Cold Gas Propulsion System for Hyperloop Pod Chassis

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Hyperloop is a new mode of transport?

Proposed by ELON MUSK American business magnate, investor, and inventor. He is currently the CEO & CTO of SpaceX and CEO & Chief Product Architect of Tesla Motors.

A high-speed train that promises travel at twice the speed of a commercial aircraft, transporting passengers from Los Angeles to San Francisco in just 30 minutes.

A high-level alpha design for the system was published on August 12, 2013, in a whitepaper posted to the Tesla and SpaceX blogs.

Musk has also said he invites feedback to "see if the people can find ways to improve it"; it will be an open source design, with anyone free to use and modify it.

A Hyperloop would be "an elevated, reduced-pressure tube that contains pressurized capsules driven within the tube by a number of linear electric motors."

This system can achieve an average speed of 598 mph (962 km/h), and a top speed of 760 mph (1,220 km/h).
Hyperloop consists of a low pressure tube with capsules that are transported at both low and high speeds throughout the length of the tube.
Components of Hyperloop Transportation System

1. Capsule
2. Tube
3. Propulsion
4. Route
| Overview |
| History |
| Technical overview |
| Test track specifications |
| Vehicle pods |
| Competition Competing teams |
| Phase 1: Design weekend |
| Phase 2: Test track runs |
COEP Hyperloop Initiative
About team
System Architecture of COEP’s Hyperloop pod

1. Drive Motor Drive
2. Levitation Mechanism
3. Cold Gas Propulsion System
4. Braking Mechanism
5. Stability Mechanism
6. Chassis
Design Concept of cold gas propulsion

• Selection of gas

Properties of Gases

<table>
<thead>
<tr>
<th></th>
<th>Air</th>
<th>Nitrogen</th>
<th>CO2</th>
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<tbody>
<tr>
<td>$k$</td>
<td>1.4</td>
<td>1.4</td>
<td>1.289</td>
</tr>
<tr>
<td>$R$</td>
<td>286.9</td>
<td>296.8</td>
<td>188.9</td>
</tr>
<tr>
<td>$T_{sat}$</td>
<td>112.3642</td>
<td>109.2096</td>
<td>242.5543</td>
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<tr>
<td>Compressibility factor</td>
<td>1.0326</td>
<td>1.0577</td>
<td>0.3899</td>
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Pressure Regulator Setting
Modelling Equations

\[ m'_{\text{max}} = \frac{A P_0 \sqrt{\frac{k}{R T_0}}}{k+1}  \left( \frac{2}{k+1} \right)^{\frac{k+1}{2(k-1)}} \]

\[ \frac{A}{A^*} = \frac{1}{M a} \left( \frac{2}{k+1} \right) \left( 1 + \frac{k-1}{2} M a^2 \right)^{\frac{k+1}{2(k-1)}} \]

\[ \frac{P_0}{\rho} = \left( 1 + \frac{k-1}{2} M a^2 \right)^{\frac{k+1}{k+1}} \]

\[ \frac{T_0}{T} = \left( 1 + \frac{k-1}{2} M a^2 \right) \]

\[ \mu = \sin^{-1} \left( \frac{1}{M a_1} \right) \]

\[ v(Ma) = K \tan^{-1}(K \cdot M) - \tan^{-1}(\sqrt{M}) \]

where,

\[ K = \sqrt{\frac{k+1}{k-1}} \]

\[ M = (Ma^2 - 1) \]
Nozzle Contour Design

<table>
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<tr>
<th></th>
<th>Air</th>
<th>Nitrogen</th>
<th>CO2</th>
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<tr>
<td>$T_0$</td>
<td>300</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>$T^*$</td>
<td>250</td>
<td>250</td>
<td>262.1232</td>
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<tr>
<td>$P^*$</td>
<td>749394.1</td>
<td>749394.1</td>
<td>776973.2</td>
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<tr>
<td>$A^*$</td>
<td>0.00151</td>
<td>0.001536</td>
<td>0.001261</td>
</tr>
<tr>
<td>$r^*$</td>
<td>0.021931</td>
<td>0.022117</td>
<td>0.020042</td>
</tr>
<tr>
<td>$r^*(mm)$</td>
<td>21.93061</td>
<td>22.1174</td>
<td>20.04187</td>
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<tr>
<td>$n^*$</td>
<td>316.8833</td>
<td>322.3042</td>
<td>252.6361</td>
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<tr>
<td>$A_1$</td>
<td>0.011251</td>
<td>0.011444</td>
<td>0.013406</td>
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<tr>
<td>$r_1$</td>
<td>0.059859</td>
<td>0.060369</td>
<td>0.065342</td>
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<tr>
<td>$r_1 (mm)$</td>
<td>59.85936</td>
<td>60.36919</td>
<td>65.34163</td>
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<td>$A/A^*$</td>
<td>7.450111</td>
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<td>10.62927</td>
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<tr>
<td>$P_1$</td>
<td>16149.81</td>
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<td>12816.26</td>
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<td>$V_{out}$</td>
<td>659.3625</td>
<td>670.6423</td>
<td>574.0622</td>
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$t = V(P_i - P_f)/CP_a$
Modelling and Simulation

- Nozzle simulation
- Far field analysis
Pressurized Systems TNT Equivalence

- Work = $17.644 \times 10^6$ Joules
- 1 joule = $2.39 \times 10^{-13}$ kiloton of TNT
- As a result,
- Work = $4.2169 \times 10^{-6}$ kiloton of TNT = $4.2169$ kg of TNT

The equation is:

$$W = P_o \cdot V_o \cdot (\ln\left[\frac{P_o}{P_a}\right] - 1) + P_a \cdot V_o$$

where,
- $W$ = Work in joule
- $P_o$ = Pressure in Mpa
- $V_o$ = volume in $m^3$
- $P_a$ = Tube pressure in MPa
CONCLUSION

Evaluation and simulation for performance and integrity of the system of various working fluids, geometrical and, physical parameters

Comparison between analytically and numerically calculated results for the exhaust velocities and pressures differed by only 1.2 %

The far-field analysis to reduce the dependency on the assumption that the nozzle/ system will be stationery

Discussion on the control algorithm and state diagram upon various possibilities

High TNT value of the system

A trade-off between the produced thrust and consumed energy


