C37 Rear Impact Vehicle Occupant Ejection and Seat Belt Slack: Comparison of Upright, Reclined, and Collapsed Seats in Field Investigations and Laboratory Tests

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The goal of this presentation is to inform the engineering, medical and legal community of the phenomenon of seat deflection in foreseeable rear impacts causing vehicle anchored seat belts to predictably fail. This phenomenon has been published in the technical literature since the 1960's but all efforts to enact safety regulations to prevent these failures have been resisted. Alternative designs exist which can prevent these failures.

This presentation will impact the forensic science community by showing how implications of this safety hazard affect all forms of seated transportation, not just ground vehicles.

This study analyzed field and laboratory investigations of rear impacts of passenger cars, utility vehicles, and pickup trucks where belt restrained occupants were partially or completely ejected from their designated upright seating position, and in some instances completely ejected from the vehicle. Hazardous slackening of locked-up vehicle-anchored seat belts was created by collapsing seats, even if seat belt pretensioner systems had been activated by another impact prior to the rear crash. Rear impact crashes analyzed in this study showed severe to fatal injury to front and/or rear seat occupants as a result of seat failure and resultant seat belt failure caused by slackened belts. Changes in velocity ranging from approximately 15 to 30 mph with impact vectors between 160 and 200 degrees. In several crashes there were two belted front seat occupants, with one remaining in a reasonably upright seat and one in a collapsed seat. In all instances the occupant of the collapsed seat was either seriously injured or killed, and the occupant of the upright seat incurred only minor to no injuries. The vehicle anchored seat belt combined with a collapsed seat, was not effective in preventing rearward occupant displacement and/or partial or complete ejection. The slackened belt and poor occupant geometry increased the hazards of submarining under the lap and torso belt. This is consistent with vehicle crash test research published since the 1960's, as well as prior research by Pozzi et. al. conducted and published since the 1970's.

Current research involved further quantifying this belt slackening phenomenon and establishing minimum threshold values for seat movement induced belt slack allowing occupant ejection. Adult male and female human surrogate static testing evaluated vehicle anchored seat belts combined with upright and reclined seats in various vehicles. Approximate seat belt slack was measured for various levels of seat displacement. Approximately 10-12 degrees of static rearward seat movement slackens vehicle anchored seat belts enough to allow rearward ejection of a belted occupant. Slack is exacerbated with dynamic rearward movement of seat belt buckles, seat foam compression, etc. These belt slackening effects were minimized or eliminated on Belt Integrated Seats (BIS). Rearward static load test comparisons using a rigid human upper torso were made between OEM and Modified OEM seats as well as production BIS to establish occupant crash load capacities to the point of allowing occupant ramping out of the seat. Sled and/or crash tests were also conducted to evaluate side-by-side comparisons of various OEM and alternative seat and seat belt designs.

In all rear impact tests in the foregoing velocity range where a weak collapsing seat (600-1,600 lb load capacity) was combined with a vehicle anchored seat belt, the occupant was not effectively restrained or protected. The weakest seats allowed the greatest remaining occupant load contributing to ejection and injury potential. Lap belt loads as the dummy was moving rearward were negligible, and peak vehicle anchored belt loads always occurred on rebound, long after the occupant struck vehicle rear interior structures or a rear seat occupant. The poorest belt performance and greatest slack occurred with vehicle-anchored lap/torso belts that utilized pass-through latch plates. In all tests where a seat remained reasonably upright, the belt remained in significantly more effective contact with the occupant pelvis and upper torso to provide restraint as intended. BIS are significantly stronger, so they resist rearward deformation. BIS upper torso restraints move with the seat so there is no belt slack generated, and proper occupant-to-belt geometry is maintained far better under the same collision conditions than in collapsing seats and vehicle anchored belts.

Crashworthiness, Seatbelt, Seat

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