

Distribution of Belt Anchorage Locations in the Second Row of Passenger Cars and Light Trucks

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ABSTRACT

Seat belt anchorage locations have a strong effect on occupant protection. Federal Motor Vehicle Safety Standard (FMVSS) 210 specifies requirements for the layout of the anchorages relative to the seating reference point and seat back angle established by the SAE J826 H-point manikin. Sled testing and computational simulation has established that belt anchorage locations have a strong effect on occupant kinematics, particularly for child occupants using the belt as their primary restraint. As part of a larger study of vehicle geometry, the locations of the anchorage points in the second-row, outboard seating positions of 83 passenger cars and light trucks with a median model year of 2005 were measured. The lower anchorage locations spanned the entire range of lap belt angles permissible under FMVSS 210 and the upper anchorages (D-ring locations) were distributed widely as well. Combined with the findings from concurrent research on the effects of belt geometry, these results suggest that occupant kinematics in frontal impact can be expected to differ widely across vehicles due to differences in belt geometry.

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INTRODUCTION

In the United States, the locations of the anchorages of seat belt systems are regulated by Federal Motor Vehicle Safety Standard (FMVSS) 210. Anchorage locations are referenced to the seating reference point (SgRP), which is measured using the SAE J826 H-point manikin. The H-point manikin torso line is also interpreted as the seat back angle for purposes of FMVSS 210. In vehicle design, a two-dimensional template representing the profile of the J826 H-point machine is often used. This template, which is depicted schematically FMVSS 210, is used to define the upper anchorage location range. Lap belt anchorages must be positioned such that a vector from the anchorage to the SgRP in side view forms an angle of between 30 and 75 degrees with the horizontal. Upper anchorages must be located within a side-view zone defined with respect to the SAE J826 two-dimensional template with the template H-point aligned with the SgRP.

Recent work at the University of Michigan Transportation Research Institute (UMTRI) has demonstrated that belt anchorage locations have a strong effect on occupant kinematics [1,4,5]. More-rearward or higher lower

anchorages (flatter lap belt angles) tend to reduce lower-body excursion, except when submarining occurs due to the belt slipping off the pelvis and into the abdomen. More-forward and higher upper anchorage locations tend to increase head excursion, except when submarining occurs.

As part of a broader effort to improve the protection of child passengers who use the belt for primary restraint, UMTRI has undertaken a series of studies that have included measurements of the rear-seat environment, with a focus on the second row [3, 11]. Second-row seat cushions are much longer than the typical thigh lengths of children younger than 12 years. Long seats are associated with slouching, more-forward hip locations, and poorer belt fit [7, 13].

The current analysis examines the locations of belt anchorages in second-row, outboard seating positions. As part of several vehicle-measurement projects, the seating environment in the second rows of 84 vehicles was measured. The belt-anchorage locations are compared with the FMVSS 210 criteria.

METHODS

The anchorage locations of the driver-side, second-row passenger positions of a convenience sample of eighty-three passenger vehicles with rear seats were measured between 2007-2011. The sample consisted of 57 passenger cars, 17 SUVs, 6 minivans, and 3 pickup trucks, of which sixty-six were model year 2000 or newer, and 8 were model year 1995 or older. A complete list of the vehicles is in [Appendix A](#).



Figure 1. CMM (FARO Arm) attached to a vehicle.



Figure 2. Using CMM to measure seat H-point.

The SAE J826 machine was installed in the rear seat position and the location of the H-point was recorded with a portable coordinate measurement machine (CMM) (FARO Arm, FARO Technologies, Lake Mary, FL) as shown in [Figures 1](#) and [2](#). The locations of safety belt anchorages, reference points on the seat frame, and other aspects of the vehicles geometry were also recorded. If the seat was adjustable, the back angle (H-point manikin torso angle) was set to 23 degrees and the seat travel set to the most rearward location on the seat track.

Measuring Anchorage Locations

The CMM was used to measure the locations of the three belt anchorages. The lower anchorages were measured two ways: at the bolt attached to the frame and at the point where the belt attaches to the anchorage assembly. The latter of the two corresponds best with the definition in FMVSS 210 of the “nearest contact point of the belt with the anchorage.” In cases where only the bolt was measured, the pivot point was calculated as 20 mm forward of the bolt, based on the average of measurements of belt-mounting hardware on other vehicles.

In cases where the upper anchorage consisted of a D-ring that was attached to the vehicle frame with a bolt around which the D-ring pivoted, the upper anchorage location was measured at the center of the bolt, as shown in [Figure 3](#). If the upper anchorage was not a D-ring (as in cases where the upper belt exits the pillar, seat or trim through a piece of plastic or over a metal bar) and the anchorage point was not accessible, the center of the exit point was considered the pivot/anchorage point, as shown in [Figure 4](#). Adjustable upper anchorages were measured at the midpoint of the adjustment range, which is the setting specified in FMVSS 210.

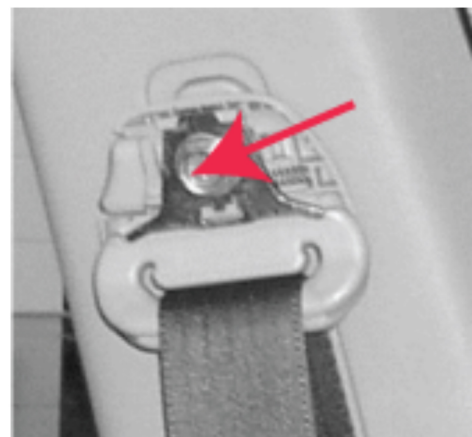


Figure 3. Point recorded on upper anchorages that were mounted with a pivoting D-ring.



Figure 5. Point recorded on upper anchorages that were not on a pivoting D-ring or did not have an accessible bolt

RESULTS

Figures 6, 7, 8, 9 and Tables 1 and 2 show the measured belt anchorage locations relative to SgRP and the FMVSS 210 zones. The lower anchorage locations spanned the entire allowable range of side-view angles. Upper anchorage locations also spanned a wide range, reflecting the wide variety of upper belt anchorage configurations, including those mounted in the C-pillar, package shelf, and integrated into the seat. Inboard (buckle-side) lower anchorages had slightly steeper (higher) lap belt angles, and the inboard anchorage was generally closer to the occupant centerline than the outboard anchorage.

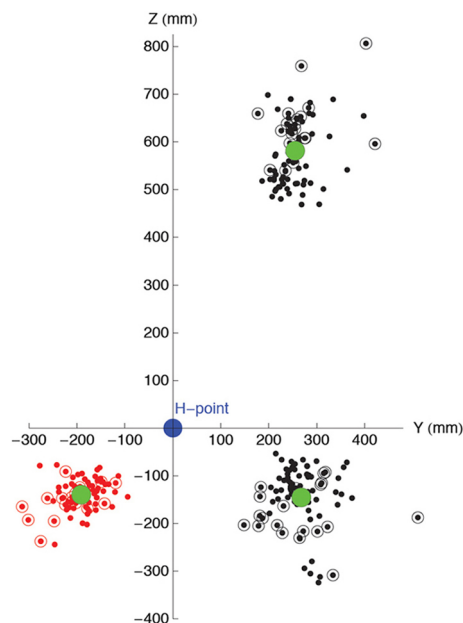


Figure 6. Front view of anchorage locations relative to seat H-point (red =inboard, black =outboard, circled points =trucks, minivans and SUVs, and green circle = mean anchorage location)

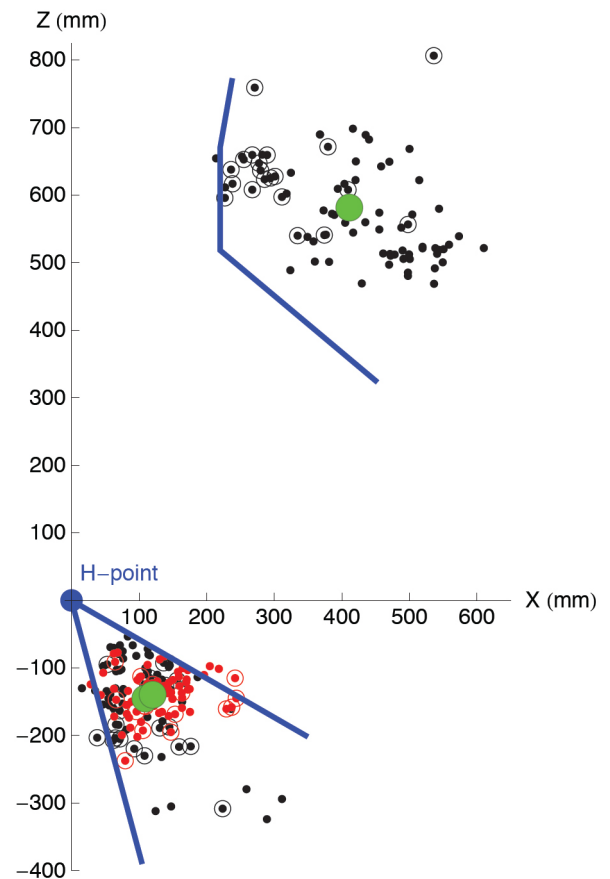


Figure 7. Side view of anchorage locations relative to seat H-point (SgRP) with FMSS 210 acceptable range (seat back angle at 23°) in blue (red =inboard, black =outboard, circled points = trucks, minivans and SUVs, and green circle =mean anchorage location).

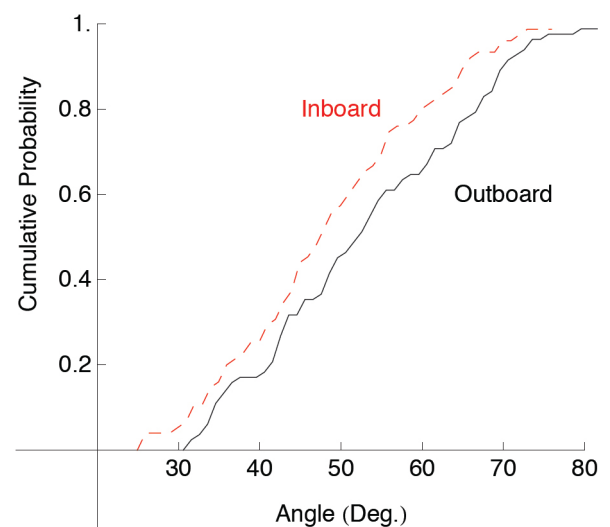


Figure 8. Cumulative probability of the side-view angle from inboard and outboard lower anchorages to H-point.