Crash simulations of electric cars in the EU project EVERSAFE

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1 Introduction

EVERSAFE is a Swedish-German project funded by the Seventh Framework Programme ERA-NET Transport Electromobility+ that has been initiated in 2012. The overall objective of the project is to provide recommendations for improved safety regulations and to find out about research needs for electrically propelled vehicles. As well as it is the case for conventional vehicles, safety issues of electric vehicles are categorized into two groups: active and passive safety and both groups have been addressed by the project. Although full electric vehicles are the main focus, results of the project are also applicable to other electric vehicle variants including hybrid electric vehicles, fuel-cell electric vehicles and plug-in hybrid electric vehicles.

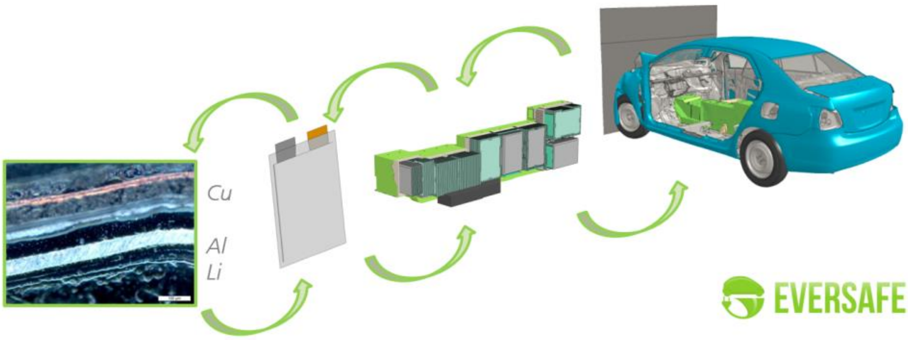

Fig.1: EVERSAFE project: from cell model to full car crash simulations.

This paper focuses on the passive safety part of the project including cell level component tests as well as comprehensive simulations evaluating battery vulnerability (Fig.1). Partners involved in the passive safety part are the Fraunhofer Institute for High-Speed-Dynamics (EMI), the Fraunhofer Institute for Chemical Technology (ICT), the German Federal Highway Research Institute (BASt), the Swedish Transport Research Institute (VTI), and Volvo Car Corporation (VCC).

2 Experiments and material characterization on Li-Ion pouch cells

Abuse tests and material characterization were conducted on Li-Ion pouch cells (Fig.2). As a result it was observed little modifications in experimental conditions could lead to harsh chemical reactions, e.g. for nail penetration testing, whereas some severe experimental setups, e.g. cell cut, showed no chemical reaction at all.

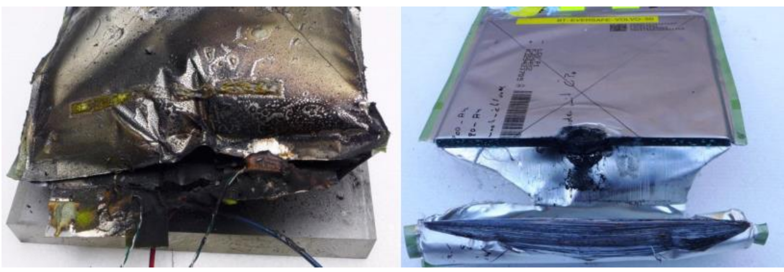

Fig.2: Different reactions for pouch cell abuse tests: imploded cell after nail penetration (left) and intact cell after cut test (right).

3 Crash simulations

The FE model of the Toyota-Yaris of the American National Crash Analysis Center NCAC has been comprehensively improved and now reaches an excellent numerical stability for a variety of crash pulses. A tunnel battery has been modeled and integrated in the car to obtain a first generation electric vehicle. The battery pack contains about 600,000 elements and the entire car model consists of about 1.6 million elements. A multitude of gauge points have been monitored for each simulation, from the battery deformation to the maximum forces applied on the cells and the maximum accelerations within each module.

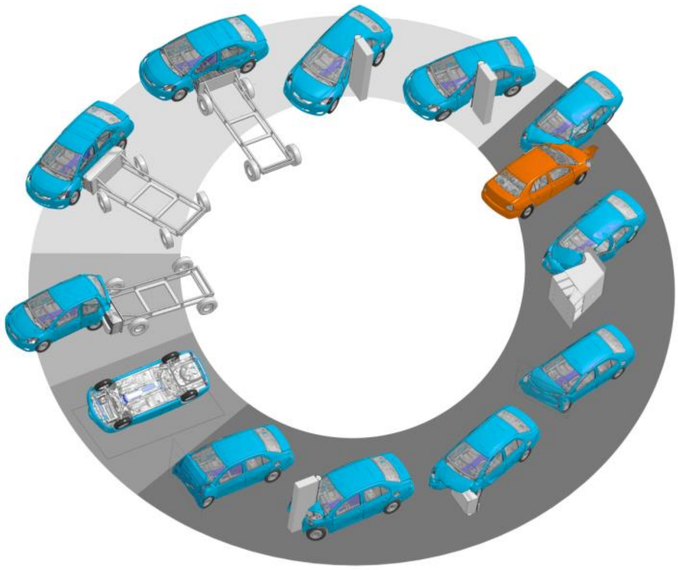

Fig.3: Simulations performed with the electric car model.

4 Conclusion

The main results that emerge from the EVERSAFE activities are that electric vehicles can be seriously damaged if hidden defects are introduced within the battery pack or a module. Experimental and numerical activities confirmed this finding. Microscopic analysis and material characterization of cells allowed gaining a better understanding of the internal failure mechanisms and the definition of a criterion for a short circuit. A special area of concern has been the reproducibility and the robustness of the cell tests, as their results might strongly differ depending on the actual test conditions. Suggestions were made to improve current test standards.

In parallel, full car crash simulations have been performed and used to build up a comprehensive overview of standardized as well as non-standardized crash load cases in order to cover a wide spectrum of accident scenarios (Fig.3). A methodology was developed to assess the crash severity and to give general guidance with regard to scenarios that are most challenging for battery packs placed centrally in the tunnel. Even if none of these cases numerically led to an intrusion in the battery pack, some scenarios with acceleration peaks above 100g recorded in the modules might be critical for the battery. However, they are not covered by current crash regulations. Thus, further recommendations were made for the critical crash scenarios and for an optimal battery placement and battery design.

5 Literature

[1] Everyday Safety for Electric Vehicles: EVERSAFE, http://www.eversafe-project.eu.

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[3] The National Crash Analysis Center NCAC, the George Washington University, http://www.ncac.gwu.edu/.

[4] GIDAS - German In-Depth Accident Study. (2010). http://www.gidas.org/en release from 05.11.2012.