Certified Advanced 208-Compliant Air Bag Investigation/ Vehicle to Objects
Dynamic Science, Inc. / Case Number: DS06025
2006 Hyundai Elantra
Oregon
September 2006

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The crash investigation process is an inexact science which requires that physical evidence such as skid marks, vehicular damage measurements, and occupant contact points be coupled with the investigator's expert knowledge and experience of vehicle dynamics and occupant kinematics in order to determine the pre-crash, crash, and post-crash movements of involved vehicles and occupants.

Because each crash is a unique sequence of events, generalized conclusions cannot be made concerning the crashworthiness performance of the involved vehicle(s) or their safety systems.

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16. Abstract

This on-site investigation focused on the Certified Advanced 208-Compliant air bag system in a 2006 Hyundai Elantra. This single vehicle crash occurred in September 2006 in a rural area of Oregon, during daylight hours. The crash occurred on the west shoulder of a two lane, two-way state highway.

The 2006 Hyundai Elantra being driven by a restrained 79-year-old male. There were no other occupants in the vehicle. The Elantra was traveling southbound on a rural highway when it departed the right side of the roadway. The front of the Hyundai struck a wooden mailbox post, shearing it from its base. The Hyundai Elantra continued in a southerly direction, traveling further off the roadway. The right front bumper corner struck a large tree trunk, resulting in the deployment of the driver's front air bag. This was a sideswipe-type impact. The tree trunk snagged on the right front axle, ripping the tire from the axle and causing the Hyundai to go into a clockwise rotation. During this rotation, the Elantra's left side impacted another large tree. This impact was not completely horizontal. As the right front axle snagged on the first tree that was struck, the Hyundai rotated sharply and began to tilt to the left. As the vehicle struck the second tree, it tilted further to the left, causing damage to the Elantra's left A pillar, windshield header and roof. According to one of the police investigators, the Hyundai came to final rest between the two trees, facing southwest and angled partially onto its left side. The driver was entrapped post-crash and had to be cut out of the Elantra by fire/rescue personnel. According to a witness who was on-scene moments after the crash, the Elantra's left A pillar had intruded into the passenger compartment and was pressing against the driver's chest, entrapping him between the pillar and the left front seat back. The witness reported that this driver was conscious post-crash, but died before paramedics arrived on-scene. According to a family member, the driver of the Elantra was diabetic and had an unspecified heart condition. One or both of these pre-existing medical conditions may have played a role during the pre-crash phase, but the official cause of death was determined to be "crushing blunt force trauma". The Hyundai was towed due to damage and was later declared a total loss.

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Background

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Figure 1. Front - 2006 Hyundai Elantra

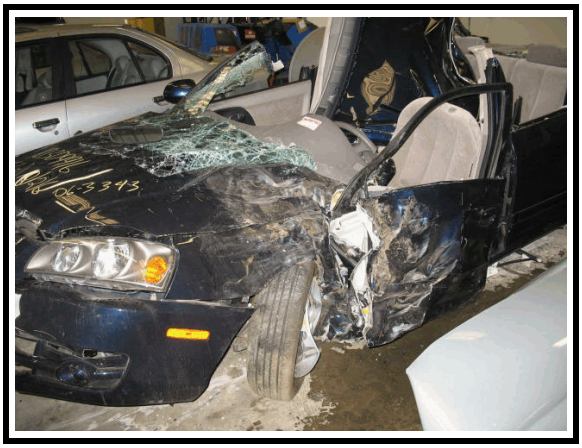

Figure 2. Front/Left - 2006 Hyundai Elantra (LF door repositioned for photo)

This crash was identified by DSI personnel and provided to NHTSA on October 18, 2006. On October 20, 2006, NHTSA requested that the vehicle be inspected. The driver's insurance company granted permission to inspect the Elantra at a salvage yard on November 6, 2006. NHTSA assigned the case to DSI on November 8, 2006. The scene inspection was completed on November 12, 2006 and the vehicle was inspected November 13, 2006. A copy of the police report was obtained on February 8, 2007. The investigating police jurisdiction's on-scene photographs and final reconstruction of this crash were requested, but were not approved for release prior to the submission of this report.

The 2006 Hyundai Elantra being driven by a restrained 79-year-old male. There were no other occupants in the vehicle. The Elantra was traveling southbound on a rural highway when it departed the right side of the roadway. The front of the Elantra struck a wooden mailbox post, shearing it from its base. The Elantra continued in a southerly direction, traveling further off the roadway. The right front bumper corner struck a large tree trunk, resulting in the deployment of the driver's front air bag. This was a sideswipe-type impact. The tree trunk snagged on the right front axle, ripping the tire from the axle and causing the Elantra to go into a clockwise rotation. During this rotation, the Elantra's left side impacted another large tree. This impact was not completely horizontal. As the right front axle snagged on the first tree that was struck, the Elantra rotated sharply and began to tilt to the left. As the vehicle struck the second tree, it tilted further to the left, causing damage to the Elantra's left A pillar, windshield header and roof. According to one of the police investigators, the Elantra came to final rest between the two trees, facing southwest and angled partially onto its left side.

The driver was entrapped post-crash and had to be cut out of the Elantra by fire/rescue personnel. According to a witness who was on-scene moments after the crash, the Elantra's left

A pillar had intruded into the passenger compartment and was pressing against the driver's chest, entrapping him between the pillar and the left front seat back. The witness reported that this driver was conscious post-crash, but died before paramedics arrived on-scene. According to a family member, the driver of the Elantra was diabetic and had an unspecified heart condition. One or both of these pre-existing medical conditions may have played a role during the pre-crash phase, but the official cause of death was determined to be "crushing blunt force trauma".

The Elantra was towed due to damage and was later declared a total loss.

SUMMARY

Crash Site

This single vehicle crash occurred in September 2006 in a rural area of Oregon, during daylight hours. The crash occurred on the west shoulder of a two lane, two-way, undivided state highway. In the pre-crash area, the lanes are divided by a painted, dashed yellow line. In the area just north of the crash location, the center lane divider changes to one solid and one dashed line, denoting a no-passing area for southbound vehicles. There are solid white fog lines separating each travel lane from the asphalt shoulders. Adjacent to the west shoulder is an area of grass and dirt that slopes downward away from the roadway at an approximate -2.7% grade. There were several trees adjacent to this sloped area.

Figure 3. Approach of Hyundai Elantra to crash location (south)

The travel lanes in the driver's pre-crash area were composed of asphalt, were straight and level and were dry at the time of the crash. The posted speed limit was 89 km/h (55 mph).

Pre Crash

The 2006 Hyundai Elantra being driven by a restrained 79-year-old male. There were no other occupants in the vehicle. The driver was traveling south in the southbound lane. The driver may have had a medical incident during the pre-crash phase, which could have caused him to lose control of his vehicle. A family member reported that the driver was diabetic, had an unspecified heart condition and was taking several different types of medication. While traveling southbound, the Elantra crossed over the narrow asphalt shoulder and drifted off the right side of the highway.

Crash

The Elantra's front end (12FZEN1) impacted a wooden mailbox post, shearing it from its base. The side of the post that was struck had a width of 18.0 cm (7.1 in). The impact severity was fairly light and was likely a low delta V event.

After striking the post, the Elantra continued in a southerly direction, traveling further off the roadway. The right front bumper corner (12FREE4) struck a large tree trunk, resulting in the deployment of the driver's front air bag. There was narrow end engagement at the right front bumper corner. During this impact, the tree moved past the bumper corner and between the engine compartment and the right front tire. The tree snagged on the Elantra's right front axle, ripping the tire from the axle and causing the Elantra to rotate clockwise.

The Elantra's left side (11LYAW4) impacted a second tree, causing damage to the left fender, left front door, left A pillar and windshield header. The second tree impact was not completely horizontal. When the Elantra's right front axle snagged on the first tree trunk, the Elantra rotated and began to tilt to the left. As the vehicle struck the second tree, it tilted further to the left, causing damage to the Elantra's left A pillar, windshield header and roof.

Figure 4. Approximate roadway departure point (south)

Figure 5. First struck object (wooden mailbox post replaced with PVC pipe)

Figure 6. Damaged/replaced mailbox post

The Elantra came to final rest between the two trees, facing southwest and angled partially onto its left side.

Post-Crash

The driver was entrapped post-crash and had to be extricated by fire/rescue personnel. According to a witness who was on-scene moments after the crash, the Elantra's left A pillar had intruded into the passenger compartment and was pressing against the driver's chest, entrapping him between the pillar and the left front seat back. The witness reported that this driver was conscious post-crash, but died before paramedics arrived on-scene. According to the police report, paramedics arrived on-scene approximately five minutes after the crash.

The Hyundai Elantra was towed due to damage and was later declared a total loss.

Figure 7. Vehicle continues southbound off the roadway

Figure 8. Trees struck by the Elantra (south)

Vehicle Data - 2006 Hyundai Elantra

The 2006 Hyundai Elantra was identified by the Vehicle Identification Number (VIN): KMHDN46D36Uxxxxxx. The vehicle's digital odometer could not be read as the vehicle had no power. The Elantra was a four-door, front wheel drive sedan with seating for five. It was equipped with a 2.0 liter 4-cylinder engine, 4 speed automatic transmission, two disc brakes and a tilt steering wheel.

The Hyundai was equipped with advanced occupant protection systems including multi-stage Certified Advanced 208-Compliant driver and front right passenger air bags with occupant sensors intelligent. The multi-stage air bags were certified by the manufacturer to meet the advanced air bag requirements of Federal Motor Vehicle Safety Standard (FMVSS) No. 208. This vehicle was also equipped with dual front seat belt pretensioners and front row seat back mounted side air bags.

The 2006 Hyundai Elantra was equipped with Michelin Energy P195/60R15 tires. The recommended cold tire pressure was 207 kPa (30 psi) for the front and rear. The specific tire information is as follows:

Position	Measured Pressure	Measured Tread Depth	Restricted	Damage
LF	Flat	6 mm (8/32 in)	Yes	Tire debeaded; dented rim
LR	186 kPa (27 psi)	7 mm (9/32 in)	No	None
RR	207 kPa (30 psi)	7 mm (9/32 in)	No	None
RF	Flat	6 mm (8/32 in)	No	Tire debeaded & torn from axle

Figure 9. LF tire damage

Figure 10. RF tire damage

The front row seating in the 2006 Hyundai Elantra was configured with dual fabric covered bucket seats. The seats were equipped with adjustable head restraints. The driver's head restraint was missing and could not be found anywhere in the vehicle. The right front head restraint was not damaged during the crash, but the roof that had been cut off by fire/rescue personnel was found partially laying on top of it, leaving an indentation. The second row was configured as a fabric covered 60/40 bench seat with folding backs. The two outboard second row seating positions were equipped with adjustable head restraints that were not damaged.

The second row outboard seating positions were equipped with the lower anchor points that are part of this vehicle's Lower Anchors and Tethers for Children (LATCH) system. All three second row seating positions were equipped with child safety seat top tether anchor points, located on the rear shelf behind the second row seat backs.

Vehicle Damage - 2006 Hyundai Elantra

Exterior Damage

The 2006 Hyundai Elantra sustained light front damage as a result of the impact with the mailbox post. The Elantra sustained 28.0 cm (11.0 in) of direct damage beginning 20.0 cm (7.9 in) right of the pre-crash center point of the vehicle, extending along the front bumper to the right.

Figure 11. Front crush profile

The Elantra sustained moderate front end damage as a result of the impact with the first tree. There was 4.0 cm (1.6 in) of direct damage beginning 61.0 cm (24.0 in) right of the pre-crash center point of the vehicle, extending along the front bumper to the right. The tree narrowly engaged the front right bumper corner and swiped down the right side of the vehicle, leaving 91.0 cm (35.8 in) of direct damage. The tree impacted the right front tire, breaking it off the axle and debeading it. Six crush measurements were documented along the front bumper as follows: C1=20.0 cm (7.9 in), C2=18.0 cm (7.1 in), C3=11.0 cm (4.3 in), C4=15.0 cm (5.9 in), C5=23.0 cm (9.1 in), C6=8.0 cm (3.1 in). Measurements at C5 and C6 were adjusted to account for a missing section of the bumper cover and energy absorbing material.

The Collision Deformation Classification (CDC) for the impact with the mailbox post was 12FZEN1. The CDC for the front impact with the first tree was 12FREE4.

The Hyundai Elantra sustained moderate left side damage as a result of the impact with the second tree. There was 151.0 cm (59.4 in) of direct damage beginning 122.0 cm (48.0 in) forward of the left rear axle, extending forward along the left side of the vehicle. The left front tire was restricted, debeaded and the rim was damaged. The left wheelbase was shortened by 32.0 cm (12.6 in).

Figure 12. Left fender, hood and tire damage from the second tree impact

This impact appears to have occurred while the Elantra was partially tilted to its left. When the first tree impact ripped the front right tire from the axle, the snag caused the Elantra to rotate sharply clockwise and tilt left. This crash event resulted in direct damage to the left fender, left front door panel, left A pillar and windshield header. The contact between the tree and the area of the Elantra located above the belt line resulted in significant longitudinal and lateral passenger compartment intrusion. The contact between the tree and the Elantra's left windshield header and roof resulted in rippled sheet metal damage to a significant area of the roof. The left front door was jammed shut due to damage and was cut off by rescue personnel. The location of maximum lateral crush was located 209.0 cm (82.3 in) forward of the left rear axle. There was 23.0 cm (9.1 in) of lateral crush in this location. The CDC for this event was 11LYAW4.

CDC (Impact 1):	12FZEN1	
(Impact 2):	12FREE4	
(Impact 3):	11LYAW4	
Delta V (Impact 2) :	Total	22.0 km/h (13.7 mph)
	Longitudinal	-22.0 km/h (-13.7 mph)
	Latitudinal	0.0 km/h (0.0 mph)
	Energy	31,759 Joules (23,424 ft lb)

Figure 13. LF door damage (door cut off vehicle by rescue personnel)

Figure 14. Roof damage (cut off by rescue personnel)

Interior Damage - 2006 Hyundai Elantra

The 2006 Hyundai Elantra sustained moderate interior damage due to occupant contact, intrusion and normal air bag deployment related damage.

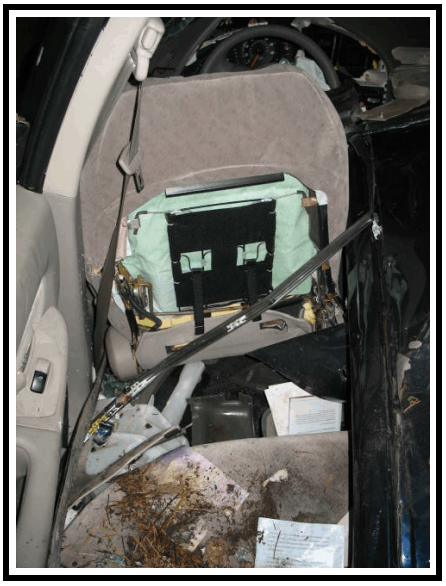

Figure 15. Driver's seat as found

Several areas of the passenger compartment were damaged post-crash by occupant extrication efforts. The Elantra's roof and left front door were cut off and were found laying on the front and rear seating areas at the time of the inspection.

The driver's seat back locks were cut by rescue personnel, presumably to assist in extricating the deceased driver. The driver's seat back and seat cushion were angled slightly to the left, giving the appearance of lateral intrusion of the left B pillar. It appeared that the driver's seat had been moved out of position during the driver's extrication.

There was quite a bit of dirt and other scene debris found in the vehicle, which was a result of on-scene post-crash clean-up activities. The majority of the debris was found on the second row seat cushions.

There were visible stress marks on the lower left instrument panel. The driver's seat belt webbing and D ring exhibited signs of occupant loading. The bottom half of the steering wheel had been cut off by rescue personnel. The steering wheel rim was not deformed due to damage or occupant contact.

Figure 16. Driver's right seat back folding lock (cut by rescue personnel)

Figure 17. Bottom section of steering wheel cut off by rescue personnel

It is likely that the left front window glazing disintegrated and the windshield was damaged during the third impact, but because the roof was cut off by rescue personnel, the extent of the Elantra's glazing integrity loss is unknown. The Elantra's left front, left rear and right front doors were all jammed shut post crash. The left front door had been removed from the vehicle by rescue personnel. The right rear door remained closed and operational.

There were multiple intrusions into the passenger compartment. The most significant intrusion involved the driver's area. Because the roof and left front door had been removed during the driver's extrication, some of the intrusions had to be estimated. The glove compartment door was forced open as a result of right side intrusion. The specific passenger compartment intrusions were documented as follows:

Row/Position	Intruded Component	Magnitude of Intrusion	Direction
1L	A Pillar	23.0 cm (9.1 in)	Longitudinal
1L	Roof	22.0 cm (8.7 in)	Vertical
1L	LF door panel	18.0 cm (7.1 in)	Lateral
1L	Instrument panel	16.0 cm (6.3 in)	Lateral
1L	Instrument panel	14.0 cm (5.5 in)	Longitudinal
1L	Side panel (forward of the A pillar)	13.0 cm (5.1 in)	Lateral
1L	A Pillar	12.0 cm (4.7 in)	Lateral
1L	Steering column	12.0 cm (4.7 in)	Longitudinal
1L	Windshield header	8.0 cm (3.1 in)	Longitudinal
1L	Plastic sill cover	4.0 cm (1.6 in)	Lateral
1R	Glove compartment door	7.0 cm (2.8 in)	Longitudinal
1R	A Pillar	4.0 cm (1.6 in)	Lateral
1R	Side panel (forward of the A pillar)	4.0 cm (1.6 in)	Lateral
1R	Plastic sill cover	4.0 cm (1.6 in)	Lateral
1R	Toe pan	4.0 cm (1.6 in)	Lateral

Figure 18. Left front door panel damage/intrusion (door cut off by rescue personnel)

Figure 19. Intrusion/damage in RF seating area

Manual Restraint Systems - 2006 Hyundai Elantra

The 2006 Hyundai Elantra was configured with manual 3-point lap and shoulder belts for each of the five seating positions. The front row seat belts were equipped with retractor pretensioners; at the time of the inspection, neither retractor was found to be locked in place. The driver's safety belt was configured with a sliding latch plate and an emergency locking retractor (ELR). There was evidence of occupant loading to the driver's seat belt webbing near the latchplate and also on the D-ring.

The right front seat belt had a sliding latch plate and a switchable ELR/automatic locking retractor (ALR). All three second row safety belts had sliding latch plates and switchable ELR/ALR retractors.

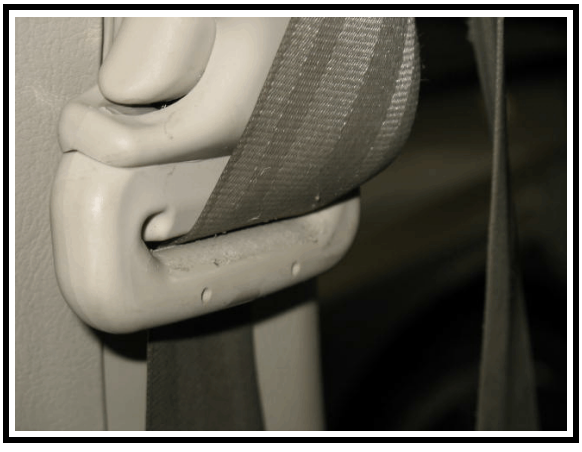

Figure 20. Evidence of occupant loading to driver's D-ring

Figure 21. Driver's seat belt (evidence of occupant loading at the D-ring and near the latch plate)

Supplemental Restraint Systems - 2006 Hyundai Elantra

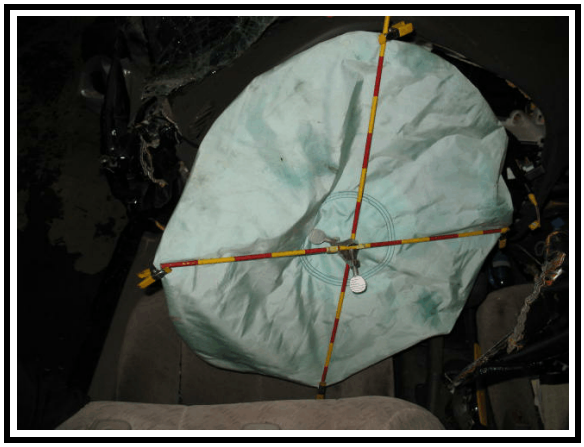

Figure 22. Deployed driver front air bag

The 2006 Hyundai Elantra was equipped with advanced occupant protection systems. These systems include the multi-stage Certified Advanced 208-Compliant driver and front right passenger air bags. This system uses sensors to gather information that helps to control the front air bag deployment(s) based on the driver and front right passenger seat track positions, seat belt usage and impact severity. According to the vehicle manufacturer, the first stage deployment level is provided for moderate severity impacts and a second stage level deployment in the case of more severe impacts. The Hyundai's Occupant Classification System (OCS) uses sensors that are designed to detect the presence of a properly seated, adult occupant and determine whether or not to prevent or allow the deployment of the front right air bag and the front right seat back mounted side impact air bag. There is a "Passenger Air Bag Off" indicator light located on the center instrument panel which is illuminated when the available passenger air bags have been deactivated by the OCS. The driver's front and side impact air bags are not controlled by the OCS.

The driver and front right passenger positions are also equipped with seat belt retractor pretensioners. Neither front row belt retractor was locked in place at the time of the inspection.

Figure 23. Location of the driver's seat back mounted side air bag (nondeployed)

The driver's front air bag was mounted in the center of the steering wheel hub. The air bag module cover flaps had a backwards C configuration. Both the left and right flaps measured 7.0 cm (2.8 in) wide at the top and bottom edges and were 12.0 cm (4.7 in) high along the outer edges. The inner section of each flap consisted of a 7.0 cm (2.8 in) circular section, with two 3.0 cm (1.2 in) high straight sections above and below it. The air bag was circular in shape and measured 60.0 cm (23.6 in) high/wide in its deflated state. The maximum excursion measured 25.0 cm (9.8 in) from the module face. The distance between the module face and the front left seat back was 40.0 cm (15.7 in). The air bag had two internal tethers. There were two circular vent ports on the back of the bag at the 10 and 2 o'clock positions. There was no damage to the air bag or cover flaps, but the front and back of the deployed bag were dirty due to scene and vehicle debris that had been placed in the left front seating area after the crash.

The front right passenger air bag was located in the upper right section of the instrument panel. There was no occupant seated in this position. The front air bag was suppressed by the OCS and did not deploy.

This vehicle was also equipped with front row seat back mounted side air bags. They did not deploy during the crash.

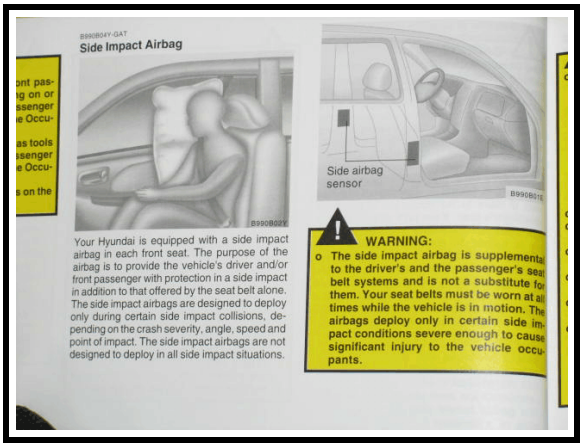

Figure 24. Side impact air bag information from the vehicle owner's manual

Occupant Demographics - 2006 Hyundai Elantra

	Driver
Age/Sex:	79/Male
Seated Position:	Front left
Seat Type:	Fabric covered bucket seat
Height:	Unknown
Weight:	Unknown
Occupation:	Retired
Pre-existing Medical Condition:	Unspecified heart condition Diabetic
Alcohol/Drug Involvement:	No alcohol or drugs found in system (blood test)
Driving Experience:	Presumed to be over 10 years
Body Posture:	Presumed to be sitting generally upright, forward facing
Hand Position:	Unknown
Foot Position:	Presumed to be on floorboards and/or foot controls
Restraint Usage:	3-point manual lap and shoulder belt available - used
Air bag:	Front air bag available - deployed Seat back mounted side air bag available - nondeployed

Occupant Injuries - 2006 Hyundai Elantra

Driver: Injuries obtained from medical examiner's report. According to the brief report, there was no autopsy.

Injury	OIC Code	Injury Mechanism	Confidence Level
Blunt force trauma, chest - NFS	415999.7,0	Left A pillar	Probable
Blunt force trauma, head - NFS	115999.7,0	Front header	Probable

Occupant Kinematics - 2006 Hyundai Elantra

Driver Kinematics

The 79-year-old male driver of the Hyundai Elantra was likely seated in a generally upright posture in the fabric covered bucket seat and was restrained by the available 3-point manual lap and shoulder belt. His seat was adjusted to the fully rearward track position and his shoulder belt anchorage adjustment was set to the full up position. At the time of the vehicle inspection, the driver's seat back was reclined 13 degrees from vertical and the seat bottom was 10 degrees from horizontal.

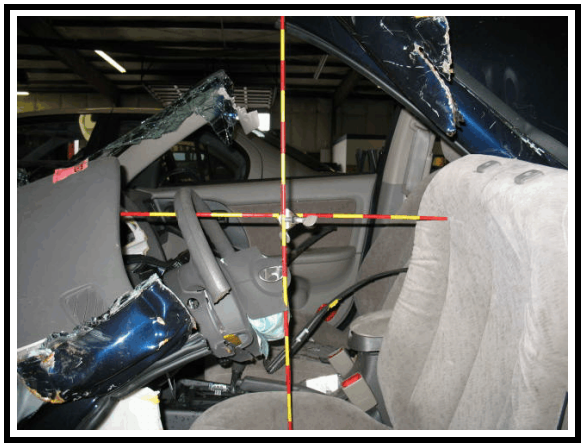

Figure 25. Driver's area; post-crash distance between the steering wheel and the driver's seat back

According to a family member, the driver had an unspecified heart condition and was diabetic. He was taking several medications for these conditions, but the type and amounts are not known. It is possible that the driver may have had a medical problem during the pre-crash phase, causing him to lose control of his vehicle.

While traveling southbound on a straight section of roadway, the Elantra began to drift off the right side of the highway. The front of the vehicle impacted a wooden mailbox post, shearing it from its base. Although this was a low delta V event, the male driver initiated a slightly forward trajectory towards the 12 o'clock direction of force.

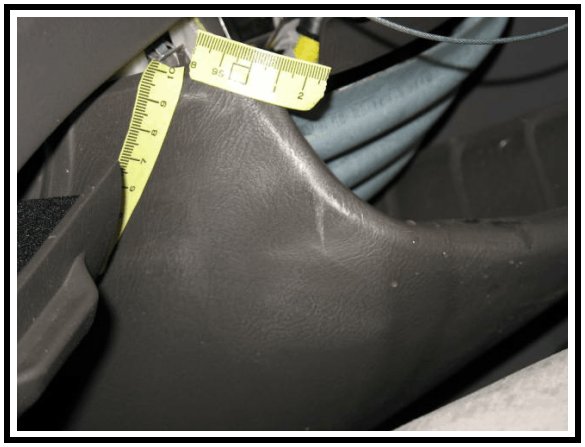

Figure 26. Occupant contact to lower steering column

After this impact, the vehicle continued traveling off the roadway and continued south towards a grouping of trees. The front right of the Elantra struck the first tree, resulting in the deployment of the driver's front air bag. The male driver initiated a forward trajectory towards the 12 o'clock direction of force. He loaded the safety belt and may have engaged the deployed front air bag with his face and head, although there were no direct indications of occupant contact.

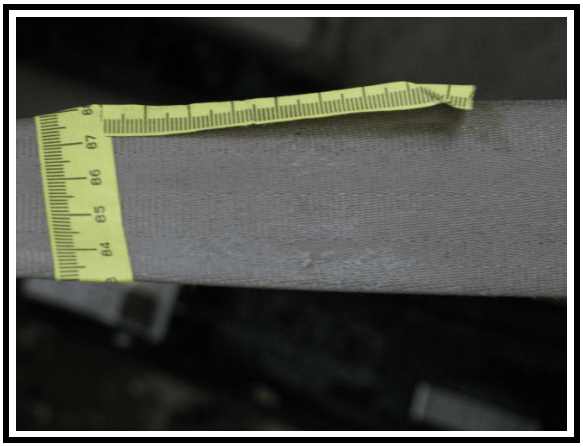

Figure 27. Close-up of occupant loading evidence on the driver's seat belt webbing

During this impact, there was narrow end engagement at the right front bumper corner and the vehicle sideswiped the tree trunk. The trunk snagged on the Elantra's right front tire, ripping the tire from the axle and sending the Elantra into a clockwise rotation. During this snag and rotation, the driver jerked abruptly forward and then pitched rearward and to his left. The Hyundai Elantra then impacted a second tree with its left side, causing the driver to pitch forward and to the left. The Elantra tipped slightly upward and to the left, resulting in contact to the Elantra's left A pillar and windshield header. As a result of this impact, the left A pillar, windshield header, roof and left instrument panel intruded into the driver's seating area. The driver's trajectory during this event, as well as the intruding instrument panel, caused the driver's left knee to contact the lower steering column, leaving evidence of occupant contact.

The Elantra came to final rest between the two trees, facing southwest and angled partially onto its left side. According to a witness who was on-scene just moments after the crash, the driver was entrapped by the intruding A pillar and was pinned between the pillar and his seat back. The witness reported that the driver was conscious and still breathing, but died before paramedics arrived.

There was no autopsy performed, but the medical examiner's report concluded that the official cause of death was due to "crushing blunt force trauma". Multiple attempts were made in order to obtain more information regarding the driver's injuries as well as how he was positioned in the vehicle post-crash. One of the investigating officers was able to disclose that the "crushing blunt force trauma" was to the driver's chest and head, but no other details were available. The investigating police jurisdiction's on-scene photographs and final reconstruction report were requested, but neither were approved for release prior to the submission of this report.

Attachment 1. Scene Diagram