Höcherl & Hackl
The electronic load

Customer Application #15

Test of Lithium-Ion-Polymer Cells for High Speed Drives

WARR Hyperloop is a student team at the Technical University of Munich (TUM) that aims at innovating our future modes of transportation by building and testing prototypes for the newly proposed Hyperloop concept.

Vehicle (Pod) in vacuum tube

Winning Team 2018

For three consecutive years, the team was able to win the annual "SpaceX Hyperloop Pod Competition" in Los Angeles, USA. Competing against 20 student teams from around the world, the team further set a new speed record for a Hyperloop prototype: 467 km/h inside the 1.2 km long competition vacuum tube.

This year's prototype features a 240 kW battery pack, powering a set of eight electric motors.
For the comparably short competition track length, our battery pack is severely constrained by power output over energy capacity. Since the battery system is the single largest system by weight and we've placed a major focus on weight reduction of the vehicle, we wanted to conduct thorough battery testing with two primary goals:

Goals

- Reduce battery capacity to the minimum by determining the true peak discharge rates of selected Lithium-Ion cells for our specific drive cycle and lifetime criteria.
- Reduce battery enclosure weight by testing operation of bandaged battery cells under vacuum (and subsequently avoid an artificial pressure containment).

Requirements

These goals required an electronic load to perform the corresponding discharge tests. Specifically we needed at least 6 kW input power and the option to run dynamic current profiles. Hoecherl and Hackl supported us with their PLI6406. Matching our power requirements (6.4 kW continuous), the electronic load offers digital control inputs (RS-232, USB, Ethernet, CAN) and features a dynamic load function (LIST). Furthermore, direct data acquisition to a USB flash drive, an internal resistance measurement function for batteries and supplementary control software proved to be a major convenience.

Discharge Tests

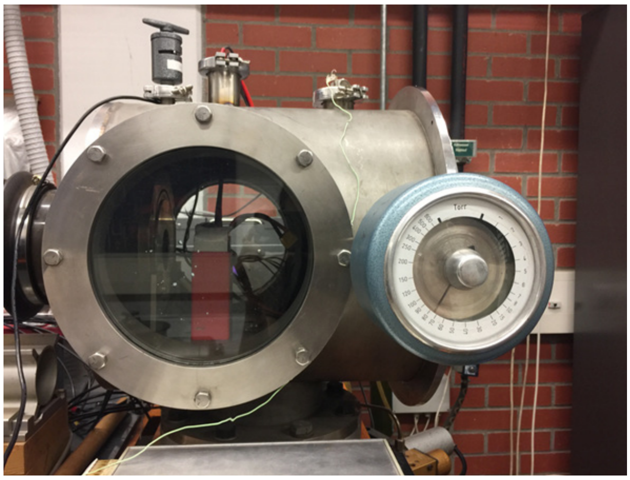
The cell's peak discharge rate was iteratively determined under our expected dynamic load at various temperatures. We've found our optimal and safe operating point to be at 50 °C. An expected finding, since a Li-Ion cell's internal resistance tends to decrease with increasing temperature and thus enables higher performance due to lower losses.

Our peak discharge rate was found to be 40 % higher than the manufacturer's rating, given our short cycle of < 15 s. Capacity tests also showed negligible cell degradation over our expected system lifetime. In total, this enabled us to reduce our battery mass by ~30 %.

Vacuum Tests

Furthermore, we've subjected our pouch style cells to the low pressure environments found inside the vacuum tube of the competition. Pouch cells have the tendency to expand and destruct when missing physical restriction (i.e. by atmospheric pressure). We've tested cell bandaging at various pressures in the vacuum chamber. Observed expansion stayed within reasonable limits. Additional tests under load, with the PLI6404, showed identical performance to ambient pressure tests. Capacity tests after a series of cycles confirmed negligible cell degradation. Thus lightweight bandaging enables us to avoid a heavy pressure containment, such as featured in our previous prototype. This enables us to shed another 6 kg from the total vehicle mass.

Vacuum chamber and electronic load PLI6404



Vacuum chamber with cells under test

We'd like to thank Hoecherl and Hackl for their generous support over the past season.
These weight savings (due to testing/characterization) attributed to a decrease of 20 % in vehicle mass and an approximate increase of 10 % in vehicle top speed. For the future, we're looking into integrating the PLI series load much more tightly into our vehicle test setup via the provided CAN interface or LabVIEW connector.

This application report was written by members of the WAR Hyperloop team of TU München.