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Comparative Study of Magnetically Levitated Railways Between Hyperloop and SC Maglev

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Abstract - The world is always seeking the betterment of its inhabitants. A study on two advanced technologies of maglev that will be used in the future for better transportation Maglevs float above the surface with clearance and are forced to move forward by a magnetic field. The aspects of the study are the comparison of hyperloop and SC maglev on their working technologies. It is aimed at investigating the advantages and disadvantages of high-speed transportation systems by comparing them in terms of speed, capacity, energy consumption, cost, and environmental effects. The friction, vibration, and noise from traditional steel wheels would simply become too great to run much quicker; they would need a new type of train, so to eliminate rail fruition, engineers would get rid of wheels altogether and instead use magnetic force to levitate the train inside a guideway. It offers remarkable travel times, energy efficiency, and better operational performance. However, high investment costs and incompatibility with other modes are seen as disadvantages of this technology. Hyperloop technology is a considerable and innovative transportation system. The benefits of the Hyperloop transportation system can be assessed based on its anticipated high speed and enticing trip times. However, there are safety, reliability, comfort, and engineering design challenges to overcome with this technology. The Hyperloop transportation system has the potential to replace existing modes of transportation when all factors are taken into account.

***Key Words*:** SC maglev, hyperloop, speed, energy sources, and capacity.

1.INTRODUCTION

In the present day, humans spend most of their time traveling and waiting for transport. By means of increasing technology, the speed of transportation has been a subject that humans have worked on for many years. Nowadays, time-saving transportation is becoming increasingly important, and the system ensures these are implemented and new ones are being researched. It's been researched for years and still is. Because of incremental environmental impacts such as traffic jams, prolonged travel times, air pollution, and noise caused by existing modes of transportation, countries have changed transport policies for people's busy lives and many other reasons.

However, high-speed ground transportation systems like bullet railways, maglev, and hyperloop transportation systems, which are the fastest high-speed railway technologies in the world, are within the scope of the study, which is aimed at researching and investigating the advantages and disadvantages of high-speed maglev and hyperloop. Where both hyperloop and maglev are based on the magnetic technology of propulsion or repulsion, these High-speed ground transportation systems can be divided into two categories based on the type of magnetic technology used: maglev and hyperloop transportation.

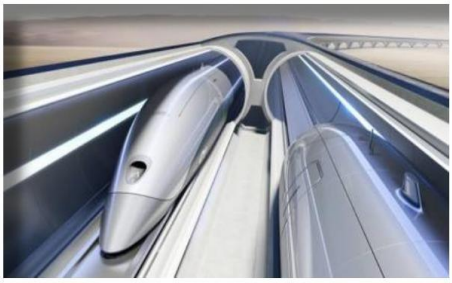

Fig -1: Hyperloop

Fig -2: SC Maglev

It was introduced in the US in the 1900s by American professor and inventor Robert Goddard and French-born American engineer Emile Bachelet and has been in commercial use since 1984. The first research and invention started with maglev technology; further, the Hyper Loop idea was first proposed in 1799 by George Medhurst under the names of airy railroad, atmospheric railroad, and orvac-train, and it gained fame in 2012 with an Elon Musk article. The things we have to consider more are the technology built into it, the speed or high capacity, comfort, safety, and reliability. Maybe the things are expensive, but you can offer remarkable travel times, energy efficiency, and better operational performance. Elon Musk's design document popularized hyperloop technology, which is a significant and innovative transportation system.

Maglev, or magnetic levitation, is not a new idea. The concept of electromagnetic propulsion was first discovered in 1889 by Professor Elihu Thomson while working with electromagnetic waves and alternating current. Maglev is an action that is achieved by magnets. Many scientists around the world were working on the same idea with different technologies and techniques.

MAGLEV TECHNOLOGY:

Maglev is the term for "magnetic levitation". It's a method in which an object is supported by a magnetic field and allowed to float.

superconducting magnetic levitation. It is one of the advanced railway technologies developed by the collaboration of the Central Japan Railway Company and the railway technology research institute. Actually,

In 1962, the Japanese National Railways (JNR) began research on a linear propulsion railway system with the goal of constructing a train that could travel in one hour between Tokyo and Osaka. However, JNR was privatized in 1987, and the SC maglev development was taken over by the Central Japan Railway Company.

The SC maglev operates on three phenomena; they are

1.levitation
2.propulsion
3.guidance

1.1 **Levitation:** the repulsion force between the same polarity of a magnet is called levitation. It achieves a strong electromagnetic field. It is also called electrodynamic suspension. They must continuously circulate current on the coil to achieve those superconductors. The coils are charged with a huge amount of DC current at 700 kA. It produces enough magnetic fields to levitate the cars.

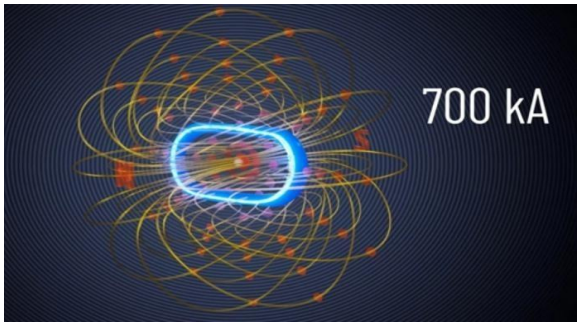

Fig -3: Levitation

To maintain that magnetic field, the conductor coil should be at the superconductivity stage. Liquid hydrogen is used to cool the coil, and the coil is covered with a radiation shield that protects the coil from temperature differences caused by radiation. The shield also maintains the same temperature as the coil by circulating liquid nitrogen around it. This system is placed on either side of each car.

Table 1: Temperature differences

Component	**Temperature (°C)**
Liquid hydrogen	-269.5°C
Liquid nitrogen	–196°C
Conducting coil	-266.7°C

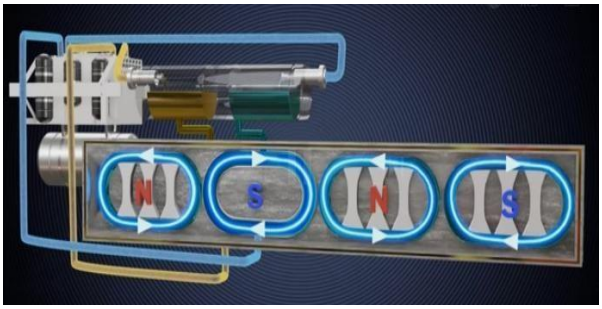

Fig -1: figure-eight-shaped coils

A pair of figure-eight-shaped coils, which are twisted circuit coils, are placed on the guideways, and the train is levitated by varying magnetic flux due to Firdaus law. When the superconductor is moved away from the coil loop, the difference in emf is increased, and that emf is brought to the center of the loop at this position.

1.2 **Propulsion:** The propulsion is achieved by placing the propelling coils. The propelling coils are a series of normal electromagnets on either side of the guideways, which are charged in alternative ways. As shown in the figure, the net force is forward. When the superconductor reaches its mean point and the propelling coils change their polarity, the net force is always forward.

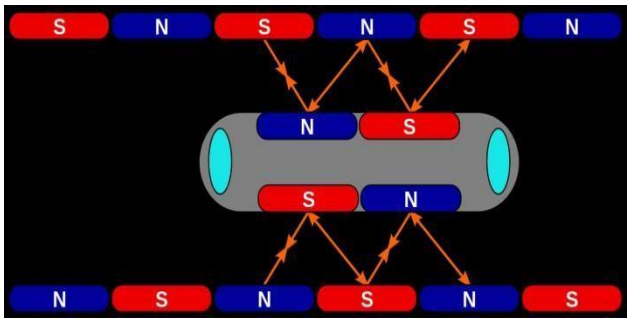

Fig -5: Propulsion

1.3 **Guidance:** Guidance is one of the important things that helps to prevent crashing into the guideways by simply connecting the figure eight coil on either side. When the train moves either way, an emf is produced on that side, which pushes the train towards the canter.

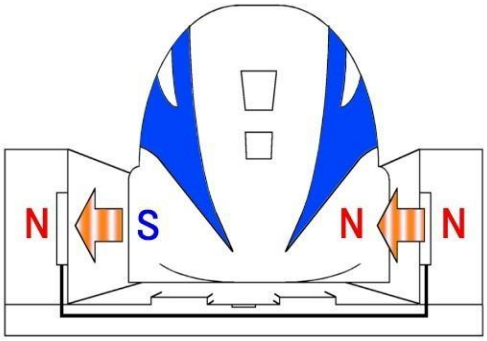

Fig -6: Guidance

Depending on the frequency of the provided alternating current, the speed of Maglev trains can be changed. Braking and stopping the train are performed by generating a magnetic force in the opposite direction. They are two main types of Maglev technologies as follows. the electromagnetic suspension system (EMS) and the electrodynamic suspension system (EDS). Where electromagnetic suspension uses magnetic attraction force to move in the air, Electrodynamic Suspension uses repulsion force.

HYPER LOOP:

The Hyper Loop is an automobile that travels in a low-pressure tube with a huge speed of up to 1500 km/h, according to research. It's one of the most fascinating and advanced future technologies. Going back to its roots in 1799, the Hyper Loop was conceptualized as a pneumatic railway, but it is still in the concept stage. In 2013, a tech industrialist, Elan Mask, brought it back to public attention by publishing 54 papers about Hyper Loop Alpha on safety, reliability, and cost. Then some company's virgin Hyper Loop, Hyper Loop One, started prototype tests.

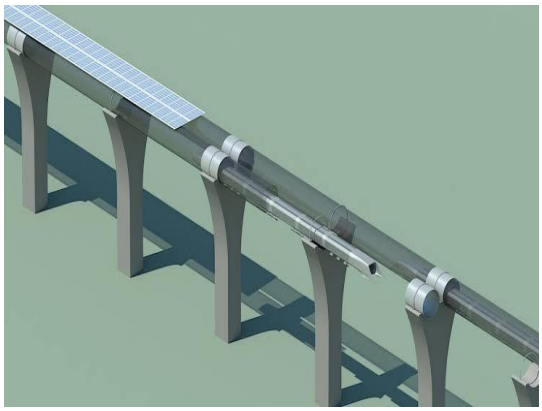

Fig -7: Hyperloop with solar plate

The hyperloop technology is similar to that used in maglev vehicles. The Hyper Loop operates on the same principle as magnetic levitation vehicles; it uses active magnets that levitate, guide, and propel on the guideways. Hyper-loops can achieve 1500 Km/h on paper, which is achieved by propelling the vehicle in the vacuum tube. The pressure is reduced by sucking 99.9% of the air out. This leads to dynamic resistance. No air means no resistance that is caused by the wind blast to reduce the speed of the vehicle. The active magnets are charged by the battery packs that are in the vehicle.

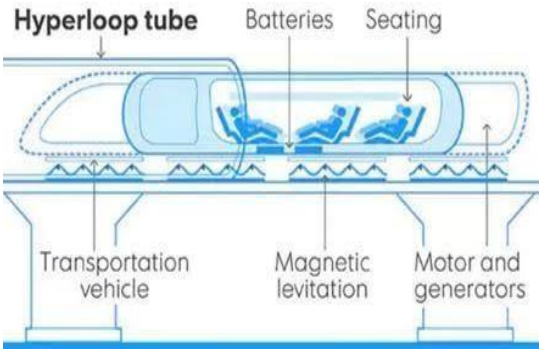

Fig -8: Hyperloop tube

In this context, the first test track, called DevLoop, was built by Hyperloop One in the Nevada desert, north of Las Vegas. This test track is approximately 500 meters long, and it is used to test prototypes of passenger and cargo capsules. While the United States dominates work on the hyperloop technology, nations including the United Arab Emirates, India, France, and the Netherlands are conducting research and studies on the potential use of this system in their own countries.

COMPARISON BETWEEN MAGLEV AND HYPERLOOP

People spend most of their time traveling from one place to another; to save time, they choose the fastest traveling process. The design and operation speed of each mode of transportation play a vital role in terms of travel time. Here we see the comparisons between both SC Maglev and Hyperloop. As part of the scope of the study, it is possible to compare the maglev and hyperloop systems from different aspects. comparisons like speed, capacity, compatibility of the system, power source, etc.

- Comparison in terms of geometric standards
- Comparison in terms of cost
- Comparison in terms of energy consumption

When comparing the SC maglev and the Hyperloop, both are advanced technologies that will rule future transportation. but each one has its

advantages and disadvantage on it's path.so considering some specific topics like speed, capacity, and energy sources.

Speed: The lack of air resistance Hyperloop can go faster than SC maglev, up to 1500 kmph, due to the vacuum chamber. where maglev is up to 640 kmph.

Table 3: comparison in terms of speed

Speed (Km/h)	SC Maglev	Hyperloop
Design speed	640	1220
Operating speed	431	760
Average speed	290	965

Capacity: Capacity-wise, the SC Maglev carries more payload than the Hyperloop because of its strong propulsion force created by the superconductor's magnetic field.

Table 4: comparison in terms of capacity:

type	SC maglev	Hyperloop
Number of section	6	1 capsule
Seat capacity	574	28
Head way (min)	15	2
capacity	2296	840

Energy sources: Sc Maglev has its own power generation system by magnetic flux developed itself instead of a battery pack in the system like Hyperloop.

Maglev transportation systems offer a safe and comfortable trip. In the Hyperloop concept, although there are concerns in terms of comfort at the targeted sound levels, there is no data that can be compared since there is no commercially operated Hyperloop line for now.

ADVANTAGES:

- **Speed:** In terms of speed, hyperloops have a greater advantage due to the reduction of air resistance while they are moving by vacuum capsules, and the vacuum is created by integrated air pumps.
- **Capacity**: When we talk about capacity, Sc maglev has a better advantage due to the strong magnetic field of superconductors, which produces a great net force to pull the automobile with a larger payload.
- **Energy source:** o operate any object, they need power. In that case, the Sc maglev advantage is that it can produce its own power to operate at the speed at which it goes. The power produced is used to run the refrigerator and electronics. When it comes to superconductors, we need to change them all at once because superconducting materials can circulate current without resistance.

DISADVANTAGES:

- **Speed:** In terms of speed, SCmaglev has a disadvantage due to air resistance. No matter how efficient the air dynamic design is, it should face resistance in the open air.
- **Capacity:** capacity-wise, hyperloop loops have a major disadvantage due to the electronic resistance of the conducting material. The electronic resistance has an impact on the magnetic field due to this pulsing, and the net force is low, which reduces the payload capacity.
- **Power source:** the hyperloop is operated on the rechargeable battery pack. It's really hard to change every time when power goes out and recharging takes time, which has an effect on the economy.

COMPARISON IN TERMS OF GEOMETRIC STANDARDS

Track geometry is a very important factor in train behavior. The notions related to track geometry can be sorted as track gauge, can't, transition curve, horizontal and vertical curve radius, and longitudinal grade. In terms of geometric standards, Maglev and Hyperloop have advantages such as moving at a lower curve radius with the same speed, traveling at higher speeds in the same curve radius, and climbing higher slopes compared to Conventional high-speed railways

A normal train runs on wheels that rotate on the tracks and provide the torque that makes the train move. friction is present on every piece of gear in the motor/wheel system, in addition to aerodynamic drag. A maglev is instead lifted from the tracks by an electromagnetic field generated by coils underneath the cars. The same coil system also provides a "static" pull through attraction and repulsion between itself and portions of the tracks. With this system, there is no mechanical drag in the transmission of the movement because there are almost no parts in rotation.

Due to the fact that lateral g forces greater than 0.5 g are typically regarded as being unacceptably high for comfort reasons, the curve radius has a significant impact on the alignment design in hyperloop. As a result, there is a straightforward relationship between turn radius and vehicle velocity. For instance, we can infer that at maximum Hyperloop operative speed, the tube structure must bend at a minimum radius of 23.5 km to be comfortable for the passengers (Alpha document). The curve's lateral acceleration rises with the square of its speed and falls with the turn radius.

Comparison in terms of Cost Cost plays an important role in selecting and evaluating any mode of transportation. There are different cost concepts, such as construction, operating, and maintenance costs, for a mode of transport. The cost of construction includes the cost of constructing the line and stations, the train control system, and the purchase of the trains. The operating cost includes the expenses required to keep the line operating. Maintenance costs include the necessary expenses to operate the line properly and efficiently.

The construction cost of maglev is higher than that of other high-speed railways due to the completely separate right of way, the construction of special facilities, and the fact that it is incompatible with existing transportation systems. The fact that Maglev trains cannot operate on standard train tracks, that they are incompatible with the current rail network, and that they need a brand-new line are all significant considerations that raise the cost of development.

The cost of building the guiding line, producing the capsules, and building the stations is included in the Hyperloop technology construction cost. The fact that Maglev trains cannot operate on standard train tracks, that they are incompatible with the current rail network, and that they need a brand-new line are all significant considerations that raise the cost of development.

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The cost of building the guiding line, producing the capsules, and building the stations is included in the Hyperloop technology construction cost. The Hyperloop Alpha report foresees a construction cost of approximately $6 billion for the passenger-carrying version alone and $7.5 billion for the passenger-plus-vehicle version. It is not included in the earthwork and special station costs in this cost estimation. Additionally, a current project between Dubai and Abu Dhabi, which is planned to be completed soon, is estimated to cost between $20 million and $40 million per kilometer.

When comparing the average construction costs between these transportation systems, it is seen that the highest construction costs per kilometer belong to the Maglev mode of transport. According to the

stipulated costs in the Hyperloop Alpha report, the Hyperloop transportation system has a lower construction cost than Maglev.

COMPARISON IN TERMS OF ENERGY CONSUMPTION

In Hyperloop technology, it is planned to meet the energy needs with solar panels built into tubes. The Maglev train is much more economical compared to Conventional high-speed railways because it has no contact with the guideway, a high-efficiency linear motor, and low aerodynamic resistance. Maglev is cost-effective in terms of energy consumption because to practical aerodynamic features and noncontact technology. It is underlined in the Hyperloop Alpha study report that the Hyperloop system will run purely on solar power. It is therefore anticipated to use less energy than Maglev.

RESULTS AND DISCUSSION

When an evaluation is made based on parameters that are compared between the examined transportation types, Hyperloop and Maglev are both highly technical transport systems. where in the hyperloop has the same method that is used in maglev, the magnetic levitation, with the addition of a vacuum tube to reduce the friction force on it. While it works on the same technology, by comparing different aspects, hyperloop is the better transportation system. with high speed. To illustrate, the route between San Francisco and Los Angeles takes 116 minutes by Maglev train and 35 minutes by Hyperloop capsule. If target speed values for the Hyperloop concept could be reached, the technology would have a serious advantage in speed and travel time parameters.

In terms of compatibility, the Maglev and Hyperloop transportation systems are not compatible with existing lines because they require their own special line structure. The geometric advantages of Maglev and Hyperloop include the ability to travel at the same speed while negotiating smaller radius curves. In terms of cost, the Maglev transportation types have the highest construction and Maintenance costs. In the Hyperloop Alpha report, the total construction cost of the 563-kilometer route between San Francisco and Los Angeles is stated as $6 billion. It should be noted that earthworks and the construction of a special station are not included in this cost estimation. Taking this average cost into consideration, the Hyperloop transportation system is cheaper than the Maglev.

A comparison is made based on energy consumption. Maglev trains consume less energy than normal trains thanks to the aerodynamic features of the train and contactless technology.

In the Hyperloop Alpha report, it is stated that the Hyperloop capsule would run entirely on solar energy

Table 5: Overall comparison

System Features	Maglev	Hyperloop
Maximum Speed (km/h)	430 (Shanghai)	1220 (theoretical)
Capacity	574 per Shanghai Maglev train	28 per capsule
Use of existing infrastructure	Need special track	Need special track
Construction Cost	high	low
Operating and Maintenance Cost	high	low
Energy Consumption	Higher then hyperloop	Solar panels Less than maglev
Safety	Proven technology	At concept stage
Noise and Vibration	less	less

As a result, the hyperloop mode of transport would be expected to use less energy. The Maglev and Hyperloop transportation modes are created as elevated tracks when evaluated in terms of land usage. As a result, land utilization can be reduced.

Moreover, less noise and vibration are achieved with the help of the contact-free technology utilized in the Maglev and Hyperloop transit systems. Finally, in this section, the references used in this study are categorized as economic analysis, engineering design, and environmental issues. The classification and comparison of references are given in Table 5.

Conclusions

Hyperloop and SC maglev are the most reliable and advanced Next Generation transplantation technologies that will be used in the future. In the future, electricity is going to play a key role as a power source by replacing fossil fuels (coal, crude oil, etc.). As our study shows, the advantages and disadvantages of two transportation systems against each other were examined. As a result, although Hyperloop technology is a highly innovative mode of transportation, work on the development of the technology continues. The projected low construction cost, speed, and minimum environmental impacts made it stand out among the transportation types studied.

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