C6 The Need for Adequate Strength Seat Back Design - A Case Study

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After attending this presentation, attendees will understand an analysis of an automobile collision during which a rear seat occupant was ejected while wearing a 3-point lap and shoulder belt.

This presentation will impact the forensic community and/or humanity by demonstrating how an inadequate seat back design, while certified by federal safety standards, failed and resulted in catastrophic injuries **THEORY OF THE ANALYSIS:** Seat back strength is essential in order to provide adequate protection and containment of occupants in passenger vehicles. Seat back failure as a result of rear-end collisions reduces the potential for occupant restraint and increases the risk of occupant ejection. Federal Motor Vehicle Safety Standard (FMVSS) 207 establishes the requirements for seat assemblies and their attachment hardware to minimize the possibility of component failure by occupant forces acting on them as a result of vehicle impact. However, real world rear-end impacts have shown that inadequate strength seat back designs can lead to lack of restraint and ejection of vehicle occupants.

COLLISION OVERVIEW: On the evening of October 6, 2002, a young male driver was operating his 2000 model year passenger vehicle at high-speed. Onboard were passengers in the right front seat and right rear seat. As the vehicle entered a downhill right-hand turn, the driver lost control and the vehicle began to yaw counter-clockwise. The vehicle veered left, crossing the opposing traffic lane, and struck a guardrail at the roadway edge. The initial guardrail strike was to the vehicle's right front corner. The principal direction of force (PDOF) of this impact was approximately 90 right of center. As a result of the right front impact, the vehicle continued to rotate counter-clockwise and struck the guardrail at the right rear corner. Rotating through this right rear corner impact, the rear of the vehicle then impacted a guardrail post. The impact to the right rear corner along with the rear guardrail post impact had a combined change in velocity of approximately 12.1m/s with a PDOF of 150 right of center. After separating from the guardrail, the vehicle continued to rotate counterclockwise until it rolled to a stop on the shoulder.

FORENSIC ANALYSIS: Inspection of the seat belts revealed forensic evidence confirming that all three passengers were wearing their 3-point lap and shoulder belts at the time of impact. In addition, photographs taken by investigating officers show the right rear seat belt still fastened at the collision scene.

The right rear seat back was deformed due to occupant loading during the rear impact. In response to this impact and subsequent vehicle rotation, the right rear occupant ramped up the seat back, sliding under the seat belt, and was ejected through the rear hatchback window. The ejected occupant sustained fatal head injuries. The autopsy report revealed this occupant suffered an atlanto-occipital disarticulation, brainstem laceration and contusion, multiple skull fractures, and bilateral cerebral subdural and subarachnoid hemorrhage.

The subject vehicle rear seat back is a 50/50 split-back design such that either half can be independently unlatched and folded forward to increase cargo space. The latching mechanism for the left and right seat back panels are located outboard on the interior of the vehicle quarter panels. There is no restraining device or reinforcing structure at the centerline of the upper area of the seat back, except for a narrow fiberboard shelf behind the seat that conceals the rear cargo area when the hatchback is closed.

FMVSS 207 section 4.3.2.2 specifies the acceleration requirements for the restraining devices of hinged or folding seat backs of forward-facing seats. The section requires that once engaged, the device shall not release or fail when subjected to a horizontal acceleration of 20gs opposite to the direction the seat back folds. Section 5.1.2 of the standard specifies the testing procedure such that the horizontal force is applied through the CG of the seat back panel. The right rear seat back panel has a mass of approximately 4.5kg: therefore, at 20gs a total force of approximately 890N would be applied. Based on the location of the latching mechanism and hinge point of the seat back panel, the 890N-applied force would subject the latching mechanism to a force of approximately 672N and the hinge point to a force of approximately 218N.

A simple haversine analysis was used to determine the peak acceleration of the vehicle as a result of the rear impact. Assuming a collision pulse duration of 100ms, the resulting peak acceleration was approximately 24.6g. Medical records indicate the right rear occupant had a mass of 115kg, approximately 14 percent greater than the mass of a Hybrid III 95th percentile male test dummy. The mass and CG location of the individual torso and upper body components of a 95th percentile ATD were used to approximate the CG height of the effective mass of the right rear occupant. The effective mass,

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approximately 70% of the overall mass, is that portion of the occupant's mass that loaded the seat back panel in the rear impact. The CG height of the effective mass is approximately 30.5cm above the seat cushion surface. Based on this analysis, the potential peak force applied to the latching mechanism was approximately 9,200N, and the potential peak force applied to the hinge point was approximately 8,400N. The potential peak forces applied to the latching mechanism and hinge point in the subject collision far exceeded the forces required by the seat back panel restraining devices to satisfy FMVSS 207. However, these calculated potential peak forces are not unlike those forces reasonably anticipated in real world collisions of this magnitude. Clearly, the seat back panel and its restraining devices were inadequately designed resulting in catastrophic failure in this unfortunate collision event.

CONCLUSION: Seat back yield strength is an important consideration in foldable rear seat back designs. Anticipated occupant loading forces resulting from real world collisions far exceed the static force requirements used to certify seat back designs. Inadequate strength restraining devices can lead to seat back failure and increase the risk of occupant ejection.

Seat Back Strength, FMVSS 207, Occupant Loading