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# Hyper loop: Transportation Redefined

Aditya Kale[1], Chinmay Bane[2], Aniruddha Dhurde[3], Akanksha Wala[4], Pragya Jain[5]

[1](Electrical, Atharva College of Engineering, India)
[2](Electrical, Atharva College of Engineering, India)
[3](Electrical, Atharva College of Engineering, India)
[4](Electrical, Atharva College of Engineering, India)
[5](Electrical, Atharva College of Engineering, India)
*Corresponding Author: Aditya Kale*

***Abstract:*** *We live in a fast paced world. Cities are the spine of the economy. Transportation facilitates this growth, and it will continue to do so for the foreseeable future. Contrary to the need of the hour, existing transport technologies are slow, expensive or a combination of both. An innovation such as The Hyperloop presents itself as a solution to this. The Hyperloop is a proposed system of transport that would see pods or capsules travel at high speeds through a tube that has been conditioned into near-vacuum. The capsules would levitate using air bearings, similar to how pucks travel across an air hockey table. With so little friction in the tunnel, the pods would be able to travel at massive speeds projected up to 1200 kmph. The pod would initially launch using a linear induction motor before levitation takes place and the pod will then glide at immense speeds in the low-pressure environment. Tunnels/tubes for the Hyperloop would be constructed either above or below ground, occupying a smaller area than traditional rail and road. Most of the current designs feature autonomous capsules that can be launched on demand frequently, within seconds. Some private undertakings suggest eco-friendly designs, powering the pressure pumps with clean energy such as solar. The agenda of this paper is verifying the principles on which the proposed Hyperloop plans to operate and present a prototype with additional contributions and modifications.*

***Keywords –*** *Air Bearings, Capacitor Bank, Capsule, Coil Gun, Compressor Fan, Evacuation, Kantrowitz Effect, Linear Induction Motor, Solar Arrays.*

## I. Introduction

The Hyperloop is a concept for high speed transportation, consisting of capsules traveling at high speeds in a tube with near vacuum pressure. The concept was originally proposed in a white paper published by SpaceX in 2013 [1] as an alternative to the high-speed rail system, currently being developed between Los Angeles and San Francisco. The Hyperloop concept would satiate a growing need for an alternative transportation mode for distances where traditional modes such as railways and airplanes are too slow or are uneconomical. For brief routes, the time spent travelling by air is way shorter than the time required in completing the entire journey because of factors such as local traffic, accessibility issues and the likes. The frequent capsule departures of Hyperloop would alleviate some of these hindrances. A study made by KPMG, backed by Hyperloop One, revealed that the travel time between Helsinki and Stockholm could be reduced by 75% of the current travelling time [2].Furthermore, the investments towards high-speed transport is projected to increase rapidly over the next few decades, and the Hyperloop concept could alleviate the strain on air and rail travel. The Hyperloop movement is gaining momentum, attracting a large number of startups dedicating themselves towards making it a success. Richard Bransons' Virgin Group is planning to construct a Hyperloop Transportation System between Mumbai & Pune.[3]

## II. Literature Survey

Elon Musk, (July 2012) pitched an idea for a fifth mode of transport which would operate on combined principles of a Concorde, an air hockey table and a rail gun. He patented this under the name – Hyperloop, of which he published an open sourced white paper. In his words, Hyperloop incorporates reduced-pressure tubes in which pressurized capsules ride on air bearings, accelerated by linear induction motors.[1]

Ahmed Hodaib, Samar F. Abdel Fattah (May 2016), proposed the use of linear induction motor for propulsion of the Hyperloop capsule which can be used for speeding and braking of the same. The study demonstrated that like rotary synchronous motors, linear motors run on 3-phase power can support very high speeds. Although rotary induction motors are more energy efficient, there are end effects that reduce the motor's thrust force, thus proving that linear induction motors are much more suitable for the required force output.

Further discussions were also made about the manufacturing of the induction motor with regard to the Hyperloop.[4]

Jeffrey C. Chin, Justin S. Gray, Scott M. Jones, Jeffrey J. Berton, in their paper, conferred about the Open-Source Conceptual Sizing Models for the travelling capsules of the Hyperloop. A thorough analysis led them to a conclusion which illuminated several interdisciplinary couplings that alter two major aspects of the initial concept. Primarily, a direct relation between the pod travel speed and the tube cross sectional area was found, forcing the tube size to be to be approximately twice the diameter of the original specification for the pod to reach the desired value. In addition to this, the steady-state tube temperature is independent of the heat generated by the pod compression system and is dominated by ambient thermal interactions.[5]

Mark Sakowski (2016) after a theoretical evaluation of the current maglev as well as the evacuated tube technology and concluded that the Hyperloop is feasible if properly designed. It has the potential to be much more efficient in terms of energy usage of pods traversing down the tube.[6]

**Table 1**. Comparison of Rail Transportation Systems

| | RAIL TRANSPORTATION SYSTEM | TRACTION | TRAFFIC | MAX SPEED | COST (Billion Rs/km) |
|---|---|---|---|---|---|
| HIGH SPEED RAIL |  | Electric power: wheel-rail friction | Passenger | 280-300 Km ph | 1.2-2.6 |
| MAGLEV TRAIN |  | Magnetic levitation and guidance technology using linear synchronous motors | Passenger | 400-500 Km ph | 7.2 |
| HYPERLOOP |  | Levitated pods through a low pressure tube over an air cushion | Passenger and Freight | 1200 Km ph | 2.4-5.6 |

*Source: Images: HSR: "ICE-3-frankfurt" by Sebastian Kasten, 2005, Wikimedia commons; Maglev Train: "ECOBEE" by Minseong Kim, 2016, Wikimedia commons; Hyperloop: "Hyperloop 1" by Hyperloop Transportation Technologies, 2015.*

## III. Basic Principle

An underground or above ground pillar-supported tube will establish a controlled environment. A low pressure system is created through which passenger capsule will travel with very little air pressure to oppose its motion. This near vacuum atmosphere which is basically pressure around 5 to 6 Pounds per square inch absolute will be maintained by providing vacuum pumps at regular intervals. An air compressor fan driven by electric motor on the front of the capsule will transfer high air pressure from its front to the rear and sides of the vessel. This will result in the reduction of friction in front of the pod, helping it to propel and create an air cushion around it, so that the pod levitates in the air within the tube. Therefore air bearings that work on same basic principle of air hockey table will replace wheels as wheels would not work at the required high speeds (1200 kmph). The capsule will be battery-powered and will be propelled by an external linear electric motor which plays important role in propulsion of capsule producing motion in straight line than rotational motion. This linear induction motor would propel the pod to near sonic velocity which is slower than the speed of sound but still fast enough for movement of capsule and provide a re-boost about every 120kms.

The propulsion system is required for as little as 1 percent of the tube length which goes to prove that propulsion system is not particularly costly. Erection of the tube on pillars above ground enables to have the benefits of saving money, provision of protection from earthquakes, rainfall and snowfall and allowing solar panels to be placed on top. The energy obtained from these solar panels more than satisfy the operational need of the Hyperloop. This energy would also be stored in battery packs for operation during cloudy and rainy condition and during nights.

## IV. Illustrations

The practically implemented prototype of Hyperloop comprises of the following fundamental parts:

**1. Tube and Evacuation System:**

Fig. 1 Tube with Evacuation Setup

The capsules carrying passengers or goods travel in tubes. One of the reasons for the high speeds of Hyperloop is its low air drag. This is possible by removing the air inside the tube and conditioning it to a near vacuum state. This can be accomplished by installing vacuum pumps/pressure pumps at regular intervals throughout the length of the tube. Accelerators such as a linear induction motor propel the capsules, which then cruise through the vacuum for the remainder of the trip using no additional power. The energy used for propulsion can is regenerated as the capsules slow down. Using evacuated tubes make the Hyperloop 50 times more efficient per kWh than electric cars or trains.

Solar arrays will be installed over the top of the tubes in order to provide power to the system. Given the length of the tube, the power generated through solar is much more than what is consumed by the propulsion system and the evacuating pumps. The tubes are laid like freeways and the capsules are automatically routed from origin to destination for making the system efficient. The tubes can be built for 1/10th the cost of High Speed Rail track, or 1/4th the cost of a freeway.

**2. Capsule**

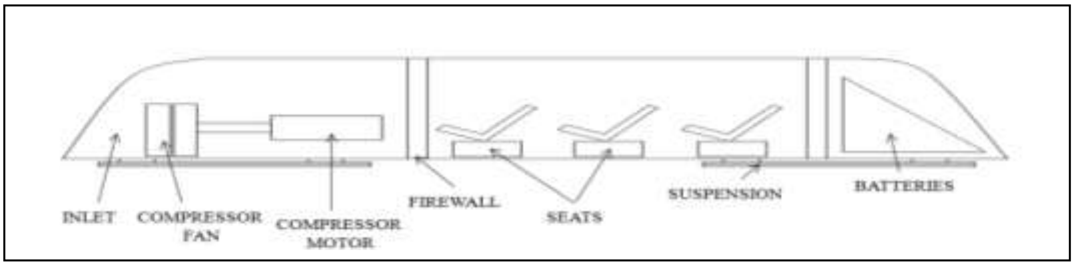


Fig. 2 Capsule Schematic

The Capsule or the Pod is the actual component of the Hyperloop responsible for transportation. It is a passenger/goods carrier that traverses within the evacuated tube at high speeds. For the capsule to move at high speeds, the major obstacles that it has to overcome are the air drag and friction. On account of high speeds of the capsule, wheels cannot be employed as vaporization of the rubber tires occurs.

In Fig.(2), the shape of the capsule chosen is streamlined to offer minimum resistance to air drag during movement. However, the design considerations by itself are not enough for achieving high speeds. When the capsule travels, because of the minimum air gap between the tube and the capsule, air accumulates at the front which is the function of the speed of the capsule. This accumulation of air hinders the movement of the capsule because of a pressure build up. This is analogous to the Syringe Effect, technically known as the Kantrowitz Effect. This is highly problematic, as it forces to either go slowly or have a super huge diameter tube. Interestingly, the solution to this seemingly grave problem can be overcome by a simple solution.

Fig. 3 3D Printed Prototype Capsule

By creating vents in the bottom side of the capsule and employing a compressor fan, the air pressure in front of the capsule can be relieved. The compressor fan aids the movement of the capsule by guiding the air flow through the vents at high pressure. When high pressure air is pumped between two surfaces, an air bearing is formed which offers zero friction to the movement of the surface. The concept of air bearings can be understood through the air hockey table. The compressor fan is run by the supplied provided through batteries installed inside the capsule.

**3. Propulsion System:**

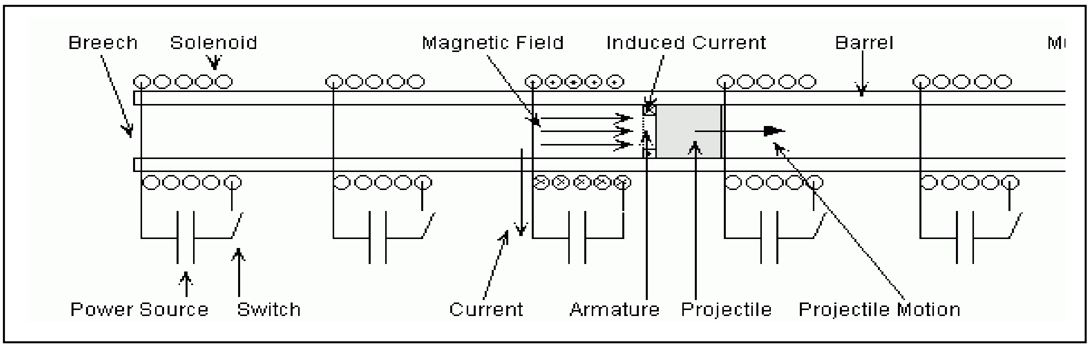


Fig. 5 Coil Gun Schematic

A high velocity accelerator is needed for the capsule to launch from its station. One of the methods by which this can be implemented is through a coil gun. A coil gun is an accelerator consisting of a coil used as an electromagnet analogous to how a linear motor accelerates a ferromagnetic projectile to high velocity. By using a 18 gauge enameled copper wire wound over a Poly vinyl chloride (PVC) pipe, the coil gun was supplied an impulse voltage of 300 volts through charged capacitors. For maximum acceleration, current through the coil gun needs to be high. To achieve this, capacitors were connected in parallel as the charges held by them when discharged in parallel fashion output a high current at the voltage of a single capacitor. The projectile was inserted inside the coil gun which accelerates at high velocities pushing the hyper loop pod. This force given by the projectile is enough to launch the pod thus satisfying the function of coil gun as a propulsion device.

Fig. 6 Prototype Coil Gun

Fig. 7 Capacitor Bank

However implementing a coil gun on a large scale is not practical as well as feasible. The coil gun generates massive amounts of magnetism. For safe operation, a majority of the costs would be required to provide magnetic shields. A safer and more feasible option would be to opt for a Linear Induction Motor.[4] The stators will be laid along sections of the tube – long enough to accelerate and decelerate the capsule between 480 and 1,220 km/h and to accelerate at 1g. They would be installed near stations and at booster points along the line. Only about 1% of the tube's length would need to be fitted with stators. The three-phase stators, laid out symmetrically on either side of the rotor, will have one slot per pole per phase. A variable number of turns per slot will allow the inverter to operate at a nearly constant phase voltage, thus simplifying the design of the power electronics. Accelerators at each terminal will employ two inverters – one to accelerate outgoing capsules and the other to capture energy from incoming capsules as they slow down, allowing for regenerative braking. The inverters will power only those sections of the track occupied by the capsule, hence improving the power factor.

## V. Conclusion

Hyperloop is the technology for the future. For the past decades, innovation in transport technology has been limited to improving or modifying traditional means. Thus growth in the transport technology has been stagnant. Hyperloop has the potential to break this slump and provide a very fast and cheap method of transportation. Proposed Hyperloop between Mumbai and Pune could cut down the commuting time from 3-4 hours to a mere 30 minutes.

Existing transportation technologies such as High speed rail (Bullet train) and Maglev are found to be wanting when it comes to expenses, effects on ecology and travel time. Solar arrays installed throughout the track, zero emission transport owing to no fuel requirement, no interference with communication lines, resistant to earthquakes, high speed of transportation coupled with low capital and maintenance cost give Hyperloop a leading edge.

The intent of this document has been to bring light to the concept of the Hyperloop. The various fundamentals involved in making this technology successful have been briefly discussed in the paper.

## VI. Future Work

The technology of Hyperloop is in its rudimentary stage. Even if the technology is successful, it can be worked upon for improvement in the future. A detailed design for the stations, including loading-unloading of passengers, improved safety features and propulsion of the capsule, has a large scope towards developing Hyperloop. One of the major challenges for Hyperloop is its adaptability to topography – sharp turns and change in altitudes.

The current capsule design allows only 28 passengers to commute at a time. Research can be focused on improving the design such that the numbers of passengers is more.

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