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Multi-Physics Crashworthiness, Occupant Safety & High-Voltage Battery Protection in Electric Vehicles

Advanced Non-Linear CAE Methodologies for FMVSS 214 & Euro NCAP Side-Impact Compliance

EXECUTIVE ABSTRACT

This technical whitepaper outlines eShocan's advanced multi-physics simulation methodology for next-generation Electric Vehicles (EVs). It addresses the dual imperatives of structural lightweighting and extreme battery pack protection during severe dynamic crash events, specifically focusing on FMVSS 214, FMVSS 305, and Euro NCAP oblique pole impact protocols.

Author: eShocan Automotive Simulation Practice
Group

Global Delivery: USA • Mexico • India •
Global

Website:
www.eshocan.com

1. Executive Summary & Industry Challenge

The structural integration of high-voltage battery enclosures into electric vehicle body-in-white (BIW) architectures introduces unprecedented engineering trade-offs. Unlike traditional internal combustion engine (ICE) vehicles with distributed crumple zones, EV floorpans house massive, chemically volatile lithium-ion battery modules that must withstand multi-directional collision forces without breaching cell casings or exceeding allowable deformation thresholds.

Critical Design Imperative: In pole side-impact tests (Euro NCAP 75° at 32 km/h), the intrusion of the rigid pole directly targets the rocker sill and battery cross-members. A structural intrusion exceeding 15mm into the battery module array initiates cell mechanical rupture, separator failure, and thermal runaway.

To eliminate costly physical prototype iterations—which average \$450,000 to \$650,000 per crash mule—eShocan has formulated an end-to-end multi-scale non-linear dynamic FEA framework using explicit solvers (LS-DYNA and PAM-CRASH) coupled with thermal-electric runaway models.

2. Multi-Scale Material Modeling & Strain-Rate Sensitivity

Accurate crash prediction requires micro-to-macro material characterization across wide strain rates (10^{-4} s⁻¹ to 10^3 s⁻¹). Standard isotropic plasticity models fail to capture anisotropic shear failure in extruded aluminum alloys (6000/7000 series) and localized necking in Ultra-High-Strength Steels (UHSS / Gen-3 1500–2000 MPa press-hardened steels).

STRUCTURAL COMPONENT	MATERIAL SPECIFICATION	YIELD STRENGTH (MPa)	FAILURE STRAIN RATE (s ⁻¹)	SIMULATION FORMULATION
Side Sill Extrusions	Al 6082-T6 (Multi-Chamber)	260 - 310	500 - 1000	MAT_024 / MAT_124 Anisotropic
B-Pillar Reinforcement	PHS 2000 (Usibor 2000)	1500 - 1950	200 - 800	GISSMO Damage / Failure Triaxiality
Battery Lower Shield	Al 7075-T6 + Composite Armor	480 - 540	1000+	MAT_054 / SPH Debris Modeling
Cell Pouch Jellyroll	Anisotropic Homogenized Core	Non-linear crush	Dynamic crush	MAT_063 / Crushable Foam Core

3. Side-Impact & Underbody Debris Simulation Protocol

eShocan's crash test matrix replicates real-world regulatory and consumer safety protocols through fully calibrated virtual test benches:

- **Euro NCAP Oblique Pole Impact (75°, 32 km/h):** Verification of progressive crush zone deformation, longitudinal sill energy dissipation, and lateral load transfer across transverse cross-members.
- **FMVSS 214 Dynamic MDB (61 km/h):** Moving Deformable Barrier simulation evaluating thoracic and abdominal occupant injury criteria (HIC, Rib Deflection, Pubic Symphysis peak loads).
- **SAE J2464 / ISO 12405 Underbody Strike:** SPH (Smoothed Particle Hydrodynamics) modeling of road debris and conical impinger impacts up to 50 km/h, preventing tray perforation.

4. Case Study: 18% Mass Reduction with Zero Intrusion

TIER-1 NORTH AMERICAN EV OEM PROJECT OUTCOME

Baseline Challenge: The initial battery tray design weighed 142 kg and exhibited 22mm lateral intrusion during oblique pole simulation, exceeding safety limits by 7mm and threatening battery module integrity.

eShocan Solution: Our engineers executed automated parametric topology optimization in LS-OPT and modeFRONTIER. We substituted single-cavity sills with an internal multi-chamber honeycomb extrusion and reinforced critical node joints with structural adhesive bonding modeled via cohesive zone elements (MAT_138).

Validated Results:

- Battery intrusion reduced from 22mm down to **8.4mm** (44% safety buffer).
- Overall enclosure mass decreased by **18.2% (26 kg saved per chassis)**.
- Physical prototype crash iterations reduced from 5 rounds down to 2 physical validation runs, saving **\$1.4M in development capital**.

5. eShocan Automotive Simulation Capabilities

eShocan delivers end-to-end full-vehicle crash, NVH, durability, and CFD simulation services with offshore-onshore hybrid engineering teams:

- 150+ CAE specialists across Detroit, USA and Bangalore, India.
- Dedicated HPC infrastructure running multi-threaded LS-DYNA, Nastran, Abaqus, and ANSYS.
- Integrated delivery from CAD concept through regulatory sign-off.

Accelerate Your Engineering Roadmap

Schedule a 30-minute technical evaluation with eShocan's senior practice leads to review your simulation architecture, battery safety models, or embedded lifecycle.

Visit: www.eshocan.com / Contact: info@eshocan.com