Theory of inventive problem solving (TRIZ) to advance the understanding of Li-ion battery thermal runaway in EV applications

Planned funding: ICube- SATT Conectus Alsace
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Workplace: ICube
Laboratory: ICube (CNRS UMR 7357)
Team: SMH-ICube & CSIP-ICube
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Worldwide energy context:

One of the barriers to the development of effective, less-polluting, economically sustainable, and transportation systems that make wise use of the world's natural resources is the energy dilemma. Constraints related to the environment and the economy must be honored in this. Despite the inherent limitations associated with the battery and the higher cost of electronic equipment, the E-mobility is now a viable option and is already available on the market. According to the most recent Canalys data, 4.2 million electric vehicles (EVs) were sold globally in the first half of 2022, an increase of 63% over the same period in 2021. Battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) are both classified as EVs.

Scientific objectives:

The spread of electric or plug-in hybrid technologies will only be possible if the energy performance and driving comfort remain equivalent to that of traditional internal combustion (ICE) vehicles while maintaining a competitive price. Today, the main axis of progress is undoubtedly based on the development of on-board energy storage systems providing solutions for improving the driving range, battery lifetime, volume, mass, total cost of ownership (TCO) and safety. The Li-ion battery is by far the most efficient technology in terms of specific power and energy. Its lifetime is equivalent to that of other technologies. This is why it has developed enormously in recent years. In automotive applications with the technology of Li-ion battery, where it is necessary to determine the lifetime of the battery and, more importantly, when to stop charging and discharging phase, accurate information on the state of charge (SOC), capacity, temperature and the state of health (SOH) is critical, as overcharging or overdischarging can result in permanent damage (battery thermal run-away phenomena). The fact that Li-ion batteries are more prone to thermal runaway is simply explained: when the temperature increases while the floating voltage is constant, the reaction kinetics increase. As a result, more oxygen will be recombined (exothermic combustion reaction) on the negative electrode, contributing to the rise in temperature within the battery. To adapt to the operating conditions, the battery management system (BMS) must estimate the SOC and measure the cell temperature to facilitate safe and efficient use of the battery.

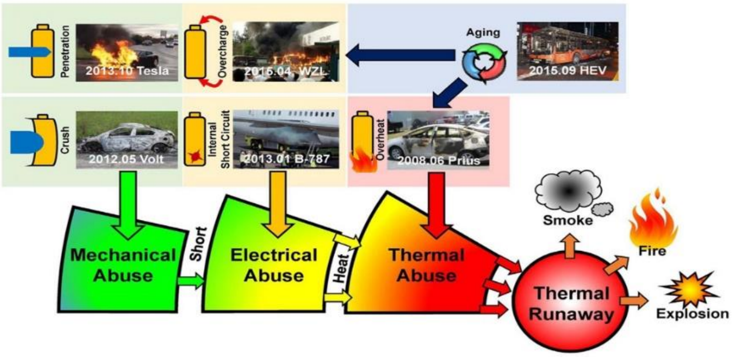

Figure. I : Causes of high temperature likely to generate thermal runaway [3]

The aim of this internship is to advance the understanding of phenomenon "battery thermal runaway" at the cellular scale, taking into account the influence of the various parameters of the technological choice and of the design in connection with the application. This project is motivated by the recurrent safety issue associated with the lack of control of the risk of thermal runaway that characterizes lithium-ion batteries since their commercialization. The main focus will be on the use of methods based on the Theory of Inventive Problem Solving (TRIZ) and to identify new research challenges focusing on the question of the thermal runaway. The "Theory of Inventive Problem Solving," also referred to as TRIZ. Many creative problem-solving techniques and tools that rely on dialectics and systems are based on this philosophy.

Work Progress

This internship will mainly take place at the SMH-ICube & CSIP-ICube laboratory (INSA Strasbourg). He/she will first have to carry out bibliographic researches on the risk of thermal runaway that characterizes lithium-ion batteries and inventive theory based on problem solving (TRIZ). A formalization work on the understanding of battery thermal runaway by using TRIZ approach will be developed. A comparison of proposed solution will highlight their interest and limitation. A digital tool based on problem solving TRIZ approach will be completed.

Candidate's skills:

Specific knowledge: Knowledge of energy storage systems and theory of inventive problem solving. Programming in Python /Matlab.

Desired education: Student about to graduate a Master or Engineer (Bac + 5) with a specialization in Electrical Computers & Industrial engineering.

Desired personal skills: Strong motivation for innovation and the search for operational solutions in an industrial context. Motivation for the combination of simulation and experimentation.

References:

[1] T. Mesbahi, N. Rizoug, P. Bartholomeus, R. Sadoun, F. Khenfri, and P. Lemoigne, "Optimal Energy Management For a Li-Ion Battery/Supercapacitor Hybrid Energy Storage System Based on Particle Swarm Optimization Incorporating Nelder-Mead Simplex Approach," IEEE Trans. Intell. Veh., vol. 8858, no. c, pp. 1–1, 2017.

[2] T. Mesbahi, Rocío Bendala Sugrañes, Reda Bakri, Patrick Bartholomeüs, "Coupled electro-thermal modeling of lithium-ion batteries for electric vehicle application," Journal of Energy Storage, Volume 35, 2021,

[3] Feng X., Ouyang M., Liu X., Lu L., Xia Y., He X. (2018) Thermal runaway mechanism of lithium ion battery for electric vehicles: A review, Energy Storage Materials 10, 246–267. DOI: 10.1016/j.ensm.2017.05.013..

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