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Design and Development of Hyperloop Train

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***Abstract*: Transportation is an industry in constant flux forced to keep up with ever growing human population. While providing faster and cheaper methods of travel. In hundred years the industry has made great improvements, has seen by the replacement of horses with the large scale implementation of mechanized cars, trains, planes and boats. The Hyperloop, a new transportation concept idealized by Elon Musk. This system is a proposed mode of transportation that propels a capsule like vehicle through a vacuum tube at more them airline speed. Preliminary analysis indicated that such a route might obtain an expected journey time 35 minutes, meaning that passengers would transverse the 350 mile (560 km) route at average speed of around 600 mph (970 km/h) with top speed of 760 mph (1,200 km/h). Hyperloop consists of a low pressure tube with capsules that are transported at both low and high speeds throughout the length of tube. Passengers may enter and exit Hyperloop at stations located either at the end of the tube, or branches along the tube length.**

***Keywords*: Air bearings, Capsules, Hyperloop, Magnetic levitation, Pod, NSDLIM.**

1. Introduction

HYPERLOOP is a very high-speed maglev train that travels by vacuum cylindrical tube to overcome speed limit from wheel–rail friction and air resistance. In superconducting maglev (SCMaglev), which is the fastest magnetic levitation train in Japan with a 603 km/h maximum speed, linear synchronous motor is applied for propulsion, and superconducting electromagnet and null flux coil are applied for both levitation and guidance. At present, there are only systems that perform a maximum of two functions among propulsion, levitation, and guidance. With many devices in the tube, the system gets complex so there are a lot of disadvantages in terms of cost, operation, and control. In this paper, a non-symmetric double sided linear induction motor (NSDLIM) that could conduct propulsion, levitation, and guidance is suggested as an all in one system for hyperloop. NSDLIM concepts such as structure and mechanism of three functions are introduced. NSDLIM is a new system that has not been studied, so requirements are investigated and a basic model is designed with several approx. private assumptions. Then by using the infinite-element method (FEM), characteristics are analyzed and parameters that affect performance are investigated. Through changing parameters, an improved model is derived and its possibility is proposed.

2. Literature review

1. Elon Musk

In August 2013, the CEO of Tesla Motors and SpaceX, Elon Musk released a design document for a new high speed transportation concept. He came up with the idea for a vacuum and maglev powered super-fast train that would travel through a tube. It would be called Hyperloop. In a research paper, he outlined its potential and challenged the other tech companies to develop it for commercialization. This new system would transport passengers and cargo within pressurized capsules that travel through tubes at similar or higher speeds than air travel.

2. The MIT Hyperloop Team

They competed in the SpaceX Hyperloop competition from June 2015 to January 2017. The goal for this competition is to design and build a scaled Hyperloop pod to test in a 1-mile long test track in Hawthorne, California. In doing so, the teams develop technology that could one day be used in a full-scale Hyperloop system. A droplet shaped aero-dynamics shell is most effective at delaying flow separation, lowering the drag substantially. By investigating the performance of the design at transonic speed, it was also found that violating the Kantrowitz Limit could lead to three-fold increase in drag coefficient for an increase in Mach-number from 0.65 to 0.80.

3. Ahmed Hodaib, Samar F. Abdel Fattah (May 2016)

They discussed the “Design of a hyperloop capsule with linear induction propulsion system” which is used to accelerate and decelerate the capsule. They studied that like rotary synchronous motors, linear motors run on 3-phase power and can support very high speeds. However, there are end effects that reduce the motor's thrust force. Linear induction motors are thus less energy efficient than normal rotary motors for any required force output. They also discussed about the manufacturing of linear induction motor in this paper.

4. Jeffrey C. Chin, Justin S. Gray, Scott M. Jones, Jeffrey J. Berton

They discussed about the “Open-Source Conceptual Sizing Models for the Hyperloop Passenger Pod” in this paper. They concluded that the refined analysis illuminates several interdisciplinary couplings that alter two major aspects of the initial concept. First, the pod travel speed and the tube cross sectional area are linked, forcing the tube size to be to be roughly twice the diameter of the original specification, in order for the pod to reach Mach 0.8. Second, the steady-state tube temperature is dominated by ambient thermal interactions

unrelated to the heat generated by the pod compression system.

5. Mark Sakowski (2016)

He demonstrated that not only evaluation of the current maglev but also evacuated tube technology and concluded that Hyperloop is feasible if properly designed. In terms of energy usage it has the potential to be much more efficient of pods traversing down the tube. He discussed "The Current Maglev Technology Along with The Theoretical Evacuated Tube Technology" and they concluded that the hyperloop is feasible and if properly designed, has the potential to be much more efficient in terms of energy usage of pods traversing down the tube.

6. N. Kayela (2014)

The investigation was based on the fact that "The Hyperloop Is a Fifth Mode of Transportation Alongside Trains, Planes, Automobiles and Boats". He discussed about the railway track for the hyperloop, stations for the hyperloop. Also, discussed about the two version of capsule that is one is passenger only version and another is passenger plus vehicle version.

7. Mohammed Imran (2016)

He focused his Study Element on The Hyperloop Technology (The Passenger Transport System). He discussed about the two version of hyperloop in that one is passenger only version and another is passenger plus vehicle version. Hyperloop System.

8. Mateusz Turkowski, Maciej Szudarek (Warsaw University of Technology, Poland)

Their aim was to investigate a concept of pipeline transport system that employs stationary linear induction motors to propel lightweight capsules. Theoretical consideration on optimal solutions as well as modelling of the systems behaviour is presented. The idea is to adapt existing pipeline construction technologies to achieve cost effectiveness. For that reason, usage of powering rails is excluded and the pipe is of circular shape. The proposed capsule dimensions are diameter of ca.1.4m and length of ca.2.8m. The exact dimensions would depend on the existing logistic chains. Eg: Pallets that are used. The main finding of the article are developed dimensionless groups, computational fluid dynamics model of a capsule moving in a pipeline and an analytical model capsule dynamics.

3. Basic principle of hyperloop train

Hyperloop is based on a principle of magnetic levitation. The principle of magnetic levitation is that a vehicle can be suspended and propelled on guidance track made with magnets. The vehicle on top of track may be propelled with the help of linear induction motor. Hyperloop is a new technology, yet the idea behind it is perfectly feasible within our understanding of physics and implementation would not require any new technology. In essence, creating a Hyperloop should only require paring together current technologies. The major theoretical hurdle for Hyperloop is something called the Kantrowitz limit. This talks about speeds of projectiles as they move in a tube. A projectile in a tube has a minimum tube to projectile ratio in order to move at a high speed efficiently. This is because as a projectile starts to move quickly in a tube it creates a large column of air in front of it. If the tube diameter is too small, the projectile will not only have to propel itself forward but also the entire column of air in front of it. This occurs because the air cannot move around the projectile if the diameter is too small. Furthermore, this situation would require an infeasible amount of power for a very little speed benefit, or in other words a horrible transportation system. The solution to this problem is to simply make a large tube, yet this too is inefficient for a largescale transportation system as material cost would be greatly increased. Luckily in 2013, Elon Musk proposed a solution to both these problems. If an electric compressor fan is placed on the nose of the pod it could actively transfer high pressure air from the front of the pod to the back. Moreover, this air could also be used to create a cushion for the train to glide on as it travels, known as an air bearing. The benefit to air bearings are that Hyperloop would not lose any energy to fighting friction. The nemesis for anyone who wants to move an object quickly. The other components of Hyperloop are electromagnets to propel the train forward and a near vacuum inside its tube. Electromagnets are current in use, known as maglev, in the fastest bullet trains in the world. The difference would be that in Hyperloop the magnets are only used for propulsion. This means that magnets will only be needed in the walls of the tube at the very start of track and about every 70 miles to keep the train at its top speed. In total about 1% of the tube would need to be made up of magnets. Another major feature of Hyperloop is the tube it travels in. While the outside is nothing special, the inside is a soft vacuum. This is very important as it also reduces the amount of drag force in the tube.

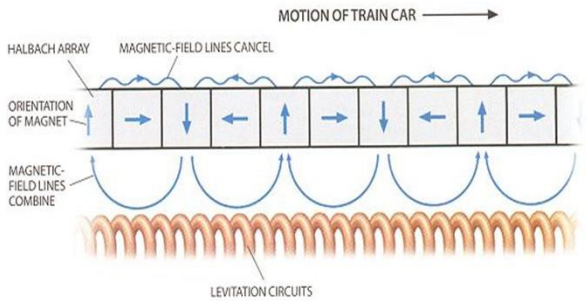

Fig. 1. Principle of hyperloop train

4. Design

The hyperloop consists of two major components, including

A. Capsule

Sealed capsules can carry about 28 travelers and moves along the inside of the tube. A bigger framework has additionally been measured that permits transport of 3 full-size vehicles along with travelers to travel in the capsule. The containers are bolstered by means of air bearings that work utilizing a compressed air reservoir and aerodynamic lift. For movement

at high speeds, the best power necessity is ordinarily to beat air resistance. Streamlined drag increments with the square of speed, and along these lines the power requirement increments with the cube of speed. The containers are isolated inside the tube by around 37 km on average during operation. Two versions of the Hyperloop capsules arc being considered (a passenger only version and a passenger plus vehicle version.)

1) Hyperloop Passenger Capsule

Expecting a normal flight time of 2 minutes between containers, at least 28 travellers for every capsule are required to meet 840 travellers for every hour. It is conceivable to additionally expand the Hyperloop limit by diminishing the time between flights. The present pattern requires up to 40 capsules in movement amid surge hour. Six of which are at the terminals for loading and unloading of the travellers in around 5 minutes.

2) Hyperloop Passenger Plus Vehicle Capsule:

The traveler in addition to the vehicle version of the Hyperloop will depart as frequently as the traveler, however will accommodate 3 vehicles in addition to the traveler. All subsystems talked about in the accompanying segments are highlighted on the two cases. For travel at high speeds, the greatest power requirement is normally to overcome air resistance. Aerodynamic drag increases with the square of speed, and thus the power requirement increases with the cube of speed. For example, to travel twice as fast a vehicle must overcome four times the aerodynamic resistance, and input eight times the power.

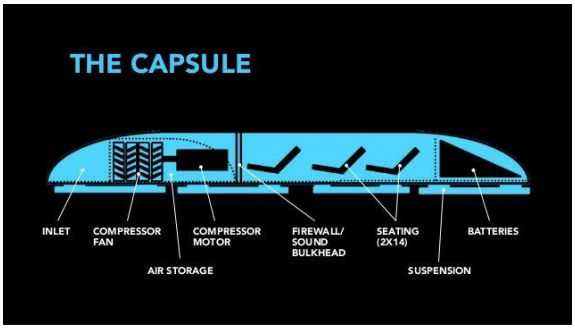

Fig. 2. Hyperloop passenger capsule

3) Tube

The tube is made of steel. Two tubes will be welded together in a side by side configuration to allow the capsules to travel both directions. Pylons are placed every 100 ft (30 m) to support the tube. Solar arrays will cover the top of the tubes in order to provide power to the system. Tubes are made by the new material "VIBRANIUM". The Hyperloop travel journey will feel very smooth since the capsule will be guided directly on the inner surface of the tube via the use of air bearings and suspension; this also prevents the need for costly tracks. The capsule will bank off the walls and incorporate a control framework for smooth returns to nominal capsule location from banking also. Some particular areas of the tube will consolidate the stationary engine component (stator) which will locally direct and accelerate (or decelerate) the capsule. Between linear engine stations, the capsule will glide with little drag by means of air bearings.

Fig. 3. Hyperloop tube

5. Propulsion

To accelerate and decelerate the capsule the linear induction motor is used in the hyperloop system. It provides some advantages over a permanent magnet motor. To accelerate the capsules there is linear accelerators are constructed on a length of the tube. Stators are placed on the capsules to transfer momentum to the capsules via the linear accelerators.

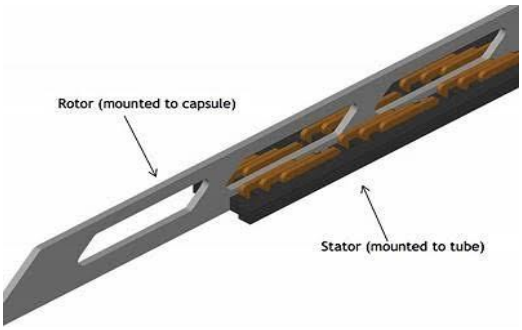

Fig. 4. Propulsion in hyperloop

6. Suspension

Air bearing suspension offers stability and extremely low drag at a feasible cost. A stiff air bearing suspension is superb for reliability and safety. When there is a gap between ski and tube walls is high then it shows the nonlinear reaction and which results in large restoring pressure.

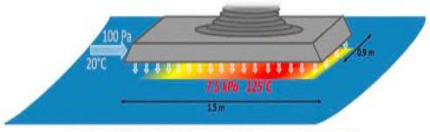

Fig. 5. Suspension in hyperloop

7. Working principle of hyperloop

Working of hyperloop system is based on magnetic levitation principle. As we know that the passenger pad travels through the low-pressure tube which is a pylon-supported tube. In the Hyperloop system, an air compressor fan is fitted on the front

side of the pod which sucks the air. It transfers high-pressure air front side to the rear side of the capsule (pod) and it propels the pod. It creates the air cushion around the pod so that the pod is suspended in air within the tube. On the basis of magnetic levitation principle, the pod will be propelled by the linear induction motor. By the linear induction motor, the capsule sends from one place to another place to a subsonic velocity that is slower than the speed of sound. The pod will be self-powered. There is a solar panel fitted on top of the tube. By this solar panel, there is enough energy is stored in battery packs to operate at night and in cloudy weather for some periods. The energy is also being stored in the form of compressed Air. The air between the capsule acts as a cushion to prevent two capsules from colliding within the tube.

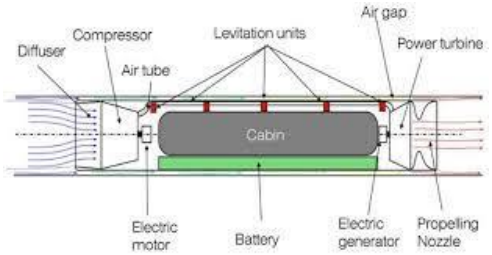

Fig. 4. Working principle of hyperloop

8. Merits and demerits of hyperloop train

A. *Merits*

- It saves traveling time.
- There is no problem with traffic.
- It is powered by the solar panel.
- It can travel in any kind of weather.
- Cost of hyperloop is low.
- Not disruptive to those along the route.

B. *Demerits*

- Turning will be critical.
- Less movable space for the passenger.
- High speed might cause dizziness in passengers.
- The punctured tunnel could cause shockwaves.

9. Conclusion

A high-speed transportation system known as Hyperloop has been developed in this report. Hyperloop transportation system can be used over the conventional modes of transportation that are rail, road, water, and air. At very high speed it provides better comfort and cost is also low. By reducing the pressure of the air in the tube which reduces simple air drag and enables the capsule to move faster than through a tube at atmospheric pressure. Requirements of the all-in-one system were investigated, and the NSDLIM basic model was designed. To increase thrust force, S08 was inserted in secondary and resistance of secondary was adjusted. An NSDLIM model that meets required thrust force was obtained, and it was analyzed by 3-D FEM to investigate levitation force. Although levitation force is insufficient, through additional study such as parameter adjustment and application of ladder type secondary plate, it could be increased and there is possibility.

10. Future work

1. Improve passenger capacity.
2. Detailed station designs with loading and unloading of passenger.
3. Safety features improvement.
4. It can be used in material handling devices.

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