Forces on the wheels

This article is mainly focussed on a steel-rimmed wheel, which runs on a resilient liner in the tube. A pneumatic tire would have similar forces.

Centripetal forces

The proposed wheels for Hyperloop would be 1,300mm (51") diameter, and they would revolve at 4,900 rpm at 1,200 km/hr. This results in a centripetal force of 17,400g, with very high hoop and radial stresses in the wheel.

The choice of materials depends on their strength/weigh ratio, and their resistance to fatigue.

- Steel is not suitable as it has a very low strength/weight ratio.
- Titanium is possible.
- Forged aluminium would be suitable, but may suffer from long-term fatigue.
- Carbon composite is ideal with its very high strength, low density, and resistance to fatigue. However, composites have poor abrasion resistance, and the wheel would need a metal rim, which must be fixed to avoid total separation resulting from a single fatigue crack.

Wheel design is a complex FEA process, but the simple calculation of hoop stresses gives the worst-case loading. The hoop stress for a carbon composite wheel is 180 mPa, which compares favourably with its strength of 800 - 1,500 mPa

Gyroscopic forces

Gyroscopic forces are significant, they resist the sideways rotation of the wheel. Lightweight wheels are needed. The challenge is to bank the pod 45 degrees in 3 seconds when entering a curve.

- The resulting bearing and axle loads are less than normal cornering forces on a road wheel.
- The tipping force is small compared to the righting force with the wide-spaced wheels.
- But the gyro forces impart a skidding force between the wheel and tube, requiring a friction coefficient of about 0.2. This must be considered when designing the wheels and requires a gradual lead-in to the curves.

With carbon composite wheels, the maximum roll speed is about 3 seconds for a 45 deg bank, which is a reasonable rate for passenger comfort. The high speed curves would need a 3-second, 1000m lead-in.

Rolling resistance

Wheels have quite low rolling resistance, depending on their technology.
We can express efficiency as a lift/drag ratio (L/D) or the coefficient of rolling resistance (Crr)

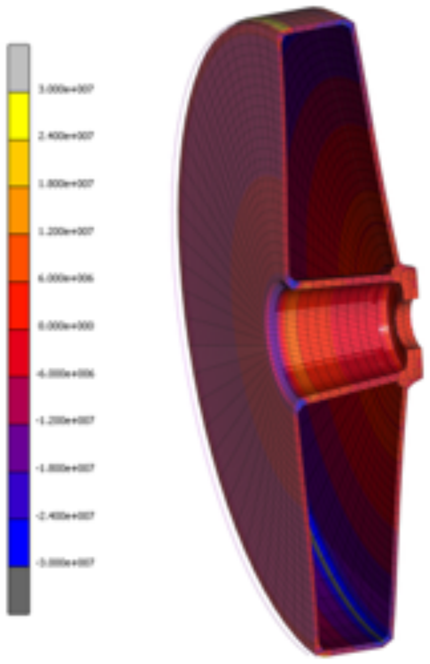
- Steel wheels on steel rails have the lowest drag. Their L/D is 500:1 (Crr .002), this would require 65 kW at 1,200 km/hr for a 10,000 kg pod.
- Low rolling resistance car tires have a L/D of 140 (Crr .007), which would require 233 kW.
- Tire development could produce a L/D up to 300 (Crr .003), which would require 109 kW.

These compare favourably with Maglev, onto a flat plate it has a L/D of about 15:1. Maglev onto coils has theoretical L/D up to 200:1. Hyperloop Alpha's compressor would use at least 275 kW.

Steering Stability

Steering stability is important, the correct steering geometry would make the pod inherently stable 'hands-off', like all road vehicles. Automated steering would give the passengers a sway-free ride.

Cheetah will be very stable, with wide curved wheels running in a circular tube. It will not suffer from the hunting which limits railway speeds, a result of the conical rolling surfaces and high centre of gravity over the rails.



Here are some images from an FEA structural feasibility study done by Kristian Zimmermann, an aerospace structural engineer.

The wheel is a carbon composite construction.

He concludes:-
"Based on the current FE results a CFRP wheel design seems feasible from a static point of view. Several design iterations are required in order to optimise and validate the design. CFRP components are highly manufacturing driven".