic levitation. In the past, magnetic levitation was attempted by using permanent magnets. Attempts were made to find the correct arrangement of permanent magnets to levitate another smaller magnet, or to suspend a magnet or some other object made of a ferrous material. Apart from permanent magnets, other ways to produce magnetic fields can also be used to perform levitation



.One of these is an electrodynamic system, which exploits Lenz's law. When a magnet is moving relative to a conductor in close proximity, a current is induced within the conductor. This induced current will cause an opposing magnetic field. This opposing magnetic field can be used to levitate a magnet. Electrodynamic magnetic levitation also results from an effect observed in superconductors. This effect was observed by Meissner and is known as the Meissner effect. This is a special case of diamagnetism.

This research paper will mainly talk about the concepts on which Maglev has been successful, Futuristic scope of the maglev which is the Hyperloop and a small experiment which will tell how maglev will work.

2. BASIC CONCEPTS BEHIND LEVITATION OF MAGNETS

IMPORTANT TERMINOLOGIES

➢ *MAGNET:* A magnet is any object that has a magnetic field. It attracts ferrous objects like pieces of iron, steel, nickel and cobalt.

➢ *MAGNETIC FIELD:* The space surrounding a magnet, in which magnetic force is exerted, is called a magnetic field

➢ *ELECTROMAGNETS:* They are produced by placing a metal core (usually an iron alloy) inside a coil of wire carrying an electric current. The electricity in the current produces a magnetic field

➢ *SUPERCONDUCTORS:* These are the strongest magnets. They don't need a metal core at all, but are made of coils of wire made from special metal alloys which become superconductors when cooled to very low temperatures

3 THE EARNSHAW THEOREM

Earnshaw's theorem basically proves that a static magnet cannot be levitated by any arrangement of permanent magnets or charges. This can be simply proved as follows: "The static force as a function of position F(x) acting on any body in vacuum due to gravitation, electrostatic and magnetostatic fields will always be divergenceless. divF = 0. At a point of equilibrium the force is zero. If the equilibrium is stable the force must point in towards the point of equilibrium on some small sphere around the point. However, by Gauss' theorem,

$$\int_s F(x).dS = \int_v divF.\, dV$$

The integral of the radial component of the force over the surface must be equal to the integral of the divergence of the force over the volume inside which is zero. "

The exceptions to Earnshaw's theorem are as follows:

1. QUANTUM THEORY

Firstly this theorem only takes into account classical physics and not quantum mechanics. At the atomic level there is a type of levitation occurring through forces of repulsion between particles. This effect is so small however, that it is not generally considered as magnetic levitation.

2. ROTATION

This property is used in the patented magnetic levitation display called the Levitron. The Levitron uses an arrangement of static permanent magnets to levitate a smaller magnet. The system overcomes the instability described in Earnshaw's theorem by rotating the levitating magnet at high speed.

3. DIAMAGNETISM

Earnshaw's theorem doesn't apply to diamagnetic materials, because they have a relative permeability less than one. This means that they don't behave like regular magnets, as they will tend to repel any magnetic flux.

4. MEISSNER EFFECT

A special case of diamagnetism is observed in conductors cooled to below their critical temperature (typically close to 0 K). Below this temperature, they become superconductors, with an internal resistance of zero. They attain a relative permeability of zero, making them the perfect diamagnetic material. This allows them to maintain their repelling magnetic field as long as a foreign source of magnetic flux is present.

5. FEEDBACK SYSTEMS

The position of the levitating magnet can be sensed and used to control the field strength of an electromagnet. Thus the tendency for instability can be removed by constantly correcting the magnetic field strength of the electromagnets to keep a permanent magnet levitated.

6. OSCILLATION

Passing an alternating current through an electromagnet causes eddy currents to flow within its core. These currents according to Lenz's law will flow such that they repel a nearby magnetic field. Thus, it causes the electromagnet to behave like a diamagnetic material.

THE MEISSNER EFFECT AND SUPERCONDUCTORS

One of the interesting properties of superconductors was researched by Meissner, and is known as the Meissner effect. The Meissner effect is a phenomenon that occurs when certain conductors are cooled below their critical temperature which is typically 0 K. It was observed that under this condition the conductor would become a superconductor, and would in fact repel magnetic fields of any orientation. In other words, a piece of superconducting material cooled to below its critical temperature will repel a magnetic south pole or a magnetic north pole, without having to move it. This is a special case of diamagnetism.
As Earnshaw showed, simple magnetic repulsion is not sufficient to maintain stable levitation. This problem is solved at the molecular level. Within the superconductor are impurities, i.e. areas which do not have electric current flowing in them, and as a result are not producing an opposing magnetic field. These areas, although small, are big enough to allow regions of the magnetic field from the nearby magnet to penetrate the superconductor. If the magnet moved, the magnetic field would have to move with it. But because the magnetic field is unable to penetrate the

superconductor in any other area, the magnetic field is effectively locked in place. Thus, because the magnetic field is being held in place by the "holes" in the opposing magnetic field of the superconductor, the magnet too, is held in place. This is what holds the magnet in place above the superconductor and keeps it stably levitated. This is known as flux pinning.

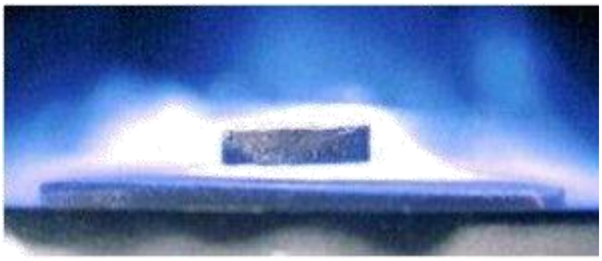


Fig: A magnet levitating above a superconductor.

ELECTROMAGNETIC LEVITATION

The main driving interest behind electromagnetic levitation is in its applications in mass transport. Much research is being done on the methods and complexities of this technology. In its applications in mass transport, particularly trains, this technology is loosely referred to as MagLev.

MAGLEV

This concept has already found commercial application in maglev trains. MagLev is an acronym for magnetic levitation, and is most commonly used when referring to trains. MagLev is desirable in such an application because of the low maintenance for the track networks, and the low friction track that it provides. Because many trains gain their energy from sources not on the actual train, the energy requirements of the system become less stringent. Therefore, even though, it takes a considerable amount of energy to levitate the train, the energy can be feasibly obtained and transferred to the train.

DESIGN CONSIDERATIONS

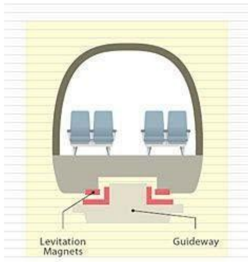
Various things need to be taken into account when considering the levitation subsystem of a greater MagLev system. The most obvious considerations are the requirements to levitate the train. These include the force required to lift the train, energy consumption, drive systems (the way in which electromagnets are arranged and triggered which causes the train to move forward) and forces acting on the train as it travels at high speed through turns.

Apart from this are the constructional and cost considerations of such a system. For something as large as a train, these are quite important. The comfort of the passengers is a priority in such an application. Oscillations and sudden movements or accelerations are undesirable and can cause great discomfort to passengers. As such, the control requirements are very rigorous. Basically, the train must be kept, levitated, on track and moving forward with the ability to stop as required. All this must preferably be achieved through non contact methods, such as through the use of magnetic fields.

ELECTROMAGNETIC SUSPENSION (EMS)

Electromagnetic suspension (EMS) is used to levitate the Trans rapidon 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 square 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 mm [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 Laithwaitewas 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.

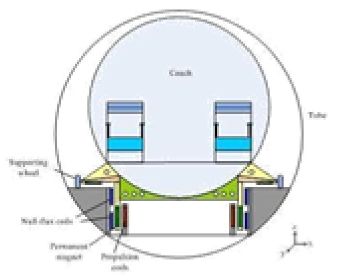
ELECTRODYNAMIC SUSPENSION (EDS)

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.

The Japanese SC Maglev'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 induced magnetic fieldin 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, and 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.

ELECTROMAGNETIC LEVITATION SYSTEM DEVELOPMENT

The model developed for this thesis topic aimed to use continuous current control to the electromagnets, instead of the switched current control used by the MagLev cradle. Experiments were also done to investigate various configurations of electromagnets in order to achieve stable magnetic levitation. The current control circuitry and Hall Effect sensor system, would be tested first, and then duplicated for each electromagnet added to the system. From there, control circuitry would be designed and added as necessary.

The systems with diagrams shown next are the basic arrangements of a maglev which we referred for the experiment of the working of the maglev.

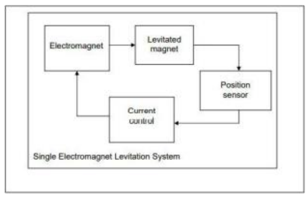


Fig: A diagram showing a systems view of a magnetic levitation device

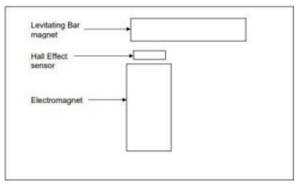
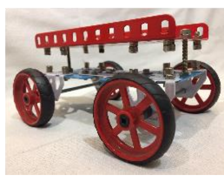


Fig: Shows a possible physical arrangement for a magnetic levitation system

HANDS ON APPROACH



Levitating a platform with help of permanent magnets and putting load on the same platform to see the capacity of the magnetic levitation


The weight was suspended and the platform was perfectly levitating on the base.

HYPERLOOP

This transportation system was firstly proposed by ElonMusk, in this report he explained this project of ultra-high speed transportation systems. This transportation system was planned for California (USA) to transport passengers between San Francisco and Los Angeles. This system uses a capsule which travels inside the tube at the speed of 1220kmph, which will cover the distance of 561km in approx. 30minutes

This ultra-high speed transportation system called as Hyperloop system was so famous that many countries started construction for the use of this transportation system.

CAPSULE

Capsule is the part in which will travel inside the tube. Two types of Hyperloop capsules are:

➢ Hyperloop passenger capsule

Supposing an avg. departure time of two minutes between capsules, a minimum number of 28 Passengers per capsule are required to meet 840 passengers per hour. By decreasing the time between the departures we can increase the Hyperloop capacity. During rush hours 40 capsules are required during movement in the current model in which six are used for the loading and unloading purpose.

➢ Hyperloop passenger plus vehicle capsule

This type of capsule will work as a passenger one but the only difference is it uses 3 more capsules for travelling.

To overcome air resistance high power is required to travel at high speed. Aerodynamics drag increases as the square of the speed and hence power increases as a cube of speed.

This is an effective pressure of 100 Pascal, which diminishes the drag force of the air by 1000 times comparative to sea level conditions and would be equivalent to flying above 150000 feet height.

Vacuums are costly and difficult to maintain compared with low pressure solutions so the vacuum is avoided. In spite of the low pressure, aerodynamic challenges must still be considered.

As the speed of the capsule reaches the speed of the sound then the formation of shockwaves takes place and the air resistance increases instantly and hence the acceleration felt by the passengers decreases and a power required by the capsule also decreases.

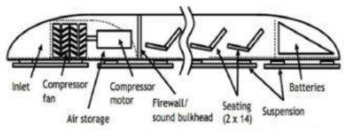


Figure 4. Hyperloop passenger capsule subsystem notional locations (not to scale).

TUBE

The capsule used for travelling moves inside the tube and low air pressure inside the tube is maintained which increases the speed of transportation. 100 pascal pressures is maintained inside the tube which is 1/1000 times pressure on earth. The drag force on the capsule gets reduced because of the low air pressure inside the tube. The tubes are constructed on the pillars which will ease the transportation system as it will not affect the traffic on the roads and will increase the area of construction. This tube also helps in the smooth journey to the passengers as it is inside the tube with the help of air bearings and suspension. To control the speed and by accelerating and decelerating motors are used which will also guide the capsule in a respective direction.

PROPULSION

The need of the propulsion system is as follows-

➢ In urban areas the speed should be low so it is maintained between 0 to 480 kmph. For mountain or hilly areas the speed is maintained near 480 kmph.

➢ For the long coasting area the speed is accelerated from 480 to 1220 kmph.

➢ After the completion of the coastal area the speed is decelerated again to 480 kmph.

The average power consumption is 28000hp or 21MW which involves the power desired by the propulsion motor including changes, air resistance interruptions, the train compressor (charging batteries) and to keep the vacuum in the tube throughout. So to fulfil the needs of the power in Hyperloop system we will cover it with a solar plant as this system is very large.

We will connect batteries at the times of peak demand or peak power as the average power is 1/3 times the peak power demand so batteries will fulfil the power demand but when the power demand is very high and the solar plant cannot withstand it only then the power from the grids will be given. Large accelerators are used to increase the speed from 480 to 1220 kmph at 1G in long coastal areas, small accelerators are used in urban areas and this system can also be used in mountain areas.

Induction motors are used to increase or decrease the speed of the capsule. We use induction motor rather than permanent magnet motor because of the following benefits:

➢ The material cost is low as we are using aluminium in the rotor.

➢ The weight of the capsule is less.

➢ The dimensions of the capsule are reduced.

4. FUTURE EXTENSION

In this we don't need to align the rotor to the air gap because of the lateral forces exerted by the stator on the rotor.

Hyperloop is viewed as an open source transportation idea. The creators energize all individuals from the network to add to the Hyperloop configuration process. Emphasis of the plan by different people and gatherings can help convey Hyperloop from a plan to a reality.

5. RESULT AND CONCLUSION

➢ We were successfully able to demonstrate the power and feasibility of magnetic levitation as a mode to propel vehicles.

➢ The usefulness of superconductivity and electromagnetism was explained.

➢ Our research diverts us to an alternative method of transportation which is efficient yet ultra-fast.

➢ This mode of transport can be compared to air transport in terms of speed.

➢ This reduces the load on air transport and saves fossil fuel.

➢ Electric power minimizes pollution and minimum noise is produced.

➢ Principles like superconductivity and electromagnetism make maglev future ready, saving several hours of time during transport.

➢ The track and capsules/ coaches need to be precisely laid and initial setup is to demand a high capital investment.

➢ With application of magnets in automobiles and industries, magnets can be used as suspension systems or to lift objects.

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