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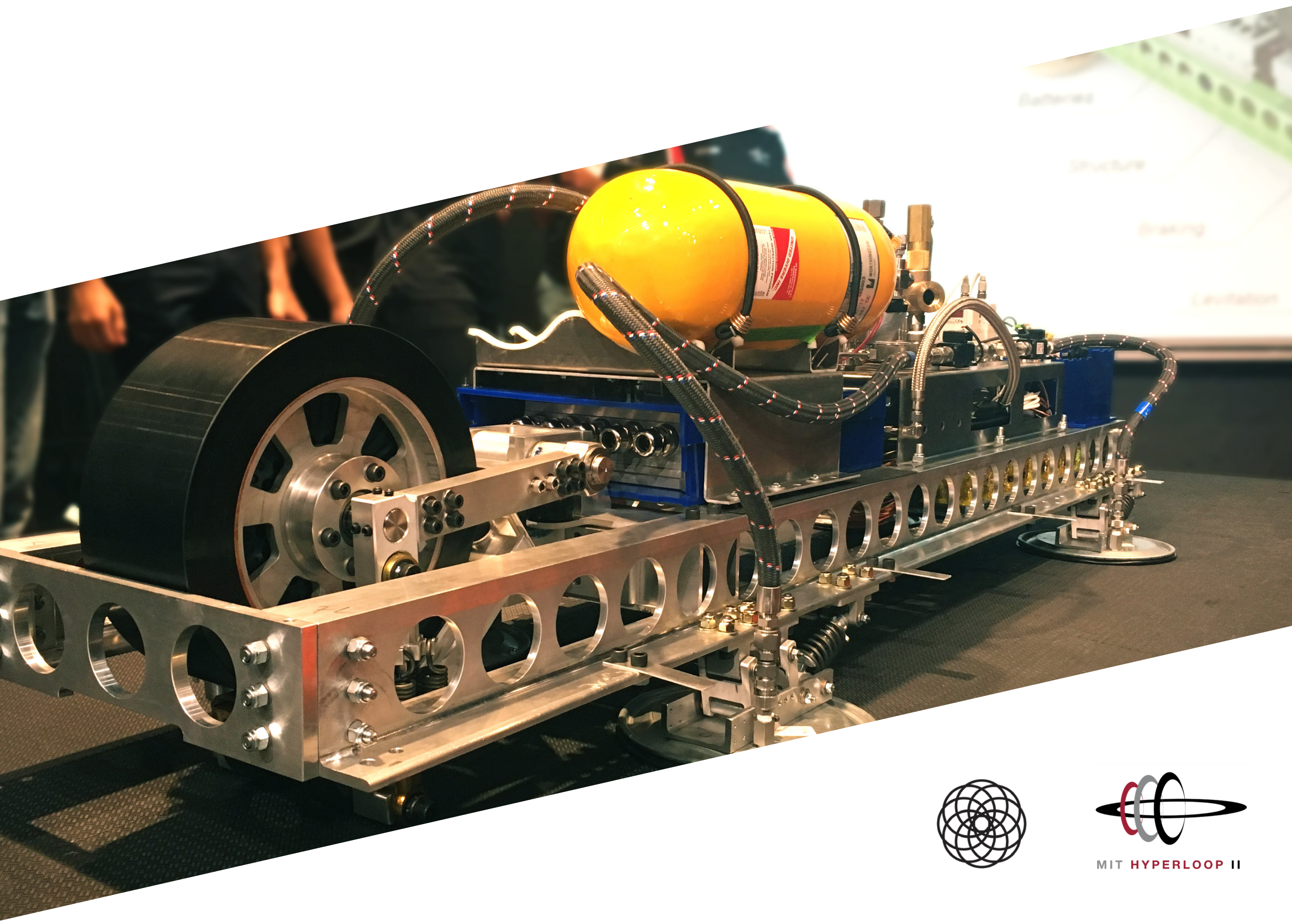
Stellana and the Hyperloop Pod Competition

The Effectiveness of Polyurethane Wheels in Proposed High-Speed Transportation



MIT HYPERLOOP II

The Effectiveness of Polyurethane Wheels in Proposed High-Speed Transportation

ABSTRACT

Student teams nation-wide were challenged to design and build the fastest, functioning prototypes for the Hyperloop Pod Competition. Judgment at the competition is based solely on the fastest speed achieved with successful deceleration. Polyurethane wheels play a crucial role in both functions as they are responsible for the acceleration and braking of the pod.

Our task was to engineer polyurethane drive wheels, stability, and clamping wheels that could hold up to ultra-high speeds. Working alongside the student teams, we assisted in hub design, advised material selection, and produced the final wheels. The wheels held up to testing, safety checks, and initial trials performed by the teams.

INTRODUCTION

Stellana faced a unique challenge to provide wheels that would not fail at the speeds of over 200 mph. Our involvement in the Hyperloop projects gave us a new reason to push polyurethane to its limits. During this time, we were able to leverage our supplier relationships to make data-driven material selections.

A vast majority of the wheels and tires we produce are used within the material handling industry on different class forklifts. These machines accommodate significant loads but operate at tops speeds around 8-10 mph. Getting a material to withstand stress and failure in the 200+ mph range posed a unique challenge for our engineers.

A combination of internal and external testing methods and research were used to narrow material selection. Internally, we used our dynamometer to test for failure at different loads and speeds. Due to the nature of our existing product range, our dynamometer tests for maximum speeds of 9 mph and up to 4,800 lbs. Our testing gave us an idea, but our prepolymer supplier was able to supplement our findings with more technical data on relevant elastomers. The physical property data we received included hardness properties, modulus, tear strength, elongation, Bashore rebound, abrasion indexes, and compression set.

Externally, the competing teams used their forms of dynamometer testing to confirm the materials were appropriate for their target loads and speeds. For instance, Paradigm ran its front vertical stability wheel on a test stand linked to their pod motor. They ran it at approximately 12,000 RPM with a 150 lb. spring at a 0.3” depression pressing the wheel; these conditions simulated the actual pod run. Each wheel underwent similar tests. The students then analyzed parts for any failure in the rim, shaft, bearing assemblies, or debonding.

METHOD

The collaborative process began with the design intent, hub design, material selection, and ended with the final production.

Our manufacturing background and knowledge of polymer formation gave us a good idea of where we needed to begin with the wheel design. Initially, our team had thought the 95 shore A TDI ether was a good material for the Hyperloop applications. To confirm this hypothesis, we completed the testing that our internal capabilities would allow and then used supplier data to support the findings further.

GENERAL PROCEDURE

Design Intent

First, the design intent had to be completed and approved by Hyperloop officials to begin prototype construction. Each team had unique objectives and strategies in mind to win the competition.

Design Strategies by Team

MIT Hyperloop II

MIT Hyperloop II constructed their pod using air bearings for levitation instead of the well-proven method of magnetic levitation. They were the first team to do so. This take on their design provided the team with unique challenges.

Paradigm

Having competed in the 2017 competition, the team won 2nd place overall. Going into the 2019 competition, they set out to continue developing their technology for a chance at another successful run.

Hub Design

Secondly, the university teams provided proposed hub drawings for all wheels (drive, stability, and clamping). Their primary focus when designing the wheels was to minimize weight while meeting load and speed parameters. The hub design process was iterative based on our feedback in terms of the material, manufacturing feasibility, and ability to work within their constraints.

Our wheels were most critical for the acceleration and braking functions of the pod. The different wheels served distinct roles on the equipment:

- The drive wheels function as a part of the propulsion subsystem responsible for the acceleration. The drive wheels had a size constraint of 300 mm OD. They were expected to reach 0.41G acceleration and experience a radial load of 2,000 N.
- Stability wheels are used to ensure the pod stays on track. These wheels had a size constraint of 150 mm OD. They were expected to experience a radial load of 1,500 N or 11,000 RPM.
- The clamping wheels are also in place to ensure the pod stays on the tracks. These wheels had a size constraint of 87 mm OD. They were expected to experience a radial load of 1,000 N.

A **MIT drive wheel** - Part of the propulsion subsystem

Specifications:

- Size constraint of 300 mm OD
- Expected to reach 0.41G acceleration
- Experience a radial load of 2,000 N

B **MIT stability wheel** - Used to ensure the pod stays on track

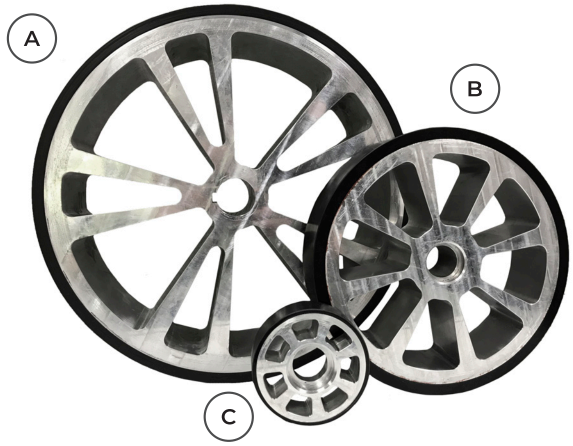
Specifications:

- Size constraint of 150 mm OD
- Experience a radial load of 1,500 N or 11,000 RPM

C **MIT clamping wheel** - Used to ensure the pod stays on track

Specifications:

- Size constraint of 87 mm OD
- Experience a radial load of 1,000 N



Paradigm ran at speeds of 85 mph on smaller wheels, 60 mph on the drive wheel.

(A) **Paradigm drive wheel**

(B) **MIT stability wheel**

(C) **MIT clamping wheel**

Material Selection

The final material was based on the below criteria:

- Wheel geometries
- Speed and load requirements (targeting 200 mph or higher)
- Application-specific coefficients of friction (0.3-0.5)
- Deflection
- Tensile strength (we provided a material strength of 4800 PSI)
- Our internal ability to process and comfort level with the material
- Recommendations and technical data from our supplies

As a result, we chose a TDI Ether material with a 95 Shore A durometer. This material was selected based upon its excellent dynamic properties, abrasion resistance, and low compression set.

Hardness (Shore A)	95A
Split/Tear (pli)	170
Tensile Strength (PSI)	4800
Elongation (%)	335
Compression Set, Method B, % After 22 hours at 158°F (70°C)	29
Bashore Resilience (%)	44
NBS Abrasion Index	300

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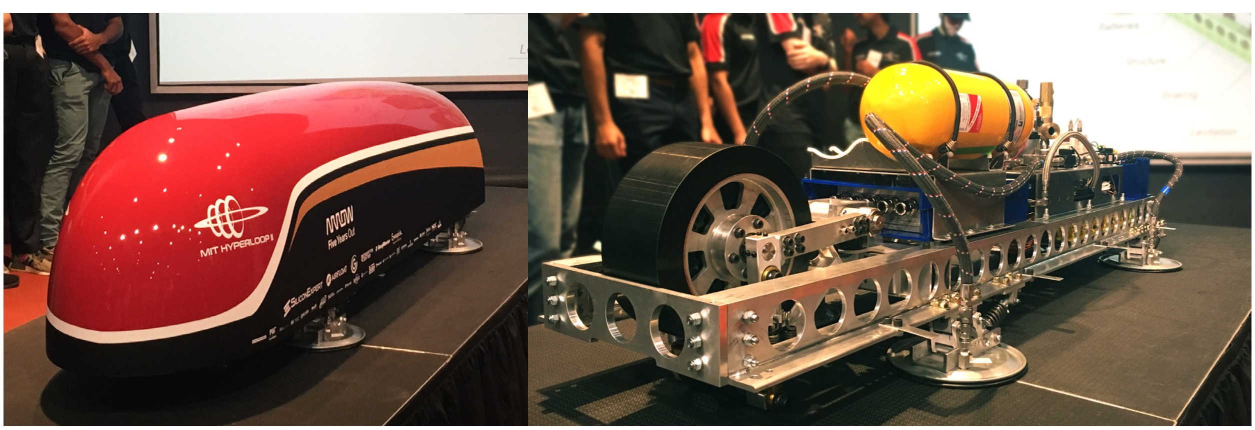
RESULTS

We received feedback from the teams that worked with us and they found our capabilities gave them an advantage in the competition for reasons including:

1. Our ability to find a material that worked for all the wheels
2. Our ability to leverage relationships with polyurethane suppliers to generate critical technical data and work collaboratively to identify existing and potentially new products to meet customer needs
3. Our internal machining capabilities allowed us to turn polyurethane to exact dimensions required that were critical to the applications
4. Our ability to utilize and modify existing tooling to accommodate the different hub designs
5. The flexibility in our manufacturing process allowed us to accommodate last-minute design changes

We were not able to directly observe results from this competition as our partnering teams did not get selected to run the official track. Even in this case, our teams were confident in the polyurethane wheels they received. MIT Hyperloop II finished 5th internationally and first in the US. They also took home an innovation award for their air levitation design. Paradigm took second place in 2017 and completed a successful run on the track. In 2019, the team took 8th overall, ranking 3rd in the US. Paradigm ran at speeds of 85 mph on smaller wheels, 60 mph on the drive wheel.

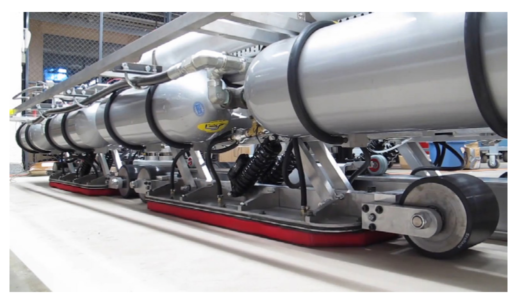


MIT Hyperloop II Pod - Covered and exposed at pod unveil

Additional shots or MIT Hyperloop II pod

Covered Paradigm Pod 2019

Covered Paradigm Pod 2017



Exposed Paradigm Pod 2019

CONCLUSION

Polyurethane wheels are a viable option for competitors today and potentially a new form of transportation in the future. The competing teams combine top talent with extensive resources to test the feasibility of their proposed pods. As teams continue to show interest in Stellana wheels, we will continue to advance our wheel technology for use in their high-speed pods.