Construction Details and Safety Features of Fastest Mode of Transportation 'Hyperloop'

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Abstract-*Hyperloop is a new transportation technology which uses a capsule to travel from one place to another inside a tube. The pod or capsule travels with speed of almost 1000 km/hr. which is equal to speed of sound. This means travelling from Pune to Delhi will be a one and half hours of journey also lossAngeles to san Francisco within 35min. This work focuses on constructional details and the safety features of Hyperloop system. Using open source information, a new sizing method is developed which encounters the fundamental problems that may arrive at the time of working. Also there are some proposed changes in material and subsystems to reduce weight, energy requirements and complexity of pod. Developing something related to human transport must have to be fulfilled on safety parameters, consideringthis some basic safety system are introduced so as to have a safer journey. In light of these finding, core concept still remains a compelling possibility, although additional engineering and economic analyses are markedly necessary before a more complete design can be developed.*

I. INTRODUCTION

Time is money perhaps that's why people always complain about travel. One always thinks that How can travelling experience be better, how can we get there faster? one dreams to travel from one place to another place within a blink of an eye. That essentially a dream behind the Hyperloop technology. This concept includes travelling people from one place to another in a capsule which will cover the distance inside a tube. There will be low pressure environment inside a tube along with a capsule that does not touch anywhere and because of low pressure does not encounters lot of resistance. It is similar to aero plane flying on higher altitudes.

The first ever concept of people transportation through a pod inside a closed tube was put forth by scientist G. Medhurust in a paper published in 1812 where concept was introduced to use power and velocity of air for travelling of passengers inside a tube. Similar concept redeveloped by young entrepreneur elon musk founder of tesla motors. the principle idea behind the Hyperloop was simple and is just to reduce the friction and air drag so as to get higher velocity, just like maglev trains. The Hyperloop system is a mean of a concord, air hockey table and railgun.

This system is faster than any existing system for passenger transport achieving speed more than 1000km/hr. Also Hyperloop is a green system as majority of energy needs are fulfilled by non-conventional energy source i.e. solar power.

This paper focuses on the actual constructional details of the Hyperloop system with the analysis and material suggestions along with the safety features for this very high speed system with the speed more than 1000km/hr. some experimental designs made are based on reference file by the elon musk. The designs were statically checked by applying various constrains so as to get best possible result. For achieving maximum feasibilityvarious assumptions based on real life applications are made such as, For the safety point of view the system is compared to aero plane as both shares the same principle ofpropagation etc.

II. CAPSULE OR POD DESIGN

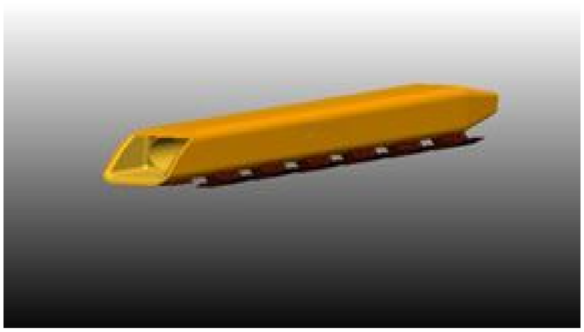
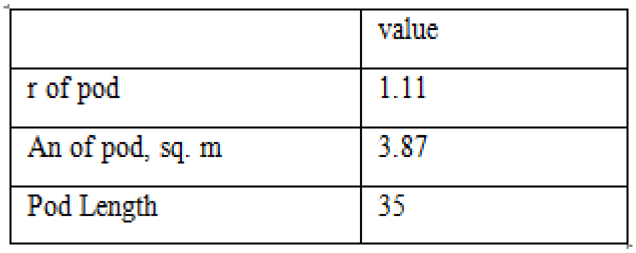


Fig no.1Capsule design in creo software

Table no.1. Calculated Capsule or Podsize



	value
r of pod	1.11
An of pod, sq. m	3.87
Pod Length	35

In the designing of Hyperloop, designing of pod is most important as end users i.e. Passengers are to be installed in the capsule or pod.

Pod or capsule is the element which is going to suffer with most of the stress. This is because there is around 70000N force inside pod along with pressure difference at outside and inside of pod. The inside pressure of tube will be atmospheric while the outside pressure will be much less than atmospheric pressure. The pod contains various elements including a suction fan, compressors, batteries, air conditioning system, safety and pressure control system etc. this all elements are heavy, also there is lots of vibrations because of this element.

Methodology for deciding the mass of total body capsule:

- Assumed weight of individual passenger as 75kg (Indian standards).
- Taken the weight of pod = density*mass,
- Assumed standard weights for system installed.

Checking the capsule in static test.

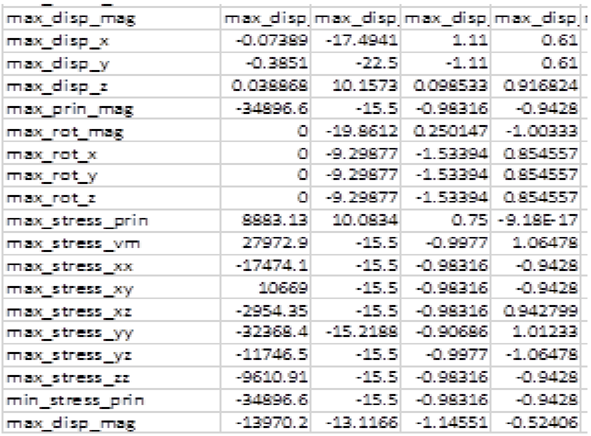
Assumptions

- Material selected is aluminum alloy
- Legs i.e. bottom most portion of a capsule are fixed
- In second iteration, instead of legs inner portion of tube is fix
- Body mass is acting as a UDL on the legs
- Inside pressure of a tube is atmospheric.
- The back pressure generated is 13.4kpa.

Preliminary Results

- ✓ Legs i.e. bottom most portion with a lesser inclination with side of tube will be better.
- ✓ Thickness of connecting material should be high to sustain back pressure.
- ✓ Angle of inclination should be less than 90 degrees to avoid bending of legs.

Table no.2 Analysis result of static model of pod in Ansys software.



max_disp_mag	max_disp	max_disp	max_disp	max_disp
max_disp_x	-0.07389	-17.4941	1.11	0.61
max_disp_y	-0.3851	-22.5	-1.11	0.61
max_disp_z	0.038868	10.1573	0.098533	0.916824
max_prin_mag	-34896.6	-15.5	-0.98316	-0.9428
max_rot_mag	0	-19.8612	0.250147	-1.00333
max_rot_x	0	-9.29877	-1.53394	0.854557
max_rot_y	0	-9.29877	-1.53394	0.854557
max_rot_z	0	-9.29877	-1.53394	0.854557
max_stress_prin	8883.13	10.0834	0.75	-9.18E-17
max_stress_vm	27972.9	-15.5	-0.9977	1.06478
max_stress_xx	-17474.1	-15.5	-0.98316	-0.9428
max_stress_xy	10669	-15.5	-0.98316	-0.9428
max_stress_xz	-2954.35	-15.5	-0.98316	0.942799
max_stress_yy	-32368.4	-15.2188	-0.90686	1.01233
max_stress_yz	-11746.5	-15.5	-0.9977	-1.06478
max_stress_zz	-9610.91	-15.5	-0.98316	-0.9428
min_stress_prin	-34896.6	-15.5	-0.98316	-0.9428
max_disp_mag	-13970.2	-13.1166	-1.14551	-0.52406

Checking the capsule in dynamic test .

Assumptions

- Capsule moving at 210 m/s, i.e. at 470 miles per hour
- Mass flow split assumed as: 50% sucked by fan, 50% goes around the capsule
- Air sucked by the fan is then distributed at 40% from the tail and remaining to the air bearings.

There are various constraints that are to be considered while designing a pod which are

- Mach number
- Aerodynamic shape
- Material selection
- Kantrowitz limit

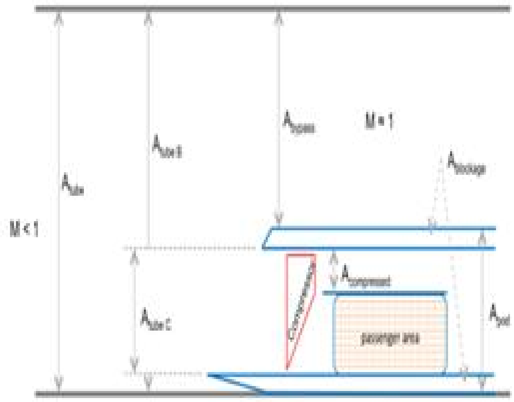


Fig no.2 capsule with tube showing parameters.

Table no.3. Material properties of carbon fibre composite

Symbol	Units	Std CF Fabric	HMCF Fabric	E glass Fabric	Kevlar Fabric	Std CF UD	HMCF UD	M55** UD	E glass UD	Kevlar UD	Boron UD	Steel S97	Al. L65	Tit. dtd 5173
ung's Modulus 0°	E1	GPa	70	85	25	30	135	175	300	40	75	200	207	72
Young's Modulus 90°	E2	GPa	70	85	25	30	10	8	12	8	6	15	207	72
In-plane Shear Modulus	G12	GPa	5	5	4	5	5	5	5	4	2	5	80	25
Major Poisson's Ratio	v12	_	0.10	0.10	0.20	0.20	0.30	0.30	0.30	0.25	0.34	0.23	_	_
Ult. Tensile Strength 0°	Xt	MPa	600	350	440	480	1500	1000	1600	1000	1300	1400	990	460
Ult. Comp. Strength 0°	Xc	MPa	570	150	425	190	1200	850	1300	600	280	2800	_	_
Ult. Tensile Strength 90°	Yt	MPa	600	350	440	480	50	40	50	30	30	90		

Match number

It has a greater significance in designing of airplanes aircrafts and high speed vehicles. It is the ratio of object speed to speed of sound. Here M is match number and A is area of corresponding section

Fig no.3Mach number analysis (max mach no.1.97 in red zone).

For isentropic flow equation, there is a relationship between Mpod and Mbypass, that defines an area ratio, $\frac{A\ bypass}{A\ tube}$, where γis heat capacity,ratio

$$\frac{A\ bypass}{A\ tube} = \frac{Mpod}{Mbypass}\left(\frac{1+\frac{(\gamma-1)}{2}Msq\ bypass}{1+\frac{\gamma-1}{2}Msq\ bypass}\right)^{\left(\frac{\gamma+1}{2(1-\gamma)}\right)}$$

For maintaining Mach number around 1 is a tricky task as too high Mach number will exert additional stresses due to various parameter and too low Mach number is sign of low speed. With just a simple design of capsule the whole air drag will start building pressure on a capsule as there will not be much space for escape of air. At a certain point pod will start acting as a piston just pressurizing the air coming in its way. This situation is not at all preferable as it will reduce speed drastically so to avoid this situation a suction fan is provided on front end of pod. This will suck the incoming air then it will compress it to certain extent. A part of this air is bypassed to get a thrust just like a rocket and remaining air is send to air bearings which are there to lift the pod to avoid any physical contact.

Aerodynamic shape

Aerodynamic shape is very important in designing such a high speed system because it deals with reducing drag and wind noise, minimizing noise emission, and preventing undesired lift forces and other causes of aerodynamic instability at high speeds. Air is also considered a fluid in this case. For some classes of racing vehicles, it may also be important to produce downforce to improve traction and thus cornering abilities. Thus the capsule design is made on the basis of bullet train in japan and considering the shape of dolphin. The extended surface at the front side helps to increase the air intake to suction fan, where the nozzle like structure at tail is helpfulin releasing highly compressed air with a great velocity to achieve thrust for proportion

Material selection

The proposed material in an open source file regarding Hyperloop is al alloy and alloy steel. But both the materials have their own advantages and disadvantages. Al alloy has an advantage of its less weight but fails in strength parameter. Whereas alloy steel is fine with strength but in not suitable because of its high weight.

A golden mean between these two materials can be carbon fiber composite or carbon reinforced plastic. These two materials have a very good strength with less weight and higher reliability .

Fig no.4 Pressure test on carbon fibre composite showinh max value of 38psi.

Kantrowitz limit

moving at high speed through a tube containing air, there is a minimum tube to pod area ratio below which you will choke the flow. What this means is that if the walls of the tube and the capsule are too close together, the capsule will behave like a syringe and eventually be forced to push the entire column of air in the system. The approach that inventor believed would overcome the Kantrowitz limit is to mount an electric compressor fan on the nose of the pod that actively transfers high pressure airfrom the front to the rear of the vessel. This is like having a pump in the head of the syringe actively relieving pressure

Air bearing and compressor

One important feature of the capsule is the onboard compressor, which serves two purposes. This system allows the capsule to traverse the relatively narrow tube without choking flow that travels between the capsule and the tube walls (resulting in a build-up of air mass in front of the capsule and increasing the drag) by compressing air that is bypassed through the capsule. It also supplies air to air bearings that support the weight of the capsule throughout the journey

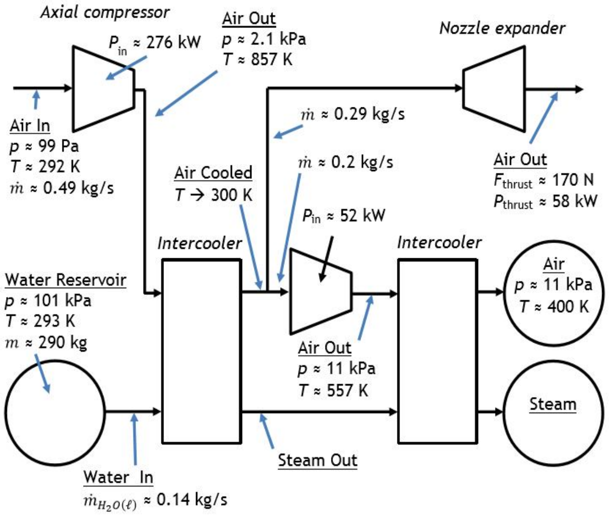


Fig no.5 Design of air bearing and compressor system

Table no.4. Calculated size of tube

	value
R of tube	1.34
A of tube, sq m	5.64
Cleanace,m	0.46(offset)

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.

Externally pressurized and aerodynamic air bearings are well suited 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 kph) and as a component of the overall safety system.

III. TUBE AND PYLON CONSTRUCTION

In tube designing the major factor is to tackle with two different pressures one at outlet i.e. atmospheric and other is low pressure maintained inside tube. A proper thickness, material and perfect dimensions can be key to good design.
The pylon design also involves cost, safety, and strength. Any project this size will also incur a large real estate acquisition cost. To decrease footprint,it is beneficial to reduce number of pylons, increase span between them, all while exceeding safety codes and regulations.

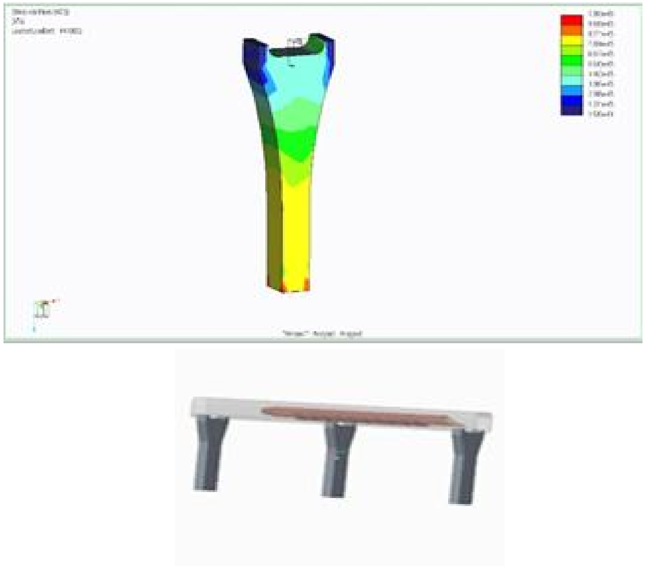


Fig no.7 Design of pod with tube in creosimulation,along with analysis result of pylon.

IV. SAFETY FEATURES

Air conditioning system

Though we consider air conditioning system a luxury but for a system such as aero plane or Hyperloop it is a necessary feature as the air available is very less and the pod is totally closed a system must be there for safety and comfort of passengers. As travelling in pod inside a tube is just similar to flying in a plane so here the safety features are designed according to the aero plane concerns. Following fig shows the system used in airplane similar system will be installed in Hyperloop but instead of engine it will be connected to batteries which will run the system

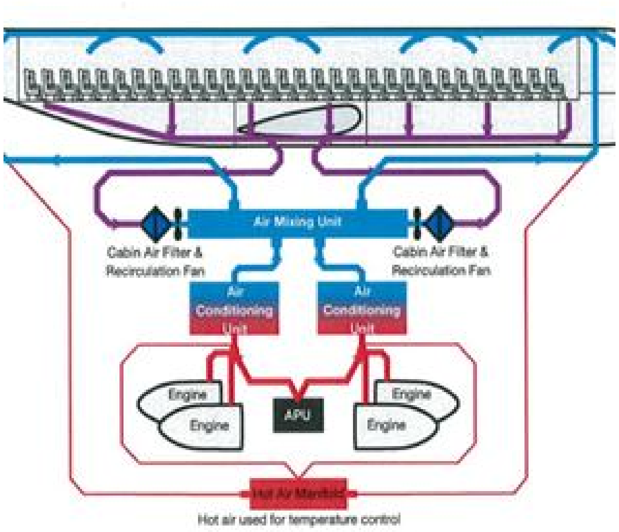


Fig no.8 Design air conditioning system in airplanes Pressure control

As one fly at higher altitude air become less dense that results in low pressure than normal atmospheric pressure. This can be very dangerous as It causes important changes in body functions, thought processes, and the maintainable degree of consciousness. The resultant sluggish condition of mind and body produced by insufficient oxygen is called hypoxia. There are several scenarios that can result in hypoxia. During low pressure operations, it is brought about by a decrease in the pressure of oxygen in the lungs at high altitudes. The air contains the typical 21 percent of oxygen, but the rate at which oxygen can be absorbed into the blood depends upon the oxygen pressure. Greater pressure pushes the oxygen from the lung alveoli into the bloodstream. As the pressure is reduced, less oxygen is forced into and absorbed by the blood. There are two ways this is commonly tackle increase the pressure of the oxygen or increase the quantity of oxygen in the air mixture. Large transport-category and high performance passenger aircraft pressurize the air in the cabin. This serves to push more of the normal 21 percent oxygen found in the air into the blood for saturation. When utilized, the percentage of oxygen available for breathing remains the same; only the pressure is increased.

By increasing the quantity of oxygen available in the lungs, less pressure is required to saturate the blood. This is the basic function of an aircraft oxygen system. Increasing the level of oxygen above the 21 percent found in the atmosphere can offset the reduced pressure encountered as altitude increases. Oxygen may be regulated into the air that is breathed so as to maintain a sufficient amount for blood saturation. Normal mental and physical activity can be maintained at indicated altitudes of up to about 40,000 feet with the sole use of supplemental oxygen.

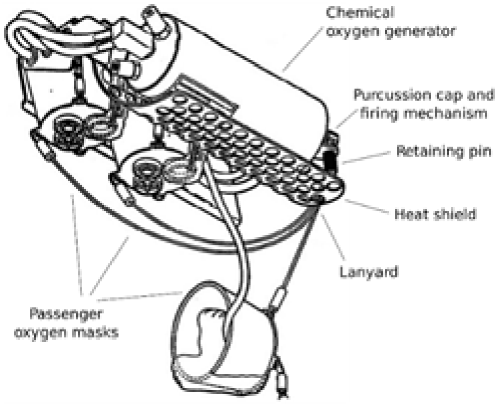


Fig no.9.Portable Oxygen Mask System.

Onboard Oxygen Generating Systems (OBOGS)

The molecular sieve method of separating oxygen from the other gases in air has application in flight, as well as on the ground. The sieves are relatively light in weight and relieve the aviator of a need for ground support for the oxygen supply. Onboard oxygen generating systems on military aircraft pass bleed air from turbine engines through a sieve that separates the oxygen for breathing use. Some of the separated oxygen is also used to purge the sieve of the nitrogen and other gases that keep it fresh for use. Use of this type of oxygen production in civilian aircraft is anticipated.

Pressurization Gauges

While all pressurization systems differ slightly, usually three cockpit indications, in concert with various warning lights and alerts, advise the crew of pressurization variables. They are the cabin altimeter, the cabin rate of climb or vertical speed indicator, and the cabin differential pressure indicator. These can be separate gauges or combined into one or two gauges. All are typically located on the pressurization panel, although sometimes they are elsewhere on the instrument panel. Outflow valve position indicator(s) are also common.

Firewall

A firewall is a fire resistant barrier used to prevent the spread of fire for a prescribed period of time. Firewalls are built between or through buildings, structures, electrical substation transformers, or within an aircraft or vehicle

They must be installed in Hyperloop in order to protect passengers from fire hazard and noise. A standard of building a firewall is given below

- Stainless steel sheet, 0.015 inch thick
- Mild steel sheet (coated with aluminum or otherwise protected against corrosion) 0.018 inch thick
- Terne plate, 0.018 inch thick
- Monel metal, 0.018 inch thick
- Steel or copper base alloy firewall fittings
- Titanium sheet, 0.016 inch thick

Two situations regarding capsule or pod under working conditions.

1. What will happen in the event of the depressurization of anHyperloop capsule? Pressure is so low (100 Pascal) that under the point of view of human physiology the conditions are closer to space than to the ones at commercial airplanes. At 100 Pascal none of the emergency measures commonly used even by military pilots (except the partial pressure suit of course), are enough to avoid severe hypoxia and traumas related to the decompression. Luckily we are not in space but on earth and believe we can find systems to compensate the pressure fast enough.

2. What happens if a capsule is stranded in the tube? Where will the emergency exits be?

A possible method to make an emergency brake procedure in a fast and reliable way might be to use the Kantrowitz effect. If air from the outside is allowed to come into the tube and equalize the pressure with the exterior, the capsule will suddenly have to go through and push a lot of air. At 300m/s the capsule will start compressing the air in front of it, working as a syringe head. If the pressure is allowed to rise above the sea level (for example closing some of the valves that initially opened to let the air in) the deceleration could possibly be more powerful. If the capsule´s area is not wide enough compared to the tube´s area, some spoilers could be deployed to help block the air in front of it.

Separating sections of the tube could be the way to avoid having to pump out the air from the whole system once the service has to be restarted. Big valves that close the whole tube could separate one section from the next one. This has the advantage that could also help build up the pressure in front a capsule that´s braking while maintain the low pressure behind, helping this way to stop the capsule in less time, just by opening the valves in front of it and letting the ones behind closed.

Instead of using a big sliding door or a similar kind of solid valve, a high-pressure inflatable plug could be used. It could be a textile closed shaped as a cylinder (imagine an inflatable Coke can, with the same diameter of the tube) that could be stored in a relatively small pack (similar to the ones that contain airplane slides or survival rafts) at the side or upper part of the tube, maybe forming a package with the recompression valves.

This depressurization packs would be installed every 10 km or so in the faster parts of the system (the capsules will be separated by 2 min, at their top speed that means 20 km), and closer at parts were the capsules go slower.

V. FUTURE SCOPE

- Power requirement calculations and cost estimation of power source
- Station designs.
- Passenger capacity improvement.
- Safety features improvement along with better travelling experience.

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