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Hyperloop: V Mode of Transportation

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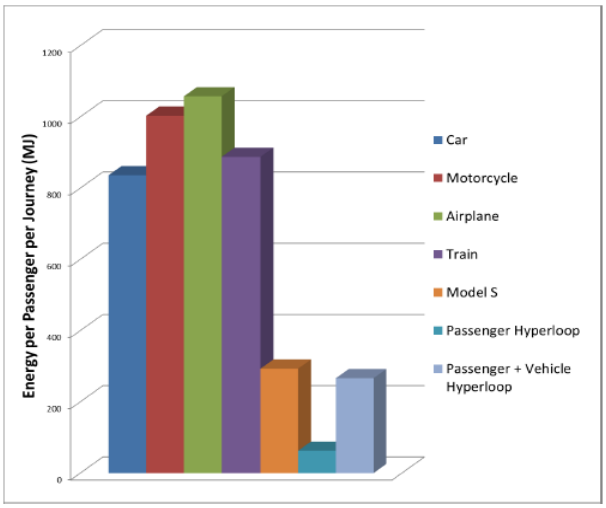
***Abstract*- The standard four modes of transportation which are used by commuters are railways, airways, waterways and roadways. Discussing its cost, it depends on certain factors such as debility, fragileness, distance, size, etc. and so sometimes cost increases for the individuals. Thus Elon Musk proposed the fifth mode of transportation known as Hyperloop, on white paper stating the advantage of giving twice the speed of a plane and efficiency in less time, low power consumption, cost efficient, environmental friendly as it will use solar panels and also it will not create noise. Hyperloop is a proposed mode in which a capsule like the vehicle (pod) is accelerated in an evacuated low-pressure tubes at very high speeds. These pods will be accelerated through linear induction motors, and it will also be levitated through magnetic levitation or air bearings. These pods will travel in these tubes, and passengers will be able to travel in these pods in a similar way like other conventional modes i.e. through provided hyperloop stations at prescribed locations. The two major problems are also eliminated - friction and air resistance which makes high efficiency of the pod. So it is the best replacement to high speed rail and air passenger transport.**

Keywords: Hyperloop; air bearings; high-speed rail; air passenger transport; supersonic speed; vacuum tube; advance linear motor

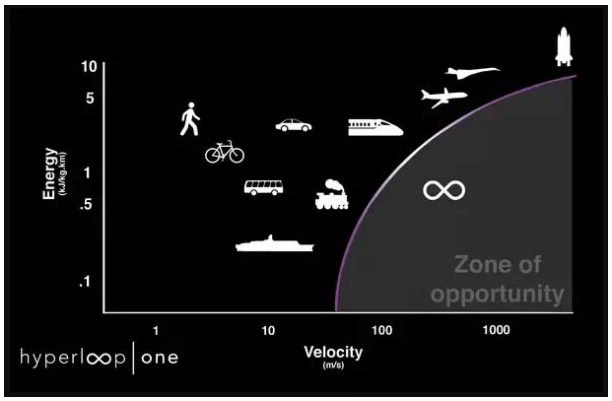
I. INTRODUCTION

Hyperloop is a new mode of transportation proposed by Elon Musk in his white paper in 2013.

The basic concept of hyperloop is that there are capsules shaped pods which travel at supersonic speed (about 1220 kph) in an evacuated vacuum tube, and it will carry passengers from one station to another station, similarly like conventional railways. As we know the railway, waterway and roadway modes are slow and inexpensive, while airway mode, on the other hand, is fast but also expensive. The below figure gives the proper understanding for transportation:



The below figure shows the energy and velocity relationship in which we can see that humans have more energy and less velocity with respect to car, car have more energy but less velocity with respect to airplane and airplane have more energy but less velocity with respect to hyperloop. Thus we can say that hyperloop have more energy and more velocity than any other transportation mode.



To solve the transportation issue and to propose a solution approach that is economically feasible, many logistics companies are designing a novel mode of transportation called hyperloop. It is a magnetically levitated capsule placed in a vacuum tube helps the passenger to transfer between cities at a supersonic speed. This study focuses on developing the Define, Measure, Analyze, Design and Verify (DMADV) approach to understand the operations of hyperloop and determine the number of pods required to fulfill demands. Thus, one can say that hyperloop will provide transportation by reducing air as well as surface

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friction and making the system to work more efficiently. These pods will be able to commute about 28 passengers at a time. The first potential route of hyperloop is to be constructed between Los Angeles and San Francisco.

The functioning of the Hyperloop system and the research objectives are structured in the defined phase, and the data are gathered from various sources and is pre-processed in the measure stage. The simulation model is then developed in analyzing the step and in the design phase, the different alternate scenarios are conceptualized. The Hyperloop pod capacity, number of pods, commuter volume variability, and willingness to use Hyperloop rate are varied and their impact on the performance measures and managerial implications for different settings are presented within the verify stage too. Elon Musk started the SpaceX Hyperloop Pod Competition so that students all over the world can participate and bring more ideas of hyperloop. This concept of hyperloop is now promoted and modified by a number of companies like Virgin Hyperloop which are trying to bring this concept into reality.

II. LITERATURE REVIEW

In 2013, Elon Musk published The Alpha document and provided a foundation for the Hyperloop study. That article described the vacuum tube and construction of the pod within the tube. The study calculated the cost of a one-way trip as $20/passenger with the estimated 7.4 million travellers between LA and SF, each way, every year and operating costs of $6 billion over 20 years. A student team at the Massachusetts Institute of Technology (MIT) conducted similar design studies and based on their final report; the capsule prototype designed by the team was able to levitate by itself. [1]

Ahmed Hodaib, Samar F. Abdel Fattah (May 2016) , discussed the “Design of a hyperloop capsule with linear induction propulsion system” which helps to accelerate and decelerate the capsule. They studied that like rotary synchronous motors; linear motors also run on 3-phase power and can support very high speeds. However, there are end effects that minimize the motor's thrust force. So linear induction motors are less energy efficient than normal rotary motors for any required force output. They also talk about the manufacturing of linear induction motors in this paper. [2]

Jeffrey C. Chin, Justin S. Gray, Scott M. Jones, Jeffrey J. Berton, they discussed 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 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. [3]

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. [4]

N. Kayela, (2014) investigated that “The Hyperloop Is A Fifth Mode of Transportation Alongside Trains, Planes, Automobiles and Boats.” He discussed the rack for the hyperloop and stations for the hyperloop. Also, discussed the two versions of a capsule, one is passenger only version and another is passenger plus vehicle version. [5]

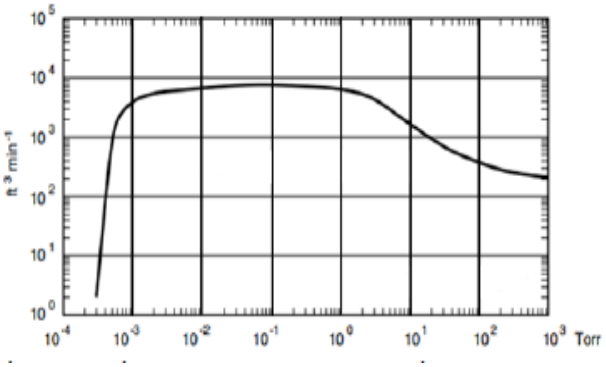
Mohammed Imran (2016) in his published paper has discussed about the various elements of Hyperloop transportation system. He also discussed about the two versions of Hyperloop transportation system in which one is the commuter only version and another is the commuter plus automobile version. Author came out with a result that the transportation of passengers can be possibly done in a very less time at cheaper rates. Further improvements in this technology can lead to more reduction in price with greater sustainability. [6]

III. CONSTRUCTION

A. COMPONENTS

1. TUBE:

The tube is specifically designed for optimal airflow around the capsule thus improving performance and reducing energy consumption at the expected travel speed thus will be partially evacuated and expected pressures inside these tubes is about 100 psi (100 Pa, 0.75 torr). As a result the low pressure reduces the drag force of air on the capsule while maintaining the relative ease of pumping out the air from the tube. Despite any possible leaks through the joint and stations, vacuum pumps will run continuously at different locations along the length of the tube to maintain the required pressure. With the further decrease in pressure the efficiency of industrial vacuum pumps decreases exponentially and thus pumping complexity increases. Which can be well understood from below figure:



The tube should be designed in such a way that there should be sufficient capsule/tube area ratio to avoid shock wave formation around the capsule. And so a compressor is placed at the nose of the pod. The tube is made of steel. Two tubes will be welded together with side-by-side configuration to permit the capsules to travel both directions. As the

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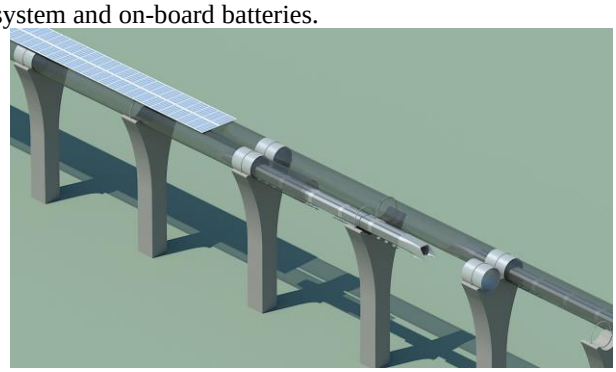
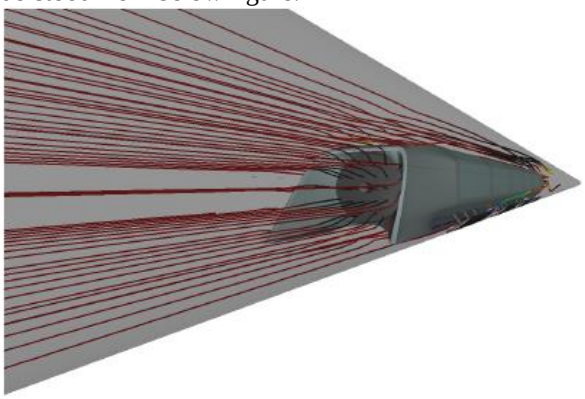
hyperloop tube is elevated on pillars that are made of reinforced concrete, which will reduce the tube cost and land area as the number of footprints on ground will be reduced. The pillars and tube will be assembled in such a manner that it will allow longitudinal slip of tubes due to thermal expansion and also the movements will be dampened to reduce the risks of earthquakes. The average spacing of these pillars is estimated to be around 30m. The Solar arrays will cover the top of the tubes in order to provide power to the system and on-board batteries.

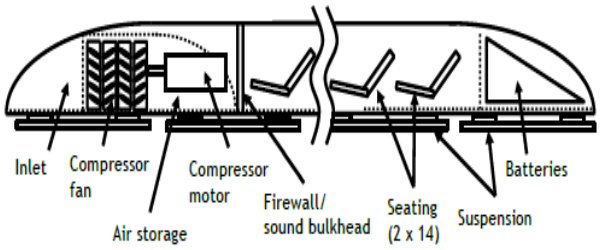


2. CAPSULE

The capsules will move with 1220 Kph in the tubes. These tubes will be provided with low pressure which will be about 100 pa to reduce air drag. Also, the outer body of the capsule is made streamlined to reduce surface friction which can be understood from below figure:

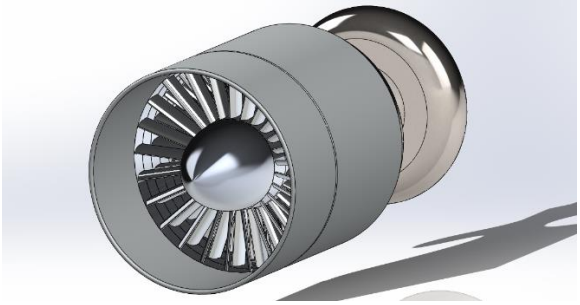


As the pod will move with supersonic speed in the tubes, there will be an accumulation of column of air in front of the pod. But as the walls of the tube and capsule are very close to each other the air will get choked and the pod will have to push the column of air. The ratio of tube to pod area is known as Kantrowitz limit, which should be properly followed to propel the pods at high speeds (1220 kph). To overcome Kantrowitz limit, the air compressor is proposed to be installed at the nose of the pod. Sealed capsules that travel along the interior of the tube carries 28 passengers each departing on average of every 2 minutes from Los Angeles to San Francisco (up to every 30 seconds during peak usage hours). During operation the capsules are parted within the tube by approximately 23 miles (37 km) on average. The interior of the capsule is designed by making safety and comfort in mind and so during the high-speed acceleration the passengers will feel comfort. The overview of the pod is shown in the figure:



3. COMPRESSOR

The compressor installed at the nose of the pod serves two purposes. Firstly, this system allows the pod to transverse at very high speeds in the narrow tubes and resulting build-up of air mass in front of the pod is bypassed by the compressor. The second purpose is that it compresses the air at about 20:1 ratio. Up to 60% of compressed air is bypassed to the bottom of the capsule to its tail through a narrow tube. A nozzle at tail expands the flow which generates thrust. The thrust generated will help in propelling the pod. The remaining portion of the air passes through the intercooler where it is cooled and further compressed with about 5.2:1 ratio, which is consumed by the air bearings which create the cushion of air in the tube on which the pod will float to maintain distance between capsule and tube walls, thus eliminating the contact between tube and pod. This compressor will be powered by electric motors which will be powered by on-board batteries.



4. SUSPENSION

The air bearings are preferred by Elon Musk for levitation as they offer stability and extremely low drag at feasible cost by keeping the low pressure inside the tube. Also these externally pressurized and aerodynamic air bearings supply a highly pressurized air at the bottom of the pod and this increased pressure pushes the bearings and balances the weight of the capsule. To pressurize this air, two mechanisms can be implemented; external pressure and aerodynamic method.

In an aerodynamic approach the ski will be elevated from the front part at a very small degree. The trapped film of air beneath the ski will get pressurized and will support the portion of the capsule's weight. The other supplementary uplift force will be provided by external pressure air which will be supplied by on board reservoir. The capsule may also have deployable wheels for smoother and safer movement below speeds of 160 kph.

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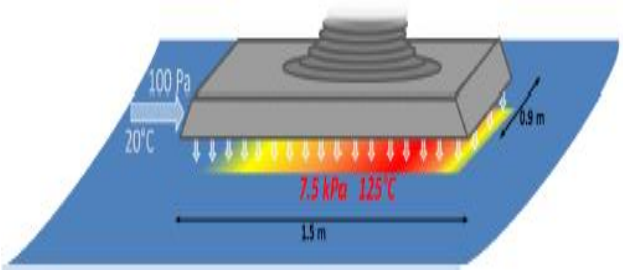
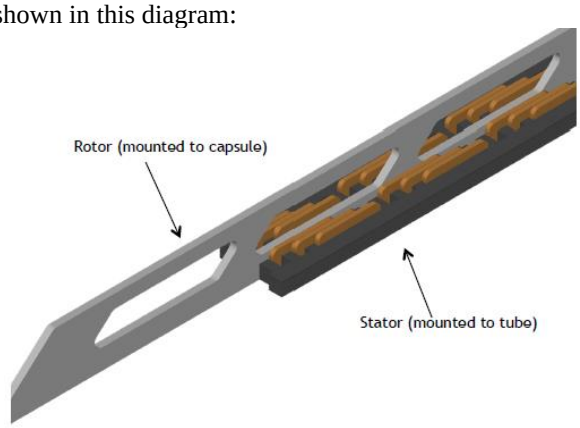


B. PROPULSION AND BRAKING SYSTEM

The function of acceleration of the capsule is done by the help of an advanced linear motor system to propel the vehicle at speed of above 760 mph. The rotor will be placed on the vehicle for weight savings and power requirements and the tube will incorporate a stator which powers the capsule. These rotors are accelerated and decelerated through linear accelerators mounted at specific locations. The power required for accelerating and decelerating the capsules is 3 times the average power required. At each of these accelerators, the battery array is installed which supplies peak power by allowing the solar power to supply only the average power required by the system. The magnetic field produced by the stator and rotor arrangement is shown in this diagram:



IV. CONCLUSION

The hyperloop system is the combination of air passenger transport system and high speed rail and by conducting a simulation study it focused on the operational effectiveness of this system. It is a levitated capsule placed in a vacuum tube helps the passenger to transfer between cities at a supersonic speed. It produces a better economy and is more affordable and secure. It reduces time and has twice the velocity of airplanes. Also, this system is energy efficient, as we can produce energy required through solar power, and compared to other transportation systems it requires less power. The main feature of hyperloop is that it is direct and can accomplish better execution for less expense. The energy benefits and positive social performance make hyperloop an attractive option for a new mode of transportation.

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