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Design, Numerical and Experimental Validation of a Simplified Side Impact Sub-System Test Approach

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Side impact collisions account for approximately 25% of traffic fatalities, driving stringent safety requirements including Euro NCAP's 32 km/h oblique pole impact test at 75 degrees. Traditional full-scale crash testing is costly and time-intensive, while existing servo-hydraulic sled systems require specialized equipment and significant capital investment. This paper presents enhanced mechanical improvements to a simplified sub-system sled test methodology addressing these accessibility challenges.

The enhanced system integrates three critical improvements: a vertically constrained sled mechanism eliminating pitching effects, a passive cylinder blocking system preventing post-intrusion rebound, and an improved brake system providing pulse regulation and emergency stopping. The methodology employs two independent sleds with two intrusion zones utilizing foam blocks and deformable elements, making it accessible to laboratories without specialized actuator equipment.

Comprehensive numerical validation using PAM-Crash finite element analysis preceded physical implementation. Foam material characterization included quasi-static compression at five strain rates (0.01–100/s), tensile testing, confined compression, and dynamic validation via ball drop (1.4 m/s) and sled impacts (10–12 m/s). Component-level validation employed three progressive build-up levels: independent sliding cylinders, cylinders with articulated structure plates, and complete assembly with door panel. CAE simulation achieved strong correlation for sled longitudinal displacements during the 0-50 ms loading phase, with CORA scores of 0.966 (platform sled), 0.934 (lower actuator), and 0.971 (upper actuator)

Experimental validation with World SID 50th percentile dummy demonstrated substantial improvements through two test iterations with side airbag time-to-fire optimization (advanced by 3 ms). Shoulder force correlation improved from 120% over-prediction in previous work to 2.23 kN (first test) and 2.01 kN (second test) versus 1.87 kN full-scale, reducing deviation to +7.5%. Upper thorax rib displacement achieved 12% deviation (30.02 mm at 42 ms vs 26.8 mm at 44 ms full-scale) with CORA score improving from 0.716 to 0.738. Pelvis lateral force showed less than 10% difference with CORA score of 0.9. The cylinder blocking mechanism eliminated artificial secondary loading peaks beyond 40 ms present in previous design. All sled displacement pulses achieved CORA scores above 0.976.

The methodology achieves correlation within 12% for critical injury metrics using passive mechanical elements, with absolute rib deflection differences of 3-4 mm comparable to <5 mm deviation reported for three-sled systems. Compared to ±5% repeatability of advanced servo-hydraulic actuators, this represents a practical trade-off exchanging moderate precision for elimination of hydraulic complexity, significantly lowering capital investment, maintenance, and training requirements while delivering accuracy suitable for restraint system development from early design phases through final validation.

Fig. 1 Sled Test Setup

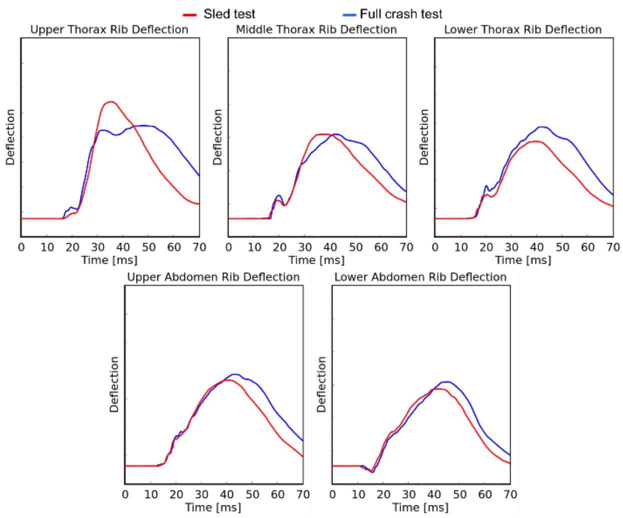

Fig. 2 Dummy Response Comparison - Sled Test vs Full-Scale Test

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