Hyperloop - The future of transportation.

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Abstract - This paper gives the explanation of introduction to hyperloop and the analysis of hyperloop. Hyperloop is a hypothetical high-speed transportation system recently proposed by American entrepreneur and inventor Elon Musk. Hyperloop consists of a low pressure tube with capsules that are transported throughout the tube. The capsules carry passengers and even vehicles, and they are able to travel at 760 miles per hour, which is near the speed of sound. With Hyperloop, a trip from Los Angeles to San Francisco would only take 35 minutes. Hyperloop has the potential to revolutionize our transportation system.

Keywords*—Capsule*Hyperloop,tube,capsule,suspension,propulsion.

I. INTRODUCTION

One of the frequently asked question is "what would be the ideal mode of transport?" According to Elon Musk, transportation is ideal when it is of low cost, safe, sustainably self-powering and immune to weather changes. Hyperloop, which is designed and proposed by Elon Musk, is able to meet all these standards. Hyperloop travels in sonic speed and makes it possible to travel long distances in very short period of time. Hyperloop includes a pair of tubes placed on pylons, making it safe during weather changes and even earthquakes. Air bearings are used for suspending the hyperloop. When traveling at sonic speed , the pressure developed ahead of the hyperloop is very high and this is overcome by placing a compressor fan in the front. Hyperloop is powered by solar panels on the top of the tube and does not require other power inputs.

II. HYPERLOOP

Comparison with the High Speed Rail

One motive of Musk to design Hyperloop is his dissatisfaction with the California High-speed Rail project. This current project proposes a $68 billion USD cost, a travel time of 2 hours and 38 minutes between San Francisco and Los Angeles, and a one-way ticket price of

$105. Musk is disappointed in the project, describing it as "one of the most expensive per mile and one of the slowest ". He claims that the Hyperloop saves much land because it is built above ground on pylons. A ground based rail system, on the other hand, requires a 100 ft. wide and very long piece of land, impedes other ground transportations, and is noisy. Hyperloop is hypothetically much faster and cheaper than the California High Speed Rail system.

The Tube

The tube forms the external structure which seperates the capsule and the external environment hence the design of the tube becomes an essential part of the hyperloop. It will determine how the hyperloop will work. Musk has considered several options for the tube environment. One approach is to have a normal air pressure inside the tube, and another is to create a vacuum. In the first case, fans would push the air at high speed and propel the capsules. However, if a sonic speed is to be reached, this approach is practically impossible due to the extremely high friction of the air against the tube. In the second case, the vacuum inside the tube would be able to get rid of the problem of friction. However, this is not practically feasible . It is extremely difficult to maintain the near vacuum environment, because a small leak in the 700-mile round trip tube can destroy the functionality of the system [1].

However, Musk proposes a third approach which turns out to be a viable solution. It is to have a tube with a low air pressure system. This system is adaptive to variations in air pressure, and it would be possible to overcome both air leaks and air friction. The system still faces a problem, which Musk calls the Kantrowitz Limit. This concept shows a minimum tube to pod area ratio below which the air flow will be choked. It means that when the capsule travels at a high speed, air is not able to pass around it and the capsule would push the entire air column forward, unless an unrealistically huge-diameter tube is built [1]. Musk was able to find a solution, which is the air compressor in front of each capsule, which will be discussed later.

The resulting low pressure Hyperloop tube will be operating at the pressure of 100 Pascals, which is 1,000 times less than the atmospheric pressure at sea level. Two low pressure tubes, made of steel, will be welded together to allow capsules to travel both directions. The tube will be supported by pylons placed every 100 ft, and it will be covered by solar arrays on the top [1].

The Capsule

The passenger-only Hyperloop capsule holds 28

passengers in side-by-side pairs and departs every two minutes. The capsules are 4.4 ft. wide and 3.6 ft. tall and travel at 760 mph [1]. There are doors on either side of the capsule which either slide or open like a gullwing. The boot space can be placed either in the front or the rear. The interior of the capsule is designed to ensure passenger safety and comfort. Since the acceleration of the capsule is high, the seats are designed such that the passengers don't feel discomfort able .The passengers would get a scenic view of the outside landscape and would also be provided with an entertainment system [1].

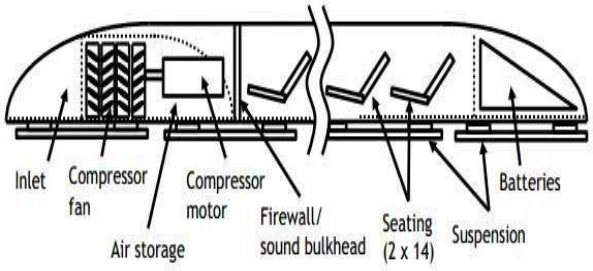


Figure 2: Hyperloop Capsule subsystem notional locations

One of the key components of the capsule is the air compressor, which compresses the air ahead of the capsule hence reducing the air drag. The unit has a cooling device to cool the air. Once the air is cooled and compressed it is then bypassed through the capsule with a compression ratio of 20:1. Some of the compressed air is supplied to the air bearings at the bottom which act as suspension and makes the capsule float [1].

Functionalities

The Hyperloop includes a variety of functions for it to operate at the required performance. Two important functions are the suspension system and the propulsion system, which will be discussed.

The Suspension System

One of the barrier faced when designing the hyperloop was the type of suspension to be used. The conventional wheel and axle system would be impossible to use as the capsule would travel at sonic speed. Magnetic levitation could have been used but it would be very expensive . Then musk came up with air bearing suspension system which is much more stable and cost effective. The air bearings are placed [1].

The suspension system includes two mechanisms: aerodynamics and external pressurization. In the aerodynamic method, the front tips of the skis are slightly elevated so that a thin film of air is trapped between the ski and the tube. The resulting increased pressure below the ski gives a force that raises a portion of the capsule's weight. In the external pressurization, highly pressurized air is injected in supplement of the aerodynamic pressure so that sufficient lift is generated to support the capsule [1]. Both mechanisms contribute to the suspension of the capsule.

The Propulsion System

Hyperloop uses linear accelerators similar to those used in maglev trains [2]. The physics in the linear accelerator is not difficult to understand. As Figure 3 shows, a body containing a current loop is placed between two lines of electromagnets with alternating polarity [3]. The dots indicate current flowing out and the crosses indicate current flowing in. Looking at the body at the bottom, the current surrounding the body creates an N pole to the right and S pole to the left, repelling the magnets near the top and attracting those near the bottom, so that the body is propelled downward. Whenever it passes a pair of electromagnets, the current is reversed so that the same process repeats [3].

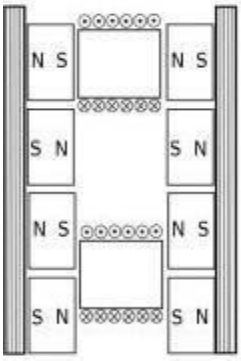


Figure 3: The basic layout of a linear motor

Hyperloop uses these accelerators to accelerate the capsules to the speed of 760 mph. In the Hyperloop system, the current carrying body is called the rotor. It is a large aluminum blade 49 ft. long, 1.5 ft. tall, and 2 in. thick, placed underneath each capsule. The track of electromagnets is called the stator, which is mounted on the bottom of the tube. The two rows of electromagnets are laid out symmetrically on each side of the rotor. The components are shown in Figure 4 [1].

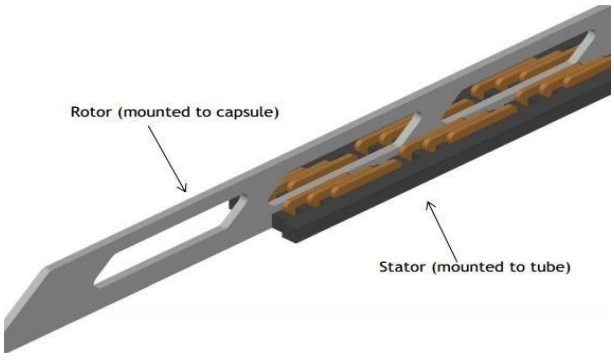


Figure 4: Rotor and stator 3D diagram

Cost Analysis

Musk estimates the cost of building 40 capsules to be $54 million and the tube to be $5.4 billion, making a total of $6 billion as the cost of the Hyperloop passenger transportation system, as shown in Table 1 [1]. Musk believes that one key advantage of the Hyperloop is that it

can be built above ground on pylons. Moreover, the land costs can be mostly eliminated by building the Hyperloop alongside the Interstate 5 highway. By his plan, the system would only occupy spaces comparable to telephone poles. [1].

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

Table 1: Total cost of the Hyperloop passenger transportation system

Some critics argue that the $6 Billion price tag is largely underestimated. Alexis Madrigal, a senior editor at The Atlantic, points out the "42,424 acres of land the Hyperloop would need to acquire" is one obstacle to Musk's budget [4]. The process to acquire land for the project is indeed an issue for the project to be realized. In the development of California's high speed rail system, many local communities have either demanded for extra viaducts and tunnels or insisted they not be bypassed, which all contributed to the expensive budget of the project. Hyperloop is probably not immune to such issues, but Musk has not put them into consideration [4].

Another critic, Michael L. Anderson, who is an associate professor of agricultural and resource economics at the University of California, Berkeley, gives a more pessimistic prediction. He estimates the cost of the entire project to be closer to $100 billion, which is even higher than the California high-speed railway system [4].

It seems uncertain how much it would actually cost to build Hyperloop, since it is an entirely new transportation system. Hyperloop faces both technical and political uncertainties. They will be solved only when Hyperloop is actually implemented. We must wait until then to know the precise cost of Hyperloop.

2. Placing the figures

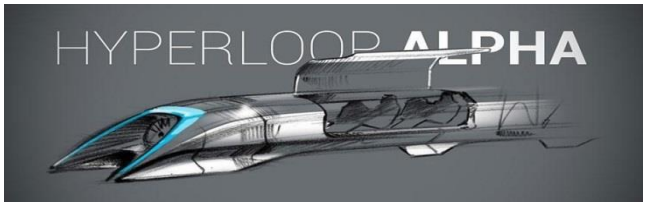


Fig 5 Hyperloop Alpha

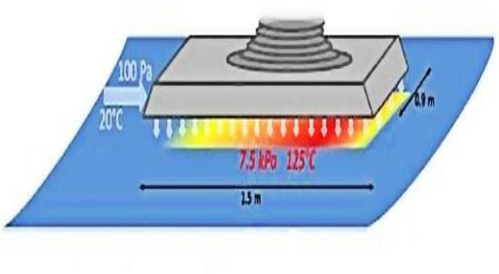
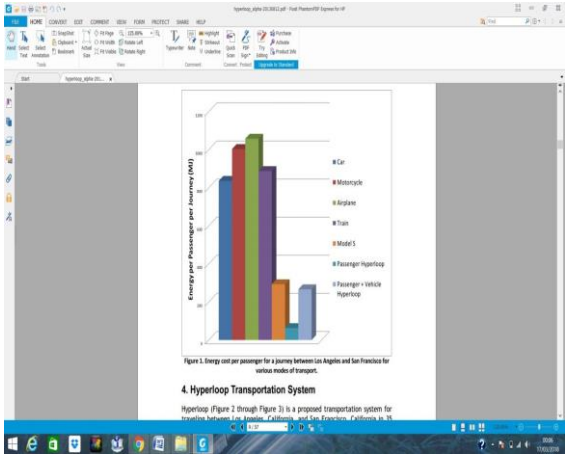


Fig 6 Air Bearing

2.1 Placing the graphs



[1]

III. CONCLUSION

The proposed concept by Hyperloop alpha has many advantages as a transportation system, yet it still remains hypothetical. If Hyperloop could succeed, there is no doubt that it would revolutionize transportation. Hyperloop is able to create megaregions of cities that are initially far apart, improving regional economy. The speed and convenience of the system can significantly benefit people living in California. Hyperloop is also a leap in technology. Even if it fails, it would be a worthwhile exploration because it can give insights to future inventions. However, Elon Musk, who is working on his Tesla and SpaceX, is too busy to work on this project that he proposed. Therefore, the Hyperloop project still remains pending. Musk has currently left this concept open to anyone who wishes to develop deeper into this project, but it is more likely to be himself who will turn his vision into reality [5].

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REFERENCES

[1] E. Musk. (2013, Aug.). Hyperloop Alpha. SpaceX Corp., CA. [Online]. Available: http://www.spacex.com/sites/spacex/files/hyperloop_alpha- 20130812.pdf

[2] T. De Chant. (2013, Aug.) Promise and Perils of Hyperloop and Other High-Speed Trains. Pbs.org. [Online]. Available: http://www.pbs.org/wgbh/nova/next/tech/hyperloop-and-hi gh-speed-trains/

[3] T. Brown, J. Dacquisto. (2011, Dec.) Maglevs: The Future of Flying Trains. *Illumin.* [Online]. Available: http://illumin.usc.edu/247/maglevs-the-future-of-flying-trai ns/

[4] N. Bilton. (2013, Aug) Could the Hyperloop Really Cost $6 Billion? Critics Say No. *The New York Times.* Aug 15, 2013. [Online]. Available: http://bits.blogs.nytimes.com/2013/08/15/could-the-hyperlo op-really-cost-6-billion-critics-say-no/

[5] A. Boyle. (2013, Aug.) Why the Hyperloop transit system is far from a sure thing

for Elon Musk. [Online]. Available: http://www.nbcnews.com/technology/why-hyperloop-transi t-system-far-sure-thing-elon-musk-6C10912162