THE CONSULTANTS PERSPECTIVE

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UNDERSTANDING THE BEHAVIOR OF THE UNRESTRAINED AND RESTRAINED OCCUPANT IN A VEHICLE COLLISION

INTRODUCTION

The normal deceleration of any motor vehicle exerts forces upon vehicle occupants that are nearly the same as those of actual acceleration, but in a reverse direction. Acceleration generally occurs gradually, except in unusual instances as with astronauts during blast-off or drivers during drag racing. Deceleration, however, can occur very abruptly, particularly in the case of vehicle accidents. When a vehicle hits a solid object or another vehicle head on, an unrestrained occupant will continue to move forward until such time as the body impacts with some part of the vehicle interior or is ejected from the vehicle. This body motion is called occupant kinematics. It deals with the motion of bodies, but without consideration of the forces required to produce or maintain the motion. The purpose of the analysis is to correlate occupant injuries with vehicle interior damage or contact/impact points to determine, for example: (1) Who was driving the vehicle; (2) The positions of occupants before the collision; or (3) The effect of using the vehicle restraint system (safety belts.)

The issue of who was driving the vehicle can be of considerable interest in both civil and criminal cases. To illustrate, a viable defense of an accused driver would be to argue that another person was driving the vehicle at the time of the accident. If the other occupant were killed in the accident, as is often the case, this would eliminate any possibility of getting testimony from such person. In yet another instance, there may be an interest in how a passenger (other than the driver) was positioned in a vehicle and how such person could have been injured in a particular position.

And, another issue that is often seen as relevant in a vehicle accident is the effect of safety belts (lap/shoulder restraint), whether they were worn and if they could have eliminated or mitigated injuries. The latter of the foregoing three issues will be the focus of attention here, and involve occupant restraint systems and restraint system theory.

Understanding occupant behavior in a vehicle collision, whether for any one of the reasons already listed or for others not mentioned, involves use of the same general methodology for all. A multiple step process is followed. However, in not every instance or case will sufficient data be available so that each step can be completely examined. The succession of steps is as follows:

Step 1: Inspect the vehicle interior for evidence of contact or impact between occupant (body) and the interior.

Step 2: Gain an understanding of how the vehicle moved from initial contact to maximum engagement to separation and, finally, to final rest position.

Step 3: From movements of the vehicle, determine how the occupant should have moved relative to the vehicle, and which parts of the vehicle the occupant could have struck with particular parts of the body.

Step 4: Review occupant injury (and autopsy) data and determine how injuries and interior vehicle contact points match.

Step 5: Compare the conclusions reached in Step 3 with the results of matching injuries to interior contact points. If there are no significant differences, then two separate approaches will have produced the same conclusion. Resolve any conflicts in the conclusions.

Step 6: This step is optional. If the issue is whether safety belts would have prevented or mitigated the injuries, then this step is included. It examines the question of whether a safety (lap/shoulder) belt would have any effect on reducing injuries or injury severity.

RESTRAINT SYSTEM THEORY

In a head-on vehicle crash, there are a series of collisions that occur. The primary impact is between the vehicle and a solid object or another vehicle. At the moment of impact, the velocity of the impacting vehicle is suddenly changed. However, the occupant continues to travel forward (in the occupant compartment) at the initial velocity or pre-crash speed. An unrestrained occupant will come to an abrupt stop as the body strikes some part of the decelerating vehicle interior or the ground outside the vehicle (in the event of an ejection.) The unrestrained occupant may impact numerous parts of the vehicle interior during the collision and post-impact phase of the accident. This event (impact) is called the “second collision” and represents the injury causing phase of the accident.

A restrained occupant, however, will “collide” with the seat belts (lap and shoulder) of the vehicle’s “active” restraint system, or air bags of the “passive” restraint system soon after the primary collision. The restraints, in combination with the padded vehicle interior, prevent large, injury-producing impact forces from arising between the occupant and vehicle components. In general, the restraint system functions to "gently" decelerate the occupant as the vehicle is stopped by avoiding body contact with interior components.

Finally, there is the "third collision." This occurs between the body's internal organs and the bony structures enclosing them (and includes the brain impacting the inside surface of the skull.) The impact forces in the third collision can be mitigated by the use of occupant restraint systems.

The front end of a vehicle is designed to crush during an impact. In doing so, it absorbs the crash (kinetic) energy of the vehicle and allows the occupant compartment to come to a stop over a greater distance (a couple of feet as opposed to inches) than does the front bumper. Occupant compartment deceleration occurs over a longer time period as well. By tightly coupling or "tying" the occupant to the vehicle (frame), as with snug-fitting restraint belts, the occupant can "ride-down" the crash with the decelerating vehicle. For adults, there is generally only one link, such as a lap/shoulder belt, in the "chain of coupling" between the occupant and the vehicle. However, in the case of infants or children, there are usually two links: the infant/child restraint seat as well as the vehicle lap/shoulder belt.

In the case of restraint belts, little energy is absorbed by them. The tighter they are adjusted prior to the crash, the lower will be the initial body deceleration into the belts. Other types of protection systems such as padding or airbags can themselves absorb impact energy between the occupant and vehicle interior. These energy-absorbing objects produce a more gradual occupant deceleration by increasing the travel distance of the occupant during such deceleration.

CASE STUDY

Use of the six steps identified earlier can be illustrated by a case study where the relevant issue concerns the effects of lap/shoulder belts and whether they could have eliminated or mitigated injuries in a collision. A late model Ford Mustang equipped with a vehicle restraint system consisting of a three-point lap/shoulder belt received damage to the left front portion of the vehicle (left offset impact) when it collided with another vehicle. The male driver of the Mustang was unrestrained and riding alone at the time of the accident.

Examination of the interior of the Mustang revealed the following signs of contact between the driver and interior components: (1) Body fluid (blood) on the trim covering the left A-pillar; (2) Damage to a portion of the instrument panel (dash) on either side of the steering wheel-column system; (3) Damage to the steering wheel rim and spokes in the form of the lower (6-o'clock) portion of the rim bent upward and a fractured rim and spoke (at the 2-o'clock position); and (4) Damage to the windshield on the driver side.

The thrust or principle direction of force on the Mustang did not pass through the vehicle's center of mass. Therefore, the event is a non-centered (eccentric) collision with the other vehicle. The left front body section was pushed rearward beyond the left front wheel placement. There was also noticeable exterior body damage across the front of the vehicle. The Mustang slowed considerably as a result of the collision. The impact caused the Mustang to rotate counterclockwise and to begin movement to its right.

There was no collapse of the Mustang's roof structure, A-pillars or doors into the occupant compartment. Equally important is that the deformation of the vehicle's front body did not extend to the base of the windshield. Moreover, there was no intrusion, penetration or deflection of vehicular parts or fixed objects into the occupant compartment. In addition, there was no obvious rearward movement of the instrument panel toward or into the driver seat.

Based on the physical damage to the vehicle, the impact was not highly destructive, excessively violent or catastrophic as to cause severe impact loadings on the body. Therefore, there were no loadings to exceed and defeat or even to degrade the limit of effectiveness of the lap/shoulder belt (if worn) in eliminating and/or mitigating body injuries.

The unrestrained Mustang driver would move primarily forward, but with a tendency to move to the left as well inside the occupant compartment. In doing so, the driver impacted the left A-pillar with the left side of his head. Both legs, in and about the area of the knee, impacted the lower portion of the instrument panel. The abdominal area and chest made forceful contact with the steering wheel-column system as evidenced by the rim and spoke damage. The driver's head impacted into the interior of the windshield as evidenced by the characteristic spider-web (and concentric circles) pattern that occur in the laminated glass.

From hospital emergency room medical reports, the driver of the Mustang sustained the following injuries from contact or impact with interior vehicle components during the "second collision": (1) Severe cerebral concussion with permanent injury to the central nervous system [caused by impact with the windshield]; (2) Deep laceration high on the forehead, near the center [caused by impact with the windshield]; (3) Scalp laceration above the left ear over the parietal bone [caused by contact with the left A-pillar]; (4) Abrasions and contusions to the head [caused by contact with the left A-pillar, windshield and perhaps windshield frame and head liner/roof]; (5) Deep laceration to the left knee [caused by impacting the left side of the instrument panel]; (6) Abrasions and contusions to arms and legs [caused by instrument panel and steering wheel-column system]; (7) Fractured left thumb and index finger [caused by impact with the left side of the instrument panel]; (8) Fractured third and fourth ribs [caused by forceful impact with the steering wheel-column system]; (9) Abrasions and contusions to the abdominal area and chest [caused by impact with the steering wheel-column system, particularly the bent, lower section of the steering wheel]; and (10) Cardiac and lung contusions [caused by forceful impact with the steering wheel-column system.] The driver of the Mustang sustained multiple skeletal and soft tissue injuries to the thorax and extremities. Injury severity can conservatively be coded as "critical."

For the Mustang driver, the findings of how his body moved relative to his vehicle compared exceedingly well with the results of matching injuries to vehicle interior contact points. There were no significant differences.

If the driver had been wearing the available three-point restraint, and if it were properly (snugly) fitted to his body, he would have been coupled to the Mustang's frame and able to "ride down" the collision by "colliding" with the lap/shoulder belt. The restraint system would have forced him to change his speed while his vehicle changed speed, thereby increasing his deceleration time and distance. Such a controlled rate of deceleration would reduce the magnitude of the forces acting on the surface of his body. At the same time, the three-point restraint would have optimized his body's tolerance to impact by distributing resulting loads from the crash forces widely across the strongest parts of his body. This would include his shoulders, chest, pelvis and thighs. The effect of controlled body deceleration coupled with proper distribution of crash forces to body areas would have greatly reduced the likelihood of injury.

Critical to the concept of occupant restraint as a method to minimize injury during the "second collision" is maintenance of occupant compartment integrity. Extensive deformation of and intrusion into the occupant compartment degrades and even defeats the injury protective potential of a properly used three-point restraint. The principle cause of occupant injury then comes from the vehicle's own structure deforming and intruding into the passenger compartment. In the case of the Mustang driver, no such deformation or intrusion occurred. Occupant compartment integrity was maintained. Thus, there were no compromising factors to proper lap/shoulder belt performance.

Had the driver used the vehicle's three-point lap/shoulder belt at the time of the collision, his injuries would have been minimized to where they would have been prevented and/or mitigated. The restraint would have limited his forward motion and displacement in the occupant compartment. His major body segments (head and torso) would have been restrained. There would have been little or no contact (essentially no major contact) with the Mustang's interior components, i.e., the A-pillar, instrument panel, steering wheel column-system and windshield. Consequently, there would be no (or only minimal) damage, deformation and fracture to the steering wheel rim and spoke as well as to the instrument panel and windshield.

It follows, therefore, that the driver would most certainly not have sustained his two most critical (and life threatening) injuries, e.g., cerebral concussion and cardiac contusion. The forehead and scalp lacerations also would have been prevented. It is highly probable that no head-to-windshield contact would have occurred if the driver were properly restrained. Moreover, torso (abdominal and chest) contact with the steering wheel-column system, if occurring at all, would have been greatly reduced such that the magnitude of any impacting forces would not have exceeded body (soft tissue and bone) injury tolerance limits. In such instance, the driver would have sustained no rib fractures. In addition, the fracture to the left thumb and index finger, and the laceration to the left knee would not have been expected to occur.

Generally, if there were any contact with vehicle interior surfaces (if the driver were restrained), it would have been limited only to the mass of the particular body segment making such contact rather than the mass of an entire, uncontrolled "free-flying" body. Interior contact forces would therefore have been substantially reduced in magnitude making such contacts minor or unremarkable and any injuries from them minor (simple bruising) as well. Injuries in the form of minor rib contusions from "colliding" into and with the diagonal portion of the three-point restraint during body deceleration are possible for the restrained driver. The contusions would be located on his chest, under the diagonal belt. Particularly noteworthy is that the foregoing restraint contact (and resulting contusions) would be attributed to the slack which must be accounted for in a properly fitted belt as well as elongation of the belt webbing during loading.

CONCLUSION

An occupant restraint system is intended to restrain, not prevent, body motion and movement in a collision. It works very effectively and most efficiently in frontal collisions, including those with an offset. It limits occupant motion and displacement so as to prevent or minimize contact (impact) with the vehicle interior. If the Mustang driver had used the three-point restraint, it would have substantially resisted and hindered his movement and displacement out of the driver seat, distributed the collision impact energy over his strongest body structures and reduced his contact velocity with any impacted interior surface or object.

The goal of the occupant restraint system is to avoid injury to the central nervous system (brain and spinal cord) and to prevent or mitigate, to the extent possible, the occurrence of broken bones and internal organ and serious soft tissue injuries. When used properly, and providing the occupant compartment is not seriously intruded upon and there is no intervention on the part of rear seated occupants, the three-point lap/shoulder seat belt is viewed to be the most effective safety device yet developed for protecting occupants in a collision. Evidence of its effectiveness is reflected in State jurisdictions and countries which have adopted some form of seat belt use legislation.

ABOUT THE AUTHOR

FORCON Consultant - Michael Romansky, Ph.D., J.D. has an educational background that includes Industrial Engineering, Human Factors, Biomedical Engineering, and Accident and Injury Epidemiology as well as a Law Degree. His work experience includes having been a Research Safety Engineer and Forensic Scientist for the National Institute for Occupational Safety and Health (NIOSH). He has developed, implemented and managed safety and health compliance and training programs, conducted accident and injury investigation and reconstructions, directed and performed product liability and reliability investigations, and has provided litigation support work involving issues of vehicular and work-place accident and injury epidemiology, personal injury mechanisms, human factors engineering and ergonomics, biomechanics and physiology, and safety engineering.

FORCON TO EXHIBIT AT RIMS

FORCON will be an exhibitor at the Risk and Insurance Managers Society's (RIMS) 37th Annual Conference and Exhibition in Dallas, Texas, April 11 through April 16, 1999.

If you will be attending RIMS this year, please stop by booth No. 2834 and say hello.

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Steve Chewning will be presenting ***"Accident Reconstruction and the Importance of Physical Evidence"*** Seminars to the Insurance Claims and Defense Industries Located in Nashville, TN. (End of April) and Jacksonville, FL (End of May). Special Notices will be sent to those located around the seminar areas.

For addition information, please contact Bob Dwyre at 1-800-436-7266

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