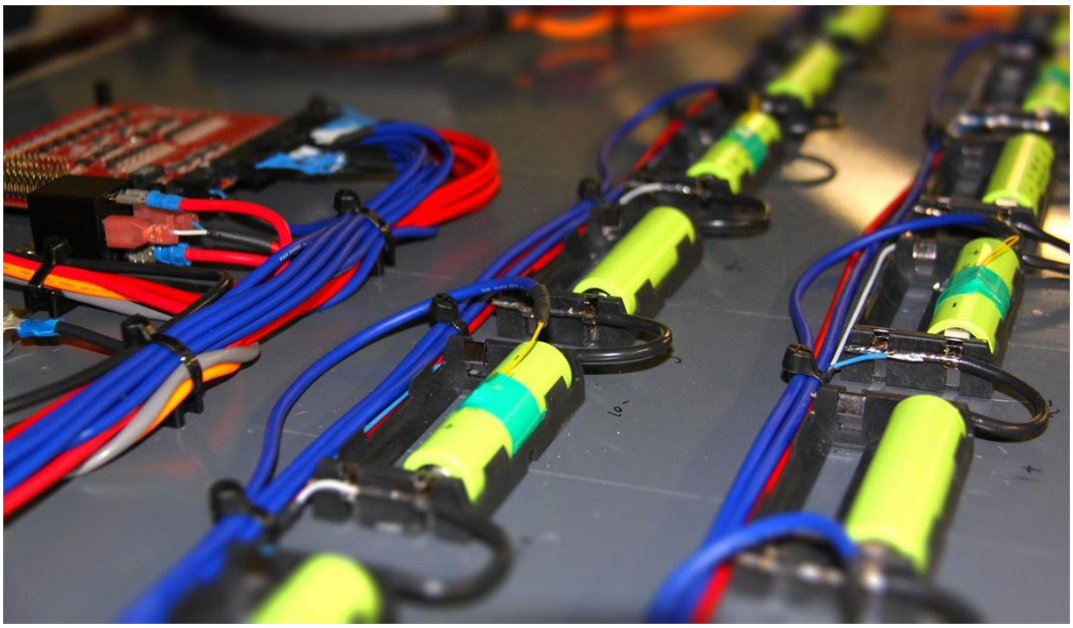
AUTOMOTIVE BATTERY RESEARCH



TNO innovation for life

Specialized in the field of Automotive Powertrains, TNO's Powertrains department performs research for the purpose of supporting OEMs and TIERs in their vehicle developments. Due to the current focus of the Automotive Industry towards (Hybrid-)Electric Vehicles (EV, HEV, PHEV), one of TNO's research topics is Battery Technology.

Working towards the goal of accurate range and lifetime prediction, the work starts with modelling, characterising and validating of the batteries behaviour.

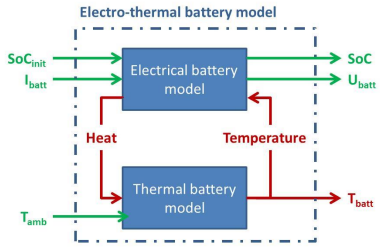


Figure 1 Electro-thermal battery modelling structure

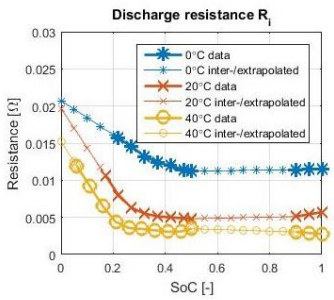


Figure 2 Example of a SoC- and Temperature-dependent battery model parameter

ELECTRO-THERMAL BATTERY MODELLING

Battery models (such as in Figure 1) form the basis of most battery related research topics, ranging from basic simulation models up to complex electro-thermal pack models combined with prediction, state and/or parameter estimation.

The most rudimental purpose of battery models is to model the terminal voltage of the battery during a typical load-cycle applicable for that specific use-case. Additionally, the models can be expanded in different directions, eg. including thermal behaviour of model parameters in Figure 2 is an often used addition.

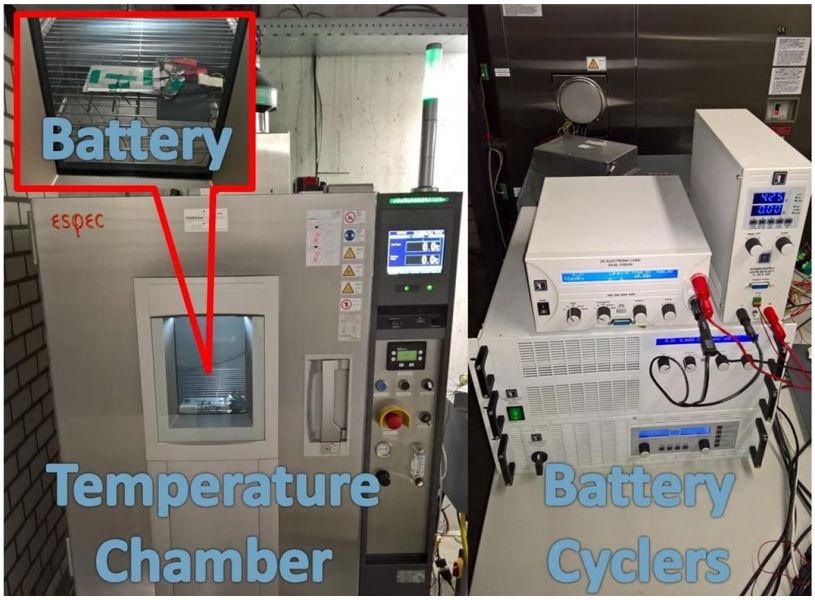


Figure 3 Battery testing facility for cells and modules, coupled to a temperature chamber

Typically, the batteries behaviour is represented by (Electrical) Equivalent Circuit Models ((E)ECM), that are capable of capturing both dynamic and steady-state behaviour of the battery.

ONLINE STATE & PARAMETER ESTIMATION

With the current focus of the Automotive Industry on accurate electrical range estimation of (PH)EVs as well as a strong focus on battery ageing topics, investigating online state and parameter estimation techniques is a topic that is a logical part of TNO's battery research.

The most common estimators that TNO develops are State-of-Charge (SoC) estimators, designed to accurately estimate the current remaining amount of 'charge'/ energy in the battery. These types of estimators are applied under demanding conditions, where straight-forward current integration does not suffice. The SoC estimators are making use of a parametrized battery model, which is cleverly combined with both voltage and current measurement by an Extended Kalman-Filter (EKF) based estimator. The SoC forms then the basis for electric range estimation, safety limit algorithms and other diagnostic purposes.

Additionally, TNO also developed several online parameter estimation techniques, both for electrical and thermal battery model parameters. These parameter estimators quantify the batteries performance (both in terms of power and energy) during the complete lifetime of the battery. Thereby providing the SoC estimators with model parameter updates during the lifetime, thus ensuring accurate SoC estimation, even at the end-of-life of the battery. Besides, they also provide diagnostic metrics, which compared to the initial values are commonly known as State-of-Health (SoH).

BMS ALGORITHM DEVELOPMENT

Closely linked to the online state and parameter estimations, TNO also develops different types of BMS algorithms. Most of these algorithms require inputs from one or more of the estimators to function correctly. As an example, the list of the BMS algorithms developed by TNO in the past includes 'Maximum power prediction' and 'Thermal prediction'.

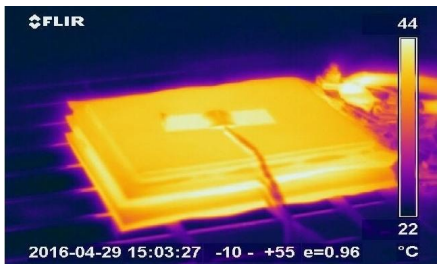


Figure 4 Thermal imaging for temperature spread analysis

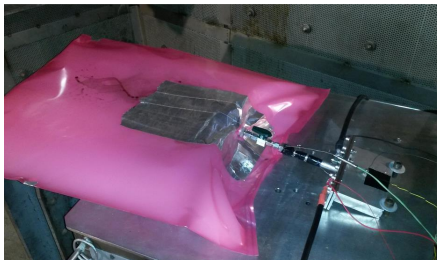


Figure 5 Example of an abuse test with gas analysis

BATTERY TESTING

For all previously mentioned developments TNO creates data with a variety of Battery Test Setups (BTS, as in Figure 3), ranging from small setups for cell level testing up to large setups for module and pack level testing. All of these battery cyclers can be combined with temperature (and humidity) controlled environments.

The testing mostly focuses on electro-thermal characterisation and validation, while in some special cases also abuse testing belongs to the possibilities. If necessary, the abuse testing can be combined with gas analysis (FTIR, GC-MS, GC-TCD, etc.), such as in Figure 5.

In addition to the standard available measurements, like voltage, current and temperature, thermal images as in Figure 4 can also be obtained to observe/identify temperature homogeneity.

All mentioned expertise and knowledge is either developed internally, together with B2B customers or within partnerships like ABattReLife, AMBER, 3Ccar, etc.

TNO.NL

TNO POWERTRAINS

For more information, please contact us:

TNO Powertrains
Automotive Campus 30
NL-5708 JZ Helmond
P.O. Box 756
NL-5700 AT Helmond

T +31 88 866 5734
E secretaryhelmond@tno.nl