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Thermal Propagation of Li-Ion batteries: a simulation methodology for enhanced and accelerated virtual development

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ABSTRACT: The safety of BEVs in driving, charging and parking condition is essential for the success of electrification in automotive industry as well as key driver of any future development of Li-Ion HV battery. AVL has developed a unique simulation approach in which the multi-physical behavior of the single cell in thermal runaway is modelled and applied to module, pack or vehicle level. In addition and beside this cell behavior, various more physical phenomena during thermal propagation on pack level are considered and predicted by the simulation method: component melting, ignition and flammibilty of venting gas and HV failures.

KEY WORDS: **thermal runaway, thermal propagation, arcing, ignition, flammability**

1. MOTIVATION

Ensuring safe BEV usage in large scale, several scenarios need to be investigated and it's passive safety must be developed and verified. Beside classical homologation tests like the current Chinese GB regulation for Thermal propagation, many OEMs are thinking in a direction, to set themselves a goal of much higher difficulty but even safety: no propagation at all. That means, that after a single cell failure which leads to thermal runaway, the battery design ensures that no flames or fire are coming out of the battery at all, even for hours. Just goals like this can ensure safe usage of BEVs in any application like charging in a garage.

Safe Battery designs in such a manner require a detailed and careful development and verification process. Therefore AVL has developed a unique simulation methodology which combines physical testing on cell level with simulation on module and pack level even with vehicle interfaces. The cell tests include measurements of heat release, venting gas composition or detection of ejected particles which are then feeded to the simulation model by a developed parametrization algorithm. This simulation methodology considers various physical phenomena contributing to the system safety – not just the cell in thermal runaway but even melting, gas ignition, combustion, arcing, particle flow and abrasion.

The simulation of thermal propagation with this methodology predicts the temperature distribution and evolution over time, considering heat transfer, gas flow, mechanical deformation of battery housing and modules and the melting of single components or materials. The outcome of the simulation contains beside detailed information about propagation times even the assessment of the risk of self-ignition or external ignition of the venting gas or the risk of arc formation in the HV-path.

Just with a methodology like described above, a target like no propagation can be achieved since this needs to understand over a long period of time the conditions inside the battery pack and its time dependent risk of burning. So the transient gas conditions and ignition risks must be evaluated which is just possible with the deep inside which a simulation can give.

4. CONCLUSION

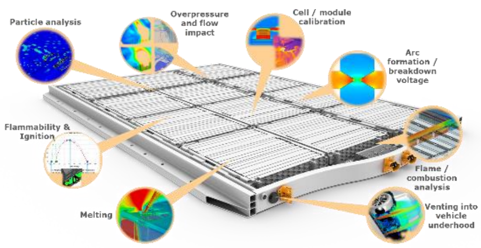

Figure 5: Example of multi-phsical consideration of thermal propagation on system level: various phsyiscal side phenomena beside cell thermal runaway

Thermal Propagation is one crucial requirement for any battery development. To ensure safe and robust design, a virtual development approach is recommended which considers the electro-chemical behavior of the cell during the cell thermal runaway but beyond this even all physical side phenomena on system level which contributes significantly to the pack propagation. This includes material melting, particle ejection, overpressure and its mechanical impact, gas ignition and combustion and electrical arcing inside the battery and between HV and housing.