Review on Redefined Transportation System: Hyperloop

Prof. Rushikesh D. Sonar[1] Prof. Sunil S. Raut[2] Prof. Deepak K. Patil[3]
[1,3]Lecturer [2]Head of Department
[1,2,3]Department of Mechanical Engineering
[1,2,3]Sandip Polytechnic, Nashik, Maharashtra, India

Abstract— Existing conventional modes of transportation of peoples consists of four unique types: rail, road, water and air. These modes of transport tend to be either relatively slow (e.g., road and water), expensive (e.g., air), or combination of both (e.g., rail). Hyperloop is a new mode of transport that seeks to change this paradigm by being both fast and inexpensive for peoples and goods. Hyperloop is also unique in that it is an open design concept, similar to Linux. Feedback is desired from the community that can help advance the Hyperloop design and bring it from concept to reality. Hyperloop consist of a low pressure tube with capsules that are transported at both low and high speeds throughout the length of the tube.

Key words: Hyperloop Transportation, Vacuum Tube, Magnetic Levitation, Green Energy, Safety, Inexpensive

I. INTRODUCTION

Wheel being the most important initial invention of human signifies the elevation of standard of human being since ancient times, as we have progressed in science and technology and entered the era of microprocessor we gained transportation means like car, trucks, airplanes, ships, etc.[5] We have brought such a huge change in these means by upgrading them time to time but since time is moving ahead we must race with it by bringing up more advance means of transportation which can be face of future. Today's transportation majorly includes

1) Roadways: Cheap, time consuming but not so eco-friendly.
2) Airways: Not cheap, time saving but not eco-friendly.
3) Railways: Not cheap, time consuming but relatively much more eco-friendly than others.

These present conditions demands for alternate transportation system which should be cheap, comfortable, time saving, sustainable and more secure than the traditional ways [1]. Hyperloop confront all these issues to provide better way to future with help of modern science and engineering solutions. Also to make a cost efficient and high speed transportation system for the utilization at a moderate distances. The Hyperloop tubes could be provided with the solar panels on a roof making it a clean and self- powering system.

II. LITERATURE SURVEY

Mr. Elon Musk proposed high speed, very reliable mode of transport at Pando Daily event held at California where he introduced the word Hyperloop. He made this technology open source to every one so that anyone can come up with their own new ideas on this technology [2].

Mark Sakowski (2016) 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 [3].

N. Kayela (2014) investigated the Hyperloop in a 5th mode of transport. He discussed about the railway track for the Hyperloop align with the stations. He also discussed the two version of capsule one passenger plus vehicle version and other passenger only version [4].

Mohammed Imran (2014), He discussed about the two version of the Hyperloop one is passenger only and other is passenger plus vehicle version. He focused his study element on the Hyperloop technology [5].

III. HYPERLOOP

Hyperloop is a completely new mode of transportation which has proven to be fastest yet economical. Hyperloop was firstly proposed by Elon Musk and a team of engineers from Tesla Motors and Space Exploration Tech. Corporation in August 2013.

Concept of Hyperloop includes the travelling of people as well as goods from one place to another in a capsule propelling at a very high speed inside a closed low pressure tube. We can also call Hyperloop as an alternative for high speed train (bullet train). So basically Hyperloop is a magnetically levitated train which runs inside a long tube or pipe. It includes 28 passenger pods and is driven by linear induction motor and compressor. For the purpose of propulsion, magnetic accelerators are planted along the length of tubes, which helps in propelling the pods forward. The tube would create a low pressure environment which surrounds with a cushion of air that allows a pod to travel safely at a very high speed. The pressure built up in the front of the pod due to the tight quarters in the tube could be a problem. A system is provided to keep the air building up in this way. Musk's design recommended an air compressor on the front of the pod which will help in moving the air from the front to the tail keeping it overhead and preventing the pressure built up due to the displacement of air [2]. A one way trip in hyper loop is projected to take only about 35 minutes in design between Los Angeles and San Francisco (Comparatively, the same distance would take about 6 hours if travelled by a car).The passengers may enter or exit Hyperloop at stations located at the ends of tube or branches along the tube length [6].

IV. BASIC PRINCIPLE OF HYPERLOOP

Fig. 1 shows the working principle of Hyperloop. The working principle is same as that of a maglev train i.e. the train is levitated and propelled forward using powerful electromagnets. The principal of magnetic levitation is that the vehicle can be suspended and propelled on a guided track which is made by the help of magnet. The vehicle on the top of the track may be propelled with the help of linear induction motor. The Hyperloop is nothing but a Maglev train enclosed

in a tube in which there is very little air pressure and hence almost no air resistance.

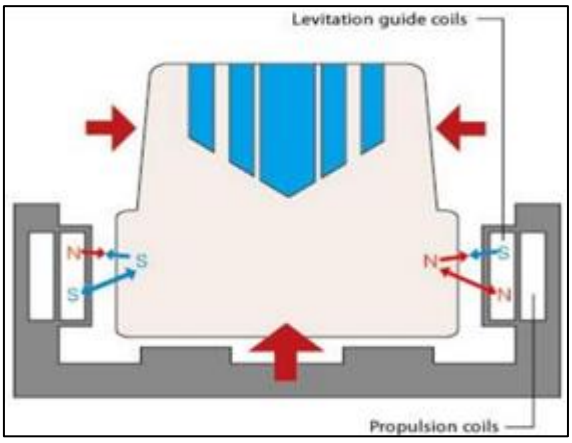

Fig. 1: Basic Principle of Hyperloop
(Courtesy:http://webjapan.org/kidsweb/hitech/maglev/images/004.jpg)[9]

V. CONSTRUCTION

A. Tube

There are two tubes welded side by side, both unidirectional and opposite to each other, acting just like highway.

Fig. 2: Hyperloop Tube
(Courtesy: Hyperloop One)[10]

These tubes were theoretically meant to have vacuum inside them which should remove any resistance offered by air in direction where train is travelling, but still practically vacuum cannot be achieved for such a long track. Thus, capsule consists of very low pressure air which offers very negligible resistance. But low pressure air doesn't solve the problem wholly. While capsule is travelling the air ahead of it get compressed and increase pressure offering resistance to capsule giving rise to Kantrowitz limit[7], which can eventually stop the train. But this problem was solved by adding compressor fan on front of train. The actual photograph of Hyperloop tube is shown in figure 2.

B. Hyperloop Capsule

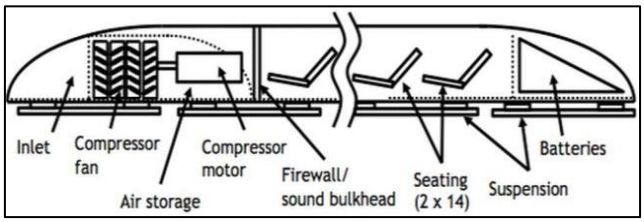

Fig. 3: Capsule
(Courtesy: SpaceX- Hyperloop Alpha)[2]

Capsule is the main transporting element of this system. It is aerodynamically designed to achieve very less friction from air passing by at very high speed. A single capsule can be economically designed for 26 or more people. Not just passengers but even goods will be less cheap to transport through Hyperloop Capsule [2]. It is pressurized to 1Atm inside the capsule, as the air pressure outside the capsule (in the tube) is only about 0.001 Atms (100 Pascal's). A battery is placed at the end of the capsule to power up the compressor and other electronics parts inside the capsule. Suspensions are placed under the capsule this helps during the loading and unloading time. While the capsule is moving in the tube it gets magnetically levitated. A simple conceptual block diagram of capsule is shown in the figure 3.

C. Propulsion System

It starts with an electric motor which is broken into two parts; Rotor and Stator (figure 4)

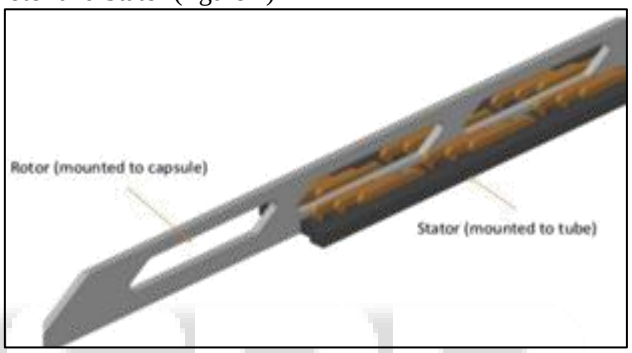

Fig. 4: Propulsion System
(Courtesy: SpaceX- Hyperloop Alpha)[2]

Rotor rotates the stator which is stationary. Stator is an electromagnet, when electric current passes through it rotor is magnetically attracted to spin unlike a normal electric motor Hyperloop motor is not circular it is linear. The rotor is on the pod which is propelled magnetically as it moves over the stator, which is more efficient and powerful.

D. Compressor

The compressor is fitted at the front side of the capsule. It supplies the air to the air bearings which supports the weight of the capsule. The compressor allows the capsule to traverse to the low pressure tube without choking the air flow that travels between tube walls and capsule [2]. Since need of vacuum was not sufficed in tube, capsule travelling in low pressure tube accumulates air on its front side, which is further compressed by motion of capsule, this compressed air will resist motion of capsule decreasing its velocity, forming a choke inside the tube and eventually stopping it. Thus, Hyperloop demands new innovation to solve this problem known as Kantrowitz limit [7]. Compressor fans were introduced to nullify effect of Kantrowitz limit (figure 4). Compressor fans are installed on front of capsules. These fans suck the accumulated compressed air from front of train and exhale it to air bearings. Thus, resistance is removed and no further choking because of Kantrowitz limit is caused.

Fig. 5: Compressor
(Courtesy:https://patrickenewman.files.wordpress.com/2016/03/compressoriso.png)[10]

E. Suspension System

Suspending the capsule within the tube presents a substantial technical challenge due to transonic cruising velocities. Conventional wheel and axle systems become impractical at high speed due frictional losses and dynamic instability. A viable technical solution is magnetic levitation; however the cost associated with material and construction is prohibitive. An alternative to these conventional options is an air bearing suspension. Air bearings offer stability and extremely low drag at a feasible cost by exploiting the ambient atmosphere in the tube (Figure 6).

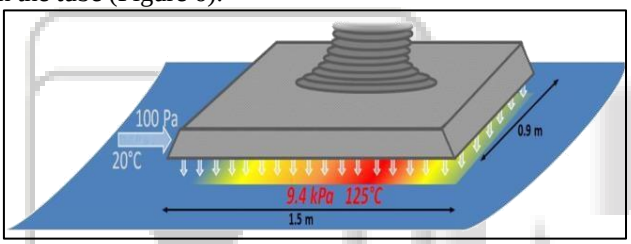

Fig. 6: Suspension System
(Courtesy: SpaceX- Hyperloop Alpha)[2]

Externally pressurized and aerodynamic air bearings are well suited [2] for the Hyperloop due to exceptionally high stiffness, which is required to maintain stability at high speeds. When the gap height between a ski and the tube wall is reduced, the flow field in the gap exhibits a highly non-linear reaction resulting in large restoring pressures. The increased pressure pushes the ski away from the wall, allowing it to return to its nominal ride height. While a stiff air bearing suspension is superb for reliability and safety, it could create considerable discomfort for passengers onboard. To account for this, each ski is integrated into an independent mechanical suspension, ensuring a smooth ride for passengers. The capsule may also include traditional deployable wheels similar to aircraft landing gear for ease of movement at speeds under 100 mph (160 kmph) and as a component of the overall safety system.

F. Onboard Power

Hyperloop uses modern technology to solve problems but this tech requires abundant power. The Tube's roof is covered with solar panel (figure 7) throughout the track which produces more energy than needed by whole Hyperloop setup without consuming a drop of petrol, diesel or kerosene. It is self-sufficient environment friendly technology.

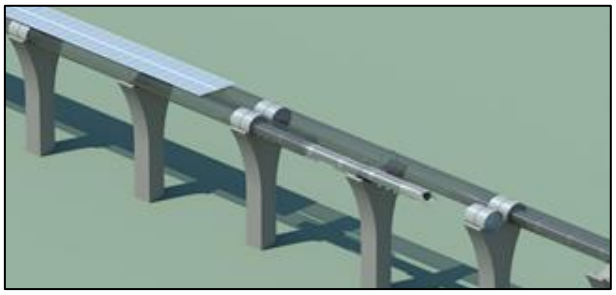

Fig. 7: Hyperloop tube attached solar arrays
(Courtesy: SpaceX- Hyperloop Alpha)[2]

VI. HYPERLOOP OPERATION

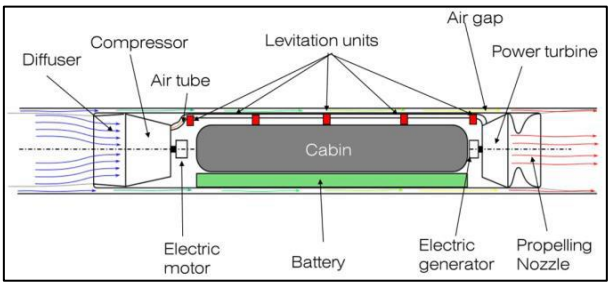

Fig. 8: Hyperloop Working
(Courtesy: http://www.climatekic-spain.org)[12]

Working of Hyperloop system, as shown in figure 8, is based on magnetic levitation principle. As we know that the passenger pad travel through low pressure tube which is pylon-supported tube. In Hyperloop system an air compressor fan is fitted on front side of pod which sucks the air. It transfer high pressure air front side to the rear side of capsule (pod) and it propel 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 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 is stored in the form of compressed air. The air between the capsule acts as a cushions to prevent two capsules from colliding within the tube.

VII. MERITS & LIMITATIONS OF HYPERLOOP

A. Merits

1) It saves the travelling time.
2) There is no problem of traffic.
3) It is powered by the solar panel.
4) It can travel in any kind of weather.
5) Cost of Hyperloop is low.
6) Not disruptive to those along the route.
7) More convenient.
8) Resistance to earthquake.

B. Demerits

1) Turning will be critical.
2) Less movable space for passenger.
3) High speed might cause dizziness in some passenger.

4) Punctured tunnel could cause shockwaves.

VIII. COMPARISON OF HYPERLOOP WITH OTHER TRANSPORTATION SYSTEMS

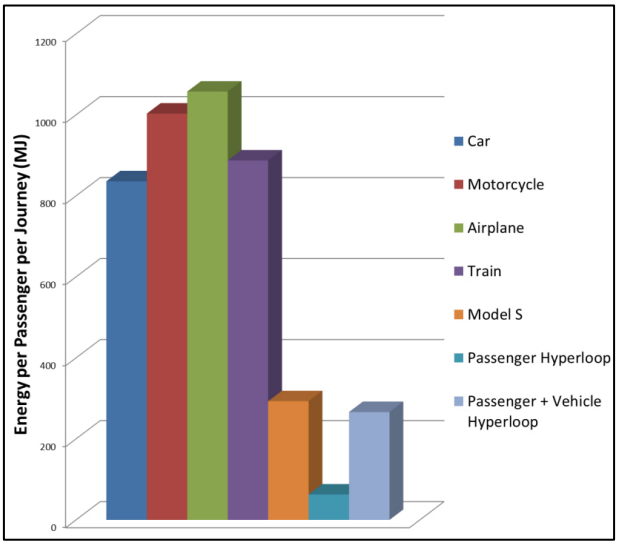

Fig. 9: Comparison of Various Modes of Transportation according to Energy consumed per passenger per journey (Courtesy: SpaceX- Hyperloop Alpha)[2]

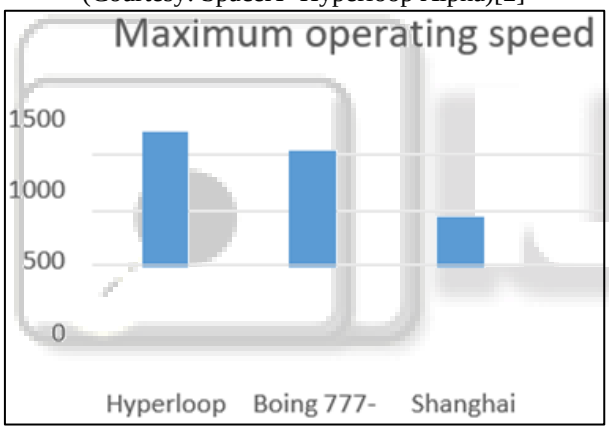

Fig. 10: Comparison of Various Speeds between Various High Speed Transportations

Component	Cost (million USD)
Capsule	54 (40 capsules)
Capsule Structure & Doors	9.8
Interior & Seats	10.2
Compressor & Plumbing	11
Batteries & Electronics	6
Propulsion	5
Suspension & Air Bearings	8
Components Assembly	4
Tube	5,410
Tube Construction	650
Pylon Construction	2,550
Tunnel Construction	600
Propulsion	140
Solar Panels & Batteries	210
Station & Vacuum Pumps	260
Permits & Land	1,000
Cost Margin	536
Total	6,000

Fig. 11: Hyperloop Cost in Million USD (Courtesy: SpaceX- Hyperloop Alpha)[2]

IX. PROPOSED ROUTES [2] [8]

Several routes are proposed for Hyperloop systems that meet the approximate distance conditions for which a Hyperloop is hypothesized to provide improved transport times. Route proposals range from speculation described in company releases cases to signed agreements.

The route suggested in the 2013 alpha-level design document was from the Greater Los Angeles Area to the San Francisco Bay Area Hyperloop. Hyperloop one on November 8, 2016 announced a new feasibility study with Dubai's Roads and Transport Authority for passenger and freight routes connecting Dubai with the greater United Arab Emirates. In September 2017, Hyperloop one selected 10 routes from 35 of the strongest proposals: Toronto-Montreal, Cheyenne-Denver Pueblo, Miami- Orlando, Dallas-Laredo-Houston, Chicago-Columbus- Pittsburgh, Mexico City-Guadalajara, Edinburgh-London, Glasgow-Liverpool, Bengaluru-Chennai and Mumbai- Chennai. Trans Pod is exploring the possibility of Hyperloop routes which would connect Toronto and Montreal, Toronto to Windsor, and Calgary to Edmonton. Toronto and Montreal, the largest cities in Canada, are currently connected by the Highway 401, the busiest highway in North America.

HTT are also in process to sign a Letter of Intent with the Indian Government for a proposed route between Chennai and Bengaluru. If things go as planned, the distance of 345 km could be covered in 30 minutes. Indore-based Dinclix Ground Works' DGW Hyperloop advocates a Hyperloop corridor between Mumbai and Delhi, passing via Indore, Kota and Jaipur.HTT also signed an agreement with Andhra Pradesh government to build India's first Hyperloop project connecting Amravati to Vijayawada in a 6-min ride where the total route is shown in figure 12.

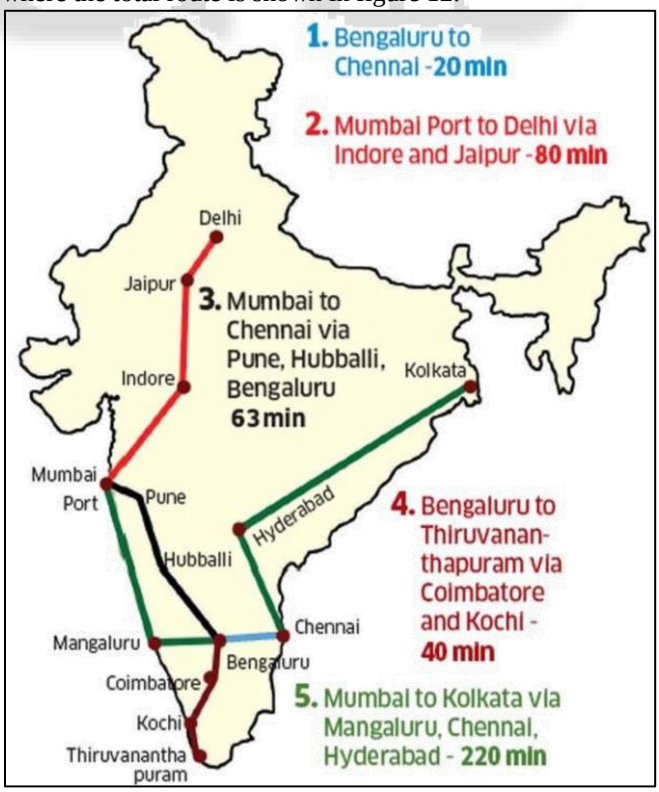

Fig. 12: Route for Hyperloop in India (Courtesy: https://www.deccanherald.com)[2]

X. 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.

XI. 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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