Insurance Institute for Highway Safety
Crashworthiness Evaluation

Crash Test Report
1998 Volkswagen New Beetle (CF98009)

Vehicle identification number: 3VWBB61C3WM005467
Body style: Small two-door hatchback
Engine/transmission: Transverse 2.0-liter 4-cylinder, 5-speed manual, front-wheel drive

Standard crashworthiness features:

Driver and right front passenger front airbags
Driver and right front passenger seat-mounted side airbags
Dual-locking shoulder belts (front and rear outboard seating positions)
Shoulder belt upper anchorage height adjusters (front seating positions only)
Seat belt pretensioners (pyrotechnic, front seating positions only)
Seat belt force-limiting mechanisms (front seating positions only)
Right front and both rear shoulder belt retractors are convertible from emergency to automatic locking for ease of child restraint use
Rear seat head restraints (outboard seating positions)

Other standard safety features:

Daytime running lamps

Optional safety features:

Four-wheel antilock brakes

Vehicle specifications (provided by manufacturer):

Wheelbase:	251 cm
Overall length:	409 cm
Overall width:	172 cm
Curb weight:	1,246 kg

Vehicle specifications (measured):

Front bumper to firewall:	105 cm
Curb weight:	1,254 kg
Test weight:	1,378 kg
Overall width:	173 cm

Nominal test parameters:

40.0 mi/h (64.4 km/h), 40 percent overlap, deformable barrier face with slotted bumper

Crash test date:

April 15, 1998

Figure 1
Precrash and Postcrash Side Views — 1998 Volkswagen New Beetle

Summary

A 1998 Volkswagen New Beetle was crash tested on April 15, 1998 into a fixed deformable barrier at 39.9 mi/h (64.2 km/h) and a 41 percent overlap on the driver side. A Hybrid III 50th percentile male dummy was positioned in the driver seat with the lap/shoulder belt fastened.

Measures of intrusion taken after the crash indicate the lower instrument panel in front of the dummy moved rearward 1-2 cm. Resultant intrusion in the driver footwell measured 9 cm at the footrest and 3-11 cm at other places on the toepan. Both doors remained closed during the crash. After the crash, the driver door required tools to open, but the passenger door opened with ease.

The driver dummy was restrained by a three-point lap/shoulder belt and an airbag. During the crash, the belt pretensioner activated and retracted 6 cm of shoulder belt webbing. A net amount of 14 cm of webbing (or a total of 20 cm including the pretensioned length) spooled off the retractor, including about 9 cm from the force-limiting mechanism. Approximately 3 cm of slack webbing was added to the lap belt due to deformation of the steel rod at the lower outboard anchorage. The dummy's head contacted the steering wheel through the airbag and then rebounded against the head restraint. After the crash, the upper end of the steering column had moved upward 3 cm and forward 2 cm.

The dummy's head experienced a maximum resultant head acceleration of 85 g when it contacted the steering wheel through the airbag.

Test Conditions

This test was conducted according to the procedures specified in the IIHS Offset Barrier Crash Test Protocol (Version IV). The Hybrid III dummy positioned in the driver seat was equipped with instrumented lower legs that included feet modified to include two accelerometers and to have a 45 degree dorsiflexion range with soft stops at all extremes of foot-ankle motion. All dummy seating parameters were set according to the procedures specified for Federal Motor Vehicle Safety Standard 208 compliance testing (49 *CFR* Part 571.208 § 11). The dummy's left foot was placed on the footrest.

Seat back, shoulder belt upper anchorage, and steering column adjustments were set according to the manufacturer's specifications for government crash testing. Other adjustments were set according to the procedure specified for Federal Motor Vehicle Safety Standard 208 compliance testing (49 *CFR* Part 571.208 § 7 and 8). After final positioning of the dummy, measurements from various parts of the dummy to a number of vehicle interior points were made. These measurements and the seat back, shoulder belt upper anchorage, and steering column adjustments are described in the Appendix, Dummy Clearance Measurements.

Vehicle acceleration measurements were made by a triaxial arrangement of accelerometers mounted on the vehicle's longitudinal centerline and 66 cm behind its center of gravity (165 cm behind the front axle). The vehicle speed recorded just prior to impact was 39.9 mi/h (64.2 km/h), and the actual overlap was 41 percent.

Structural Performance

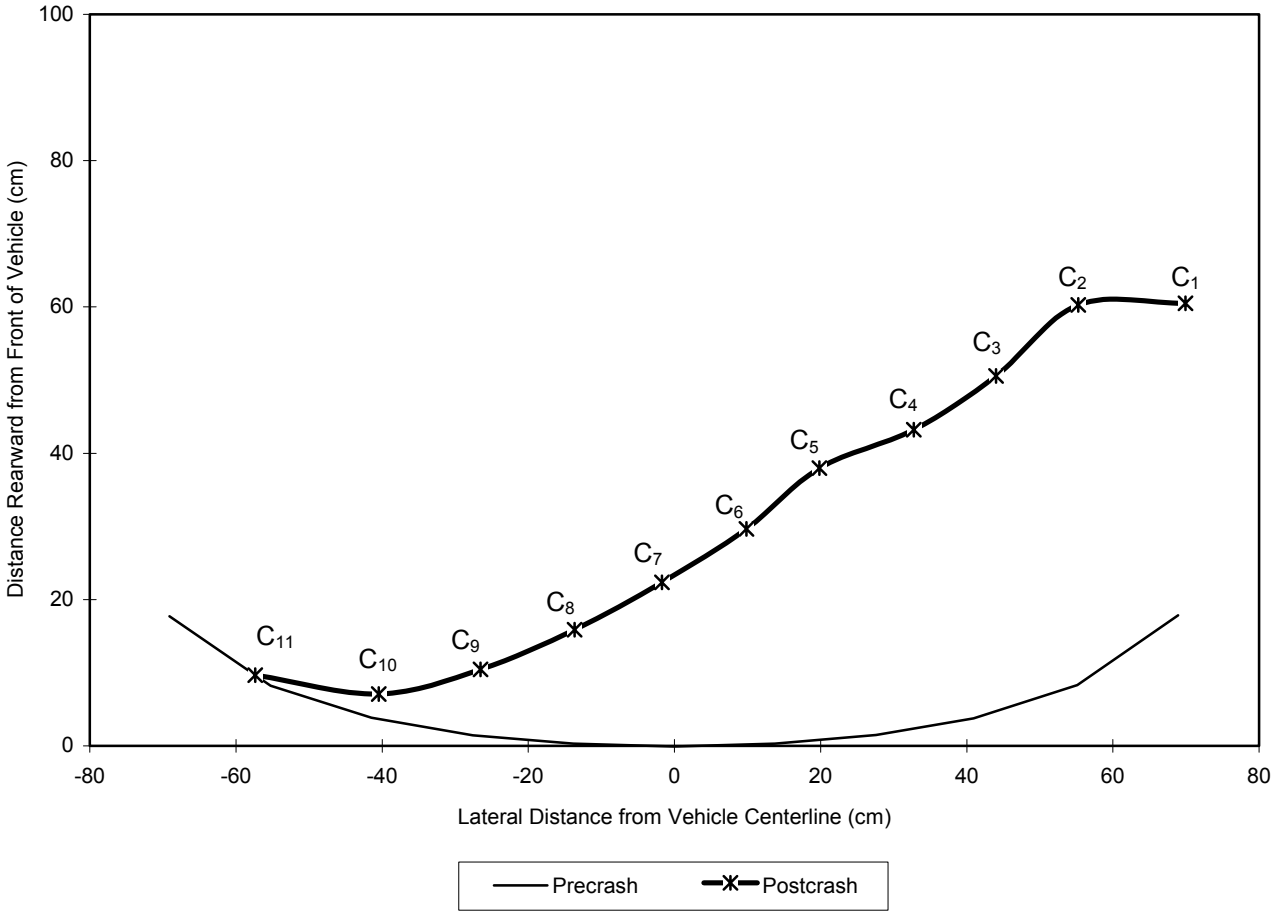
Both doors remained closed during the crash. The driver door aperture shortened 2 cm as measured at the lower edge of the window. After the crash, the driver door required moderate prying with tools to open, but the passenger door opened with ease.

A fuel system leak totaling 76 ml from the fuel line where it connects to the fuel filter outlet was observed in the first 30 minutes following the crash. Subsequent inspection indicated the line had not been fully secured during precrash vehicle preparation (the line had been disconnected at this location to drain the gasoline from the vehicle's fuel system). No additional leakage from any part of the fuel system was observed when the vehicle was rotated onto its right side to allow postcrash photography.

Figure 2 shows the overhead view of the crash deformation. Figure 3 illustrates the precrash and postcrash contour measures of the front bumper cover and the resulting permanent crush. Figure 4 illustrates the corresponding measures of both the front bumper reinforcement bar and the upper crossmember of the radiator support. Figure 5 shows the precrash and postcrash views from below. Figure 6 illustrates the deformation of the side rails, door sills, and engine support, which are visible in Figure 5.

Figure 2
Overhead View of Crash Deformation — 1998 Volkswagen New Beetle

Figure 3
Front Bumper Cover Crush Contour — 1998 Volkswagen New Beetle



	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}
Postcrash Contour (cm)	61	60	51	43	38	30	22	16	10	7	10
Precrash Contour (cm)	18	8	4	1	0	0	0	1	4	8	18
Resulting Crush (cm)	43	52	47	42	38	30	22	15	6	-1	-8

The length of the reference line was 138 cm precrash and 127 cm postcrash.

Figure 4
Front Bumper Bar and Upper Radiator Support Crossmember Crush Contour — 1998 Volkswagen New Beetle

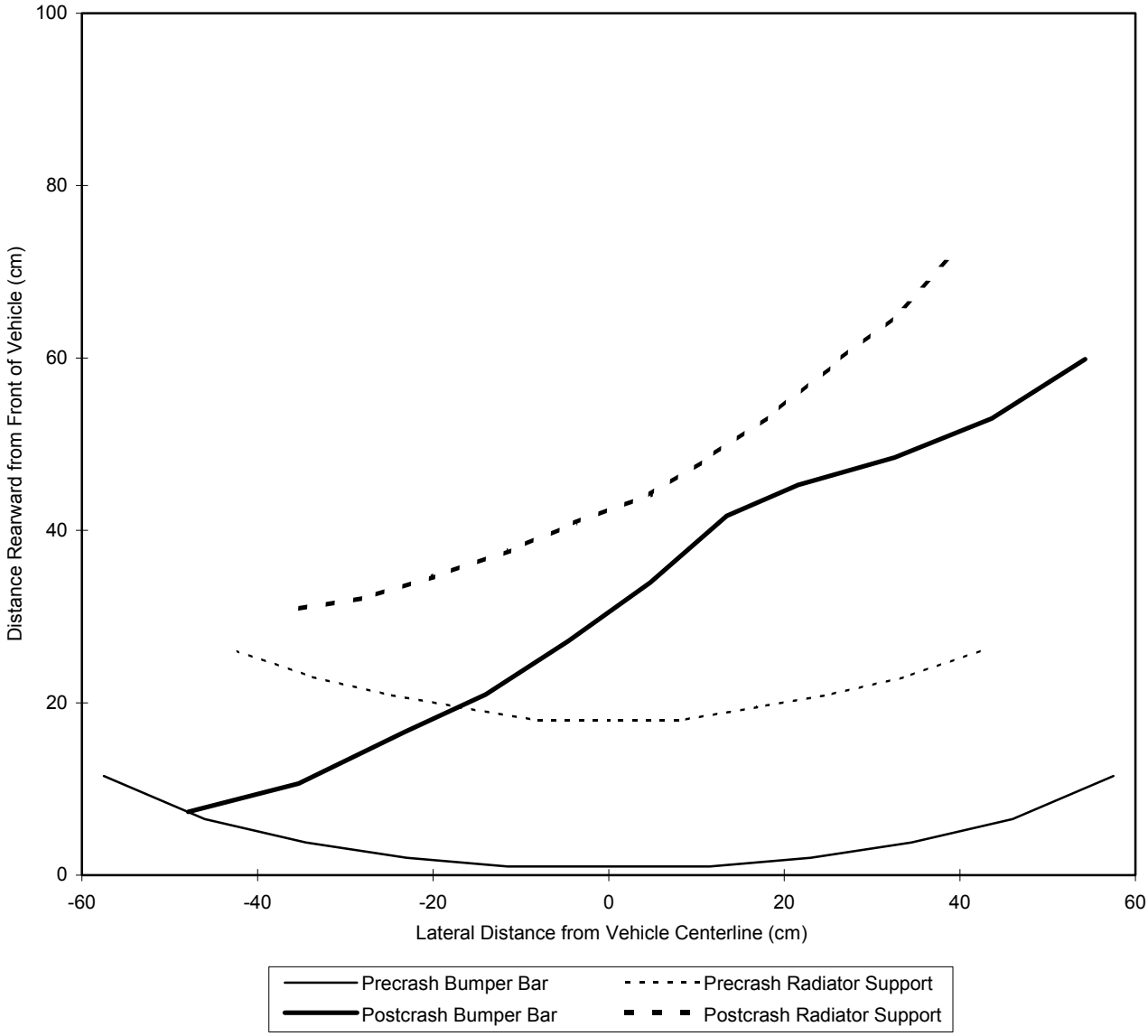
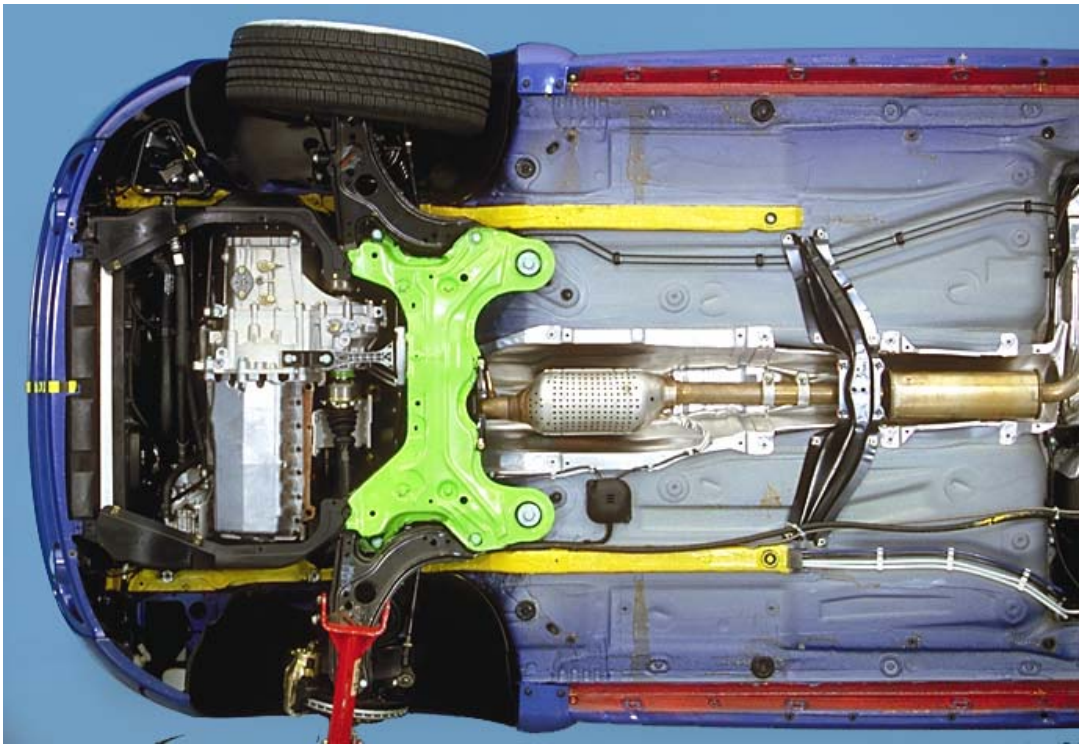


Figure 5
Precrash and Postcrash Views from Below — 1998 Volkswagen New Beetle



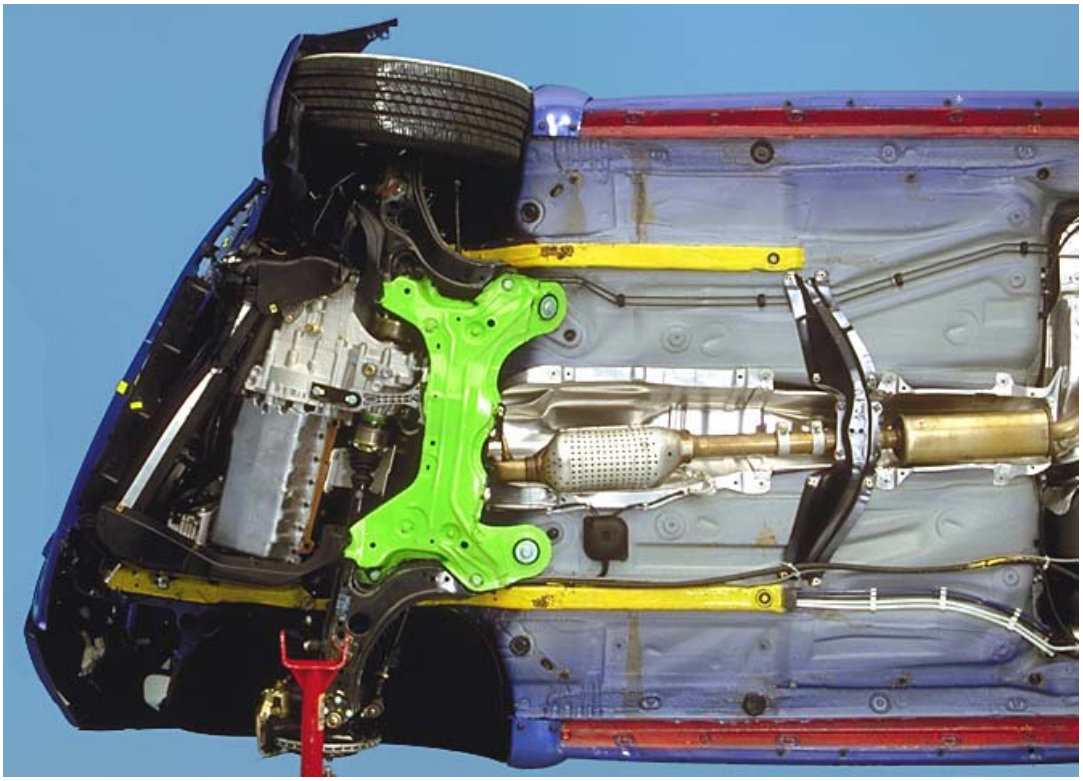
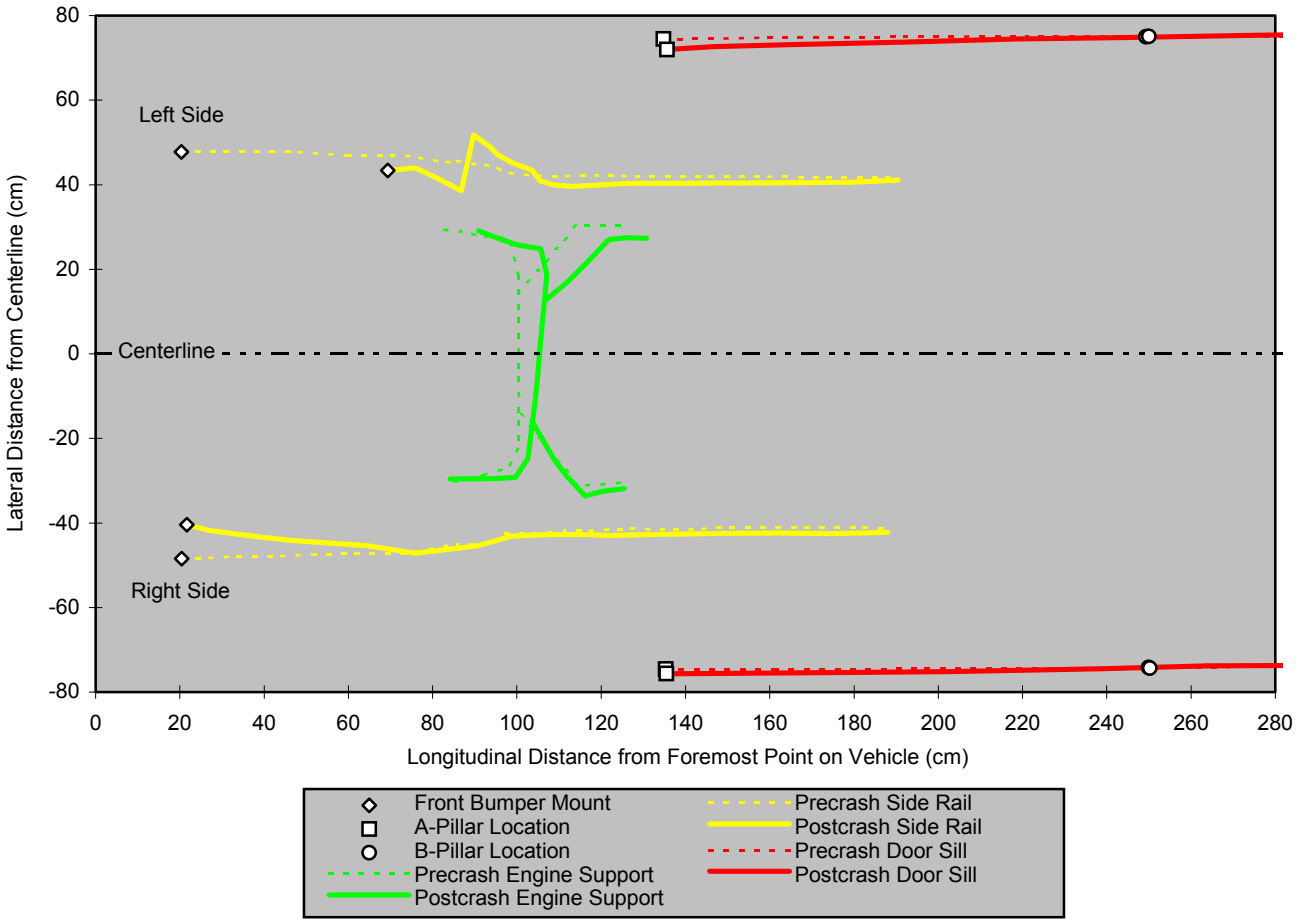
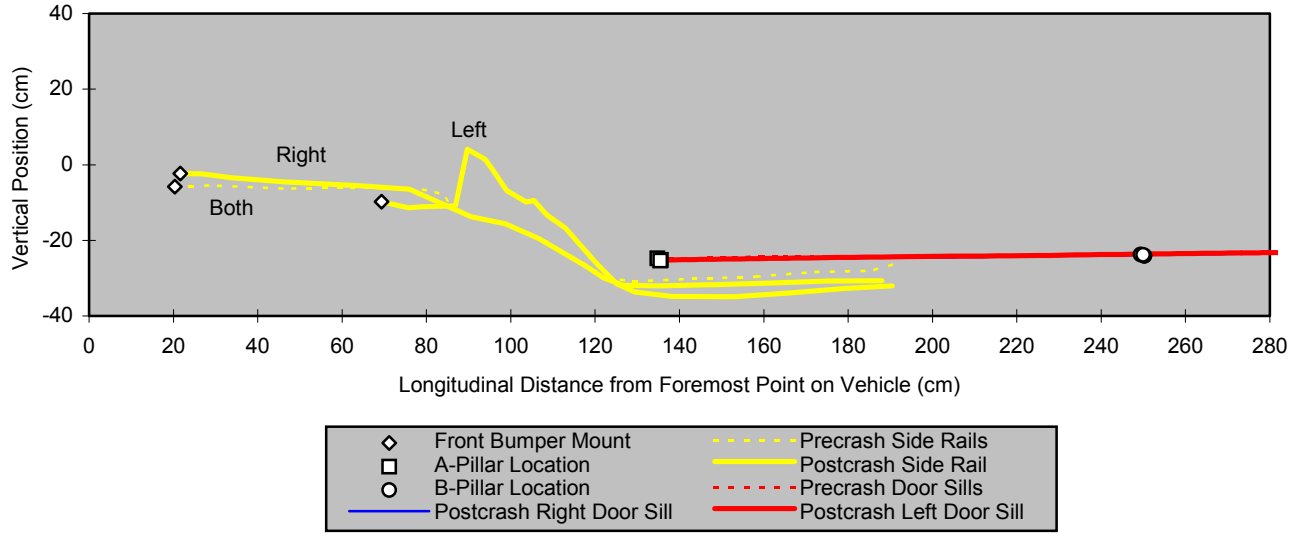


Figure 6
Frame Rail Deformation, Views from Below and Side — 1998 Volkswagen New Beetle





Various measures of intrusion were made after the crash. These residual measures of intrusion typically are less than the maximum deformation that occurs during the crash. The primary coordinate reference system for these measures is described in the IIHS Offset Barrier Crash Test Protocol (Version IV). The measures of deformation shown in Table 1 have been adjusted to better reflect the displacement of the various target locations relative to the driver. This was done by subtracting the average component displacements of the four seat-attachment bolts, which also were measured relative to the primary coordinate system, from the respective components of displacement for each of the target locations. The average displacement of the four seat-attachment bolts relative to the primary reference system also is shown in Table 1.

Table 1
Residual Measurements of Intrusion Relative to Driver Seat — 1998 Volkswagen New Beetle

Selected Locations*	Longitudinal	Lateral	Vertical	Resultant
Steering column (cm)	2	0	3	4
Left lower instrument panel (cm)	-2	-1	1	2
Right lower instrument panel (cm)	-1	-1	0	2
Brake pedal (cm)	-5	-1	-1	5
Left toepan (cm)	-10	-2	3	11
Center toepan (cm)	-6	1	1	6
Right toepan (cm)	-3	0	-1	3
Footrest (cm)	-9	-2	3	9
Average displacement of the four seat-attachment bolts from primary reference system (cm)**	0	0	-1	n/a

* All measurements taken on driver side. From the driver's position, positive is forward, left, and up.
** The front-seat bolt measurements were taken at the bolts that secure the central seat adjustment rail to the floor. The rear-seat bolt measurements were taken at positions along the rear adjustment rails that corresponded to the seat's precrash position.

Restraint System Performance

Airbags

Driver: The uninflated driver airbag was 66 cm in diameter, and the excursion of its center when inflated was limited by three 27 cm-long tethers. The airbag was vented by one 50 mm-diameter hole located on top of the forward-facing surface of the airbag. Analysis of the high-speed film taken from camera positions D and E indicates the airbag deployed at 22 ms into the crash and appeared to be fully inflated at 48 ms. The seat-mounted side airbag did not deploy during the crash.

Passenger: The corner-mounted passenger airbag deployed at angle, and its excursion when inflated was limited by one broad 48 cm-long tether. The cylinder-shaped airbag was vented by two 50 mm-diameter holes located at the lateral ends. The airbag did not contribute to windshield damage during deployment. The seat-mounted side airbag did not deploy during the crash.

Seat Belts

This vehicle is equipped with dual-locking lap/shoulder belts with sliding latch plates and adjustable upper anchorage points at both front seating positions. The front belts also are equipped with pyrotechnic crash pretensioners and mechanical force-limiting mechanisms. The front inboard lower anchorage points are attached to and move with the seats. The webbing at the outboard end of the lap portion of each front belt is sewn around a 27 cm-long steel rod, which is bolted to the sill at the base of B-pillar. This rod permits the belt webbing to be slid out of the way for easier access to the rear seat. During the crash, 6 cm of webbing was pulled by the pretensioner into the retractor through the D-ring, as measured by a pull-string mounted between the webbing and B-pillar trim above the D-ring. A net amount of 14 cm of webbing (or a total of 20 cm including the pretensioned length) was pulled from the retractor through the D-ring, as measured by a second pull-string mounted between the retractor housing and the webbing beyond the retractor. The force-limiting torsion bar within the retractor spool contributed about 9 cm of webbing to the total amount pulled though the D-ring. The steel rod at the lower outboard anchorage bent slightly, adding about 3 cm of slack webbing to the lap belt.

Seat

Postcrash examination of the driver seat rails indicated both the left rear and right rear seat legs moved forward 2 cm along their tracks during the crash. However, there was no observed failure of the central latching mechanism; the latch pin was found secure and in the same position as before the crash. It appears the seat pitched forward with respect to the tracks, deforming and pulling forward slightly the steel seat structure including the rear legs. There was only slight upward deformation of the floor under the driver seat.

Steering Column

The upper end of the steering column moved upward 3 cm and forward 2 cm relative to the driver seat. The portion of the steering column between the instrument panel and firewall uses two tube-in-tube, energy-absorbing segments connected by a universal joint (there is a second universal joint below the lower segment). Following the crash, the upper, larger diameter segment was found compressed 2 cm, but the lower, smaller diameter segment was found unchanged in length. There was no separation of the shear modules on either side of the upper portion of the column.

Dummy Kinematics

Head, Neck, and Torso

Analysis of the high-speed film taken from camera positions D and E indicates the dummy's head began to load the airbag at 54 ms into the crash (6 ms after the airbag was fully inflated). Paint transferred from the dummy's face onto the airbag indicates the nose loaded the airbag directly at its center. As the dummy's head loaded the airbag, the head tilted slightly to the left. Film analysis of the dummy's head and steering wheel movements shows their close proximity at the time head acceleration rapidly increases (101 ms), indicating the dummy's head bottomed out the airbag and contacted the steering wheel underneath. During rebound, the upper rear of the dummy's head contacted the outboard edge of the head restraint at 278 ms. Table 2 provides the timing and duration of these events.

Table 2
Restraint System Performance and Dummy Kinematics —
1998 Volkswagen New Beetle

Event	Time (ms)
Deployment of airbag	22
Airbag fully inflated	48
Head begins to load airbag	54
Head contacts steering wheel through airbag	101
Upper rear of head contacts head restraint	278

Figure 7
Dummy and Vehicle Interior, Postcrash — 1998 Volkswagen New Beetle

Legs and Feet

Left leg and foot: Paint transferred from the dummy's left knee indicates the knee contacted the flat portion of the knee bolster 3 cm above and 2 cm to the right of the left instrument panel intrusion reference point. Paint transferred from the dummy's left shin indicates the shin contacted the bolster below and to the left of the left knee impact location. The left foot was found fully dorsiflexed, slightly everted, and internally rotated about 15 degrees. The back of the heel was resting on the floormat/carpeting behind the footrest. The sole was back from the footrest (not touching it).

Right leg and foot: Paint transferred from the dummy's right knee indicates the knee primarily contacted the right underside portion of the steering column plastic trim, including the tilting and telescoping adjustment lever. There also were some small paint transfer marks on the edge of the knee bolster trim next to the lower right corner of the steering column. Paint transferred from the dummy's right shin indicates the shin contacted the flat part of the bolster directly below the right knee impact location. There also was a small paint transfer mark on the lowermost recessed portion of the bolster. The right foot was found fully dorsiflexed, considerably everted, and externally rotated about 5 degrees. The back of the heel was resting on the floormat/carpeting, and the sole at the ball of the foot was still on the accelerator pedal. The dorsal medial portion of the foot was barely touching the right edge of the brake pedal, and the lateral edge of the sole was against the center console left side trim.

Dummy Injury Measures

Head

The HICs were calculated during an interval that corresponds with the dummy's head excursion into the airbag. The maximum resultant head acceleration (85 g at 106 ms) was recorded shortly after the head contacted the steering wheel through the airbag. Table 3 provides a summary of the maximum head injury measurements recorded during the crash.

Table 3
Head Injury Measurements — 1998 Volkswagen New Beetle

Measure	Published Tolerance Threshold	Result	Time (ms)
Vector resultant acceleration (g)	80	85	106
Vector resultant acceleration — 3 ms clip (g)	80	61	104-107
Head Injury Criterion (HIC)	1000	536	77-113
Head Injury Criterion — 15 ms interval (HIC-15)*	700	354	93-108

* A proposed amendment to the Canadian Motor Vehicle Safety Regulations suggests calculating HIC during a 15 ms interval rather than the 36 ms interval specified by the U.S. standard. The Canadian proposal includes an injury threshold of 700 for front-seat occupants protected by airbags.

Neck

Table 4 provides a summary of the maximum neck injury measurements recorded during the crash.

Table 4
Neck Injury Measurements — 1998 Volkswagen New Beetle

Measure	Published Tolerance Threshold	Result	Time (ms)
A-P shear force (kN)	±3.1*	-1.0	106
Axial compression force (kN)	4.0*	0.2	123
Axial tension force (kN)	3.3*	1.5	98
Flexion bending moment (Nm)	190**	34	160
Extension bending moment (Nm)	57**	29	245

* These values are for instantaneous loading. Neck loads are compared with magnitude-duration injury criteria in Figures A-13 to A-16.

** These published thresholds are recommended injury assessment reference values from Backaitis and Mertz (1994), but significant neck injury may occur at lower bending moments. Mertz and Patrick (1971) report that bending moments of 47 Nm in extension and 88 Nm in flexion would be non-injurious for occupants represented by the Hybrid III 50th percentile adult male dummy.

Chest

Table 5 provides a summary of the maximum chest injury measurements recorded during the crash.

Table 5
Chest Injury Measurements — 1998 Volkswagen New Beetle

Measure	Published Tolerance Threshold	Result	Time (ms)
Vector resultant spine acceleration — 3 ms clip (g)	60	52	101-104
Rib compression (mm)	50	34	98
Viscous criterion (m/s)	1.0	0.2	78

Legs and Feet

Left and right legs and feet: None of the injury measures approached the reference values.

Table 6 provides a summary of the maximum leg and foot injury measurements recorded during the crash.

Table 6 Leg and Foot Measurements — 1998 Volkswagen New Beetle					
Measure	**Published Tolerance Threshold**	**Left**	**Time (ms)**	**Right**	**Time (ms)**
Axial femur force (kN)	9.1*	1.3	87	3.5	82
Tibia-femur displacement (mm)	15	1	68	8	81
Upper Tibia					
L-M moment (Nm)	±225	-35	112	41	82
A-P moment (Nm)	±225	136	66	-84	78
Vector resultant moment (Nm)	225	139	66	87	81
Index	1.00	0.67	66	0.41	81
Lower Tibia					
L-M moment (Nm)	±225**	45	70	67	89
A-P moment (Nm)	±225**	111	90	49	85
Vector resultant moment (Nm)	225**	115	90	79	90
Axial force (kN)	8.0**	1.8	66	1.8	91
Index	1.00	0.54	90	0.40	90
Foot					
A-P foot acceleration (g)	±150	-95	67	-52	78
I-S foot acceleration (g)	±150	126	65	41	50
Vector resultant foot acceleration (g)	150	143	66	55	78

* This critical value is for instantaneous loading. Femur loads are compared with magnitude-duration injury criteria in Figures A-23 and A-34.

** These published thresholds are for fractures of the tibia. Ankle and foot injuries have been associated with bending moments as low as 50-100 Nm, and heel fractures have been associated with axial forces as low as 6.0 kN.

References

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Appendix

Dummy Clearance Measurements

Graph Index — index to graphs of time plots of dummy and vehicle data

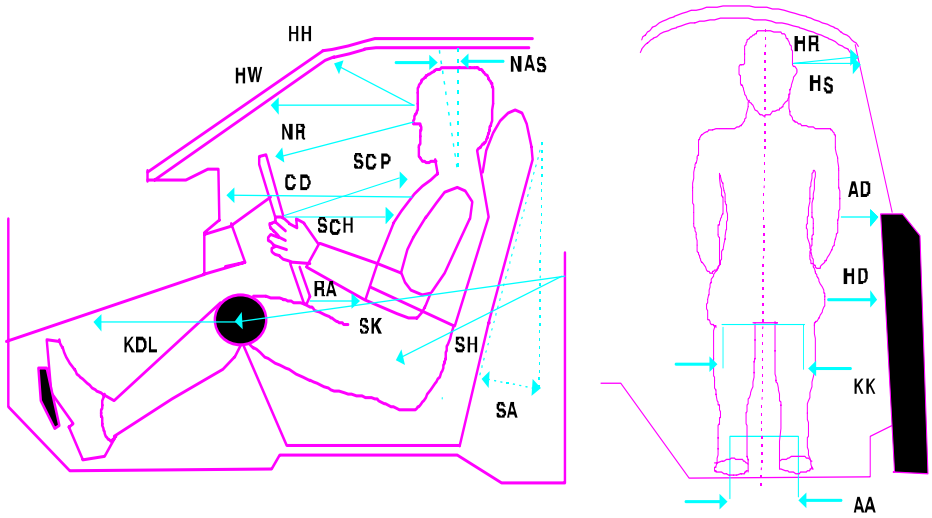
Dummy Clearance Measurements

Test Number: CF98009
Vehicle Make/Model: Volkswagen New Beetle
Vehicle Model Year: 1998
Seat Type: Manually adjusted bucket seat (fore/aft, seat height, and seat back angle)

Manufacturer's Specifications
Seat Back Information: Reclined to provide an H-point machine torso angle of 21 degrees from vertical
Upper Belt Anchorage: Midpoint of 5 positions
Steering Column Adjustment: Midpoint of tilt and telescopic ranges

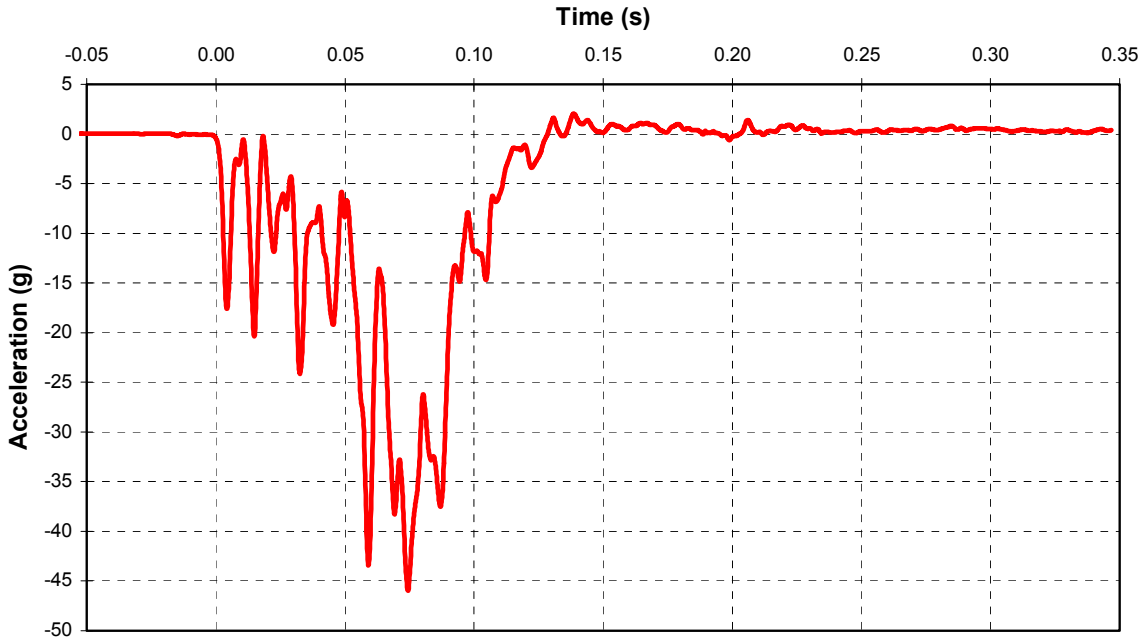
Location	Code	Measure	Location	Code	Measure
Head to header	HH	595	Neck angle, torso 90	NAT90	21.1°
Head to windshield	HW	915	Neck angle, seated**	NAS	3.6°
Nose to rim	NR	425	Torso angle (NAT90 - NAS)	TA	17.5°
Chest to dash	CD	669	Striker to knee***	SK	687
Rim to abdomen	RA	240	Striker to knee angle***	SKA	-10.9°
Knee to dash, left	KDL	248	Striker to H-point, horizontal	SHH	305
Knee to dash, right	KDR	223	Striker to H-point, vertical	SHV	-236
Steering wheel to chest, horizontal	SCH	311	Ankle to ankle	AA	328
Steering wheel to chest, perpendicular	SCP	381	Knee to knee	KK	302
Steering wheel to chest, reference	SCR	368	Arm to door	AD	110
Hub to chest, minimum	HCM	267	H-point to door	HD	143
Pelvic angle	PA	24.6°	Head to A-pillar	HA	750
Seat back angle*	SA	21°	Head to roof	HR	260
			Head to side window	HS	272

All distance measurements are in millimeters (mm).
* Measurement represents H-point machine torso angle.
** Dummy's neck bracket was adjusted to +7.0 degrees to achieve a level instrumentation plane.
*** These measurements were made in a vertical plane containing the striker and parallel to the driver door sill.

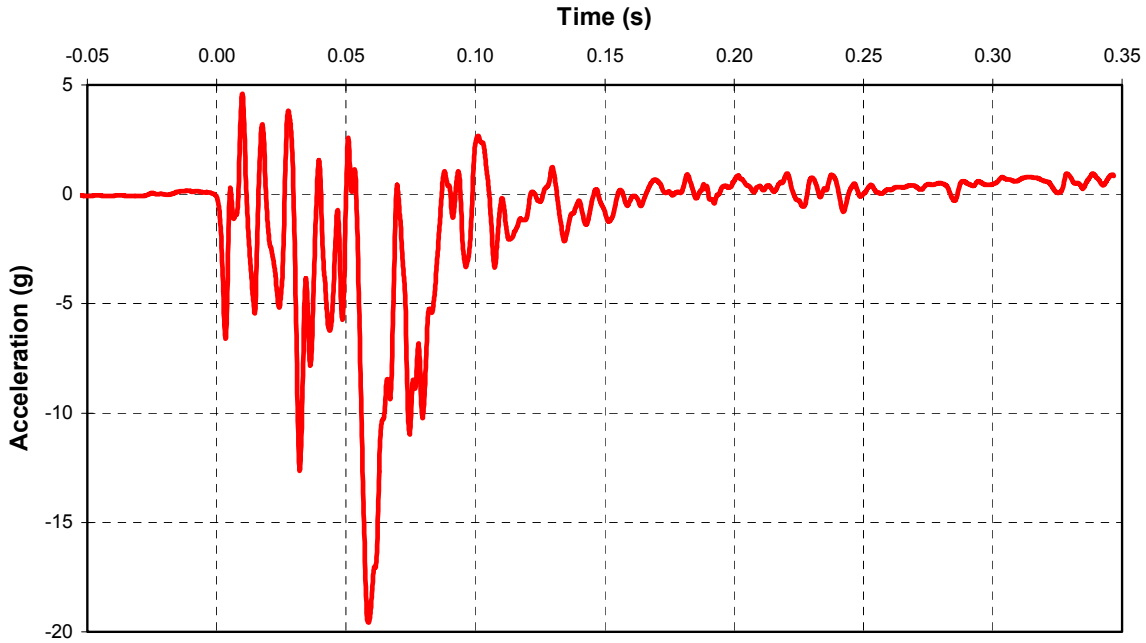


Graph Index

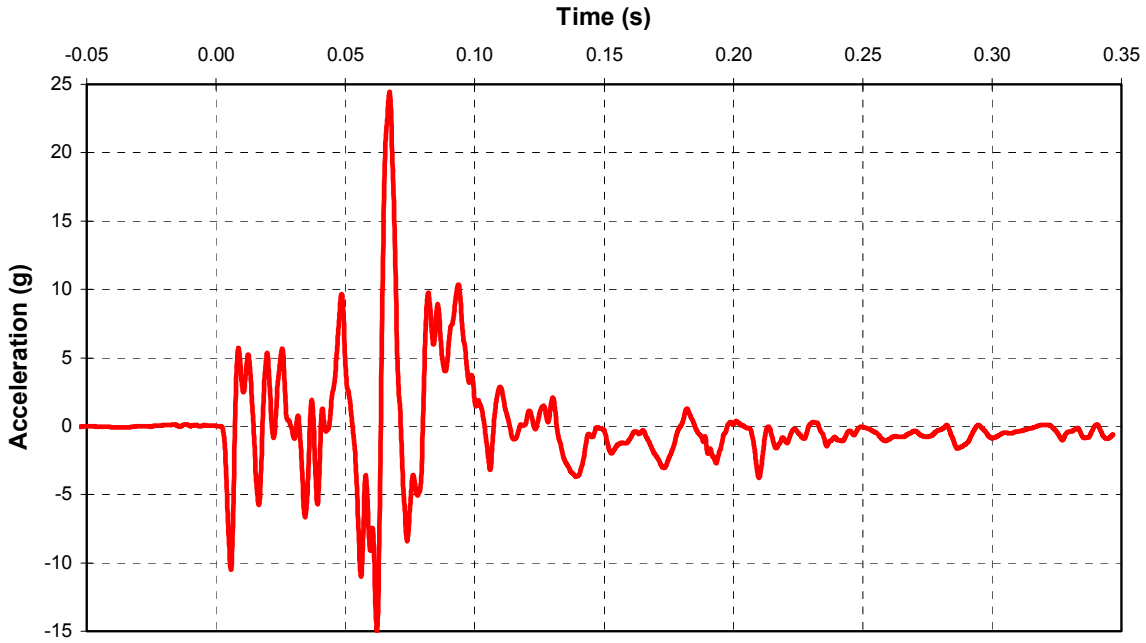
A-1 CF98009 1998 VW New Beetle Vehicle Longitudinal Acceleration



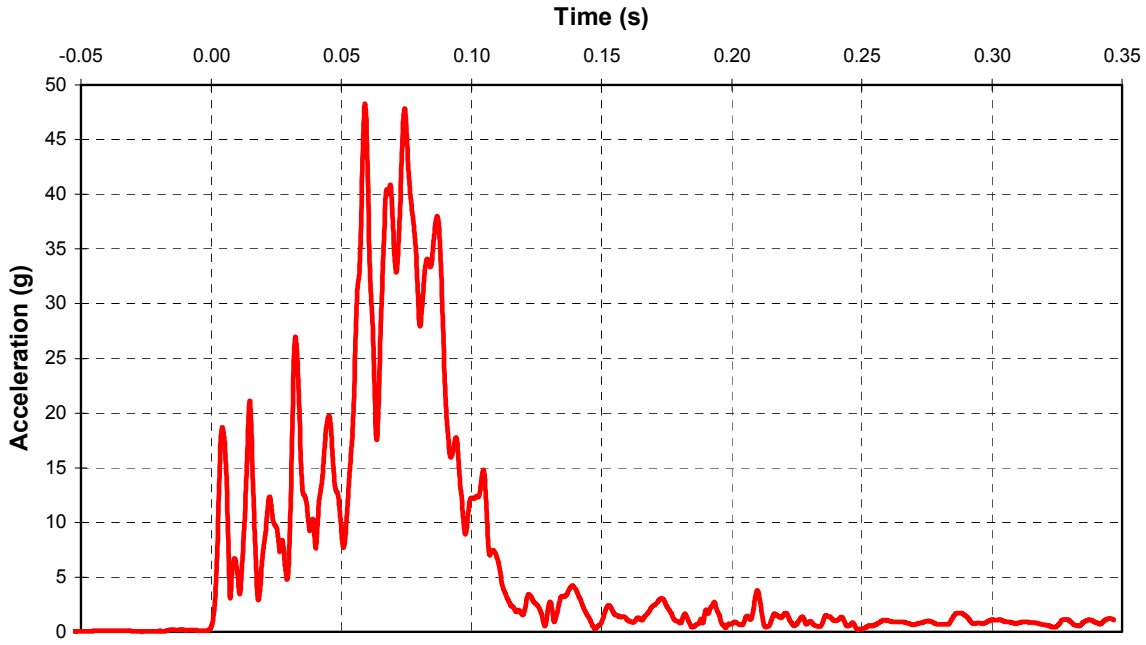
A-2 CF98009 1998 VW New Beetle Vehicle Lateral Acceleration



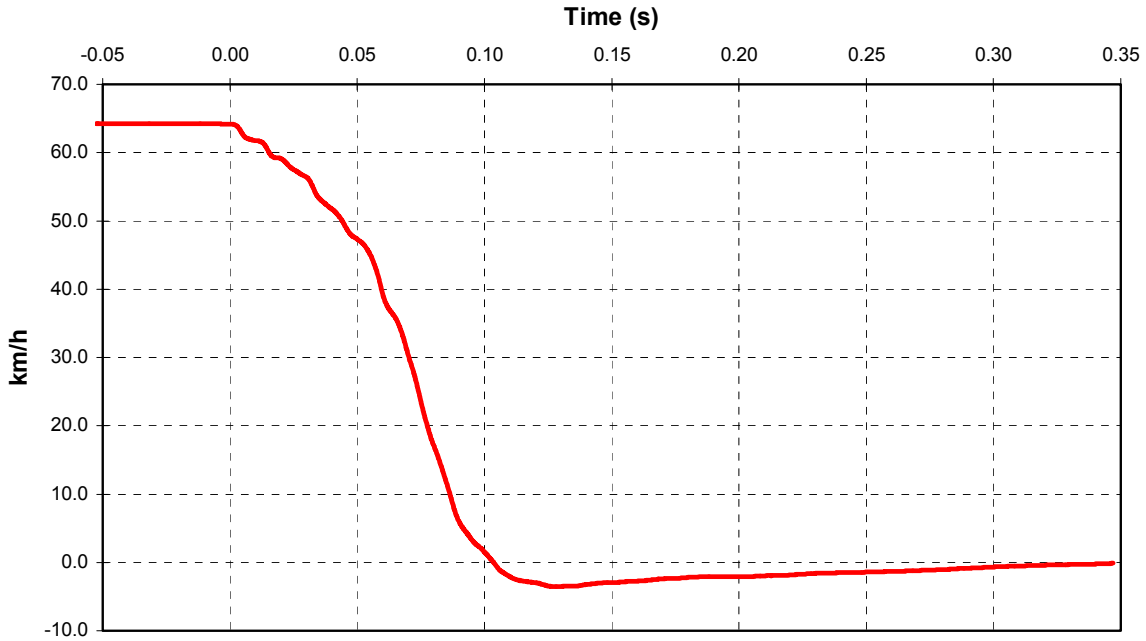
A-3 CF98009 1998 VW New Beetle Vehicle Vertical Acceleration



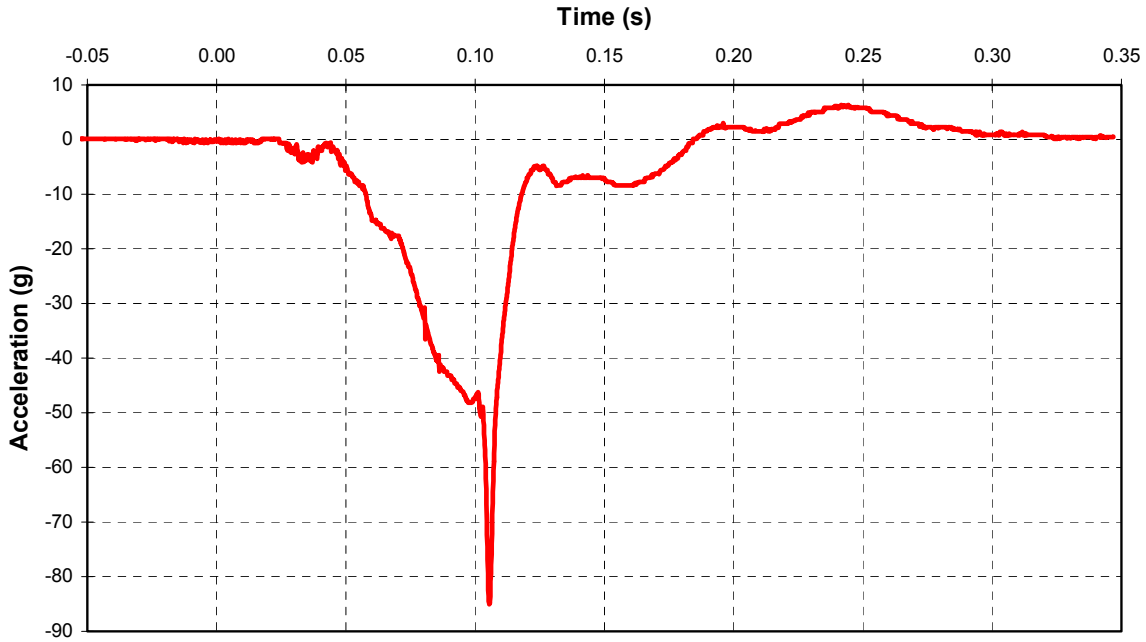
A-4 CF98009 1998 VW New Beetle Vehicle Vector Resultant Acceleration



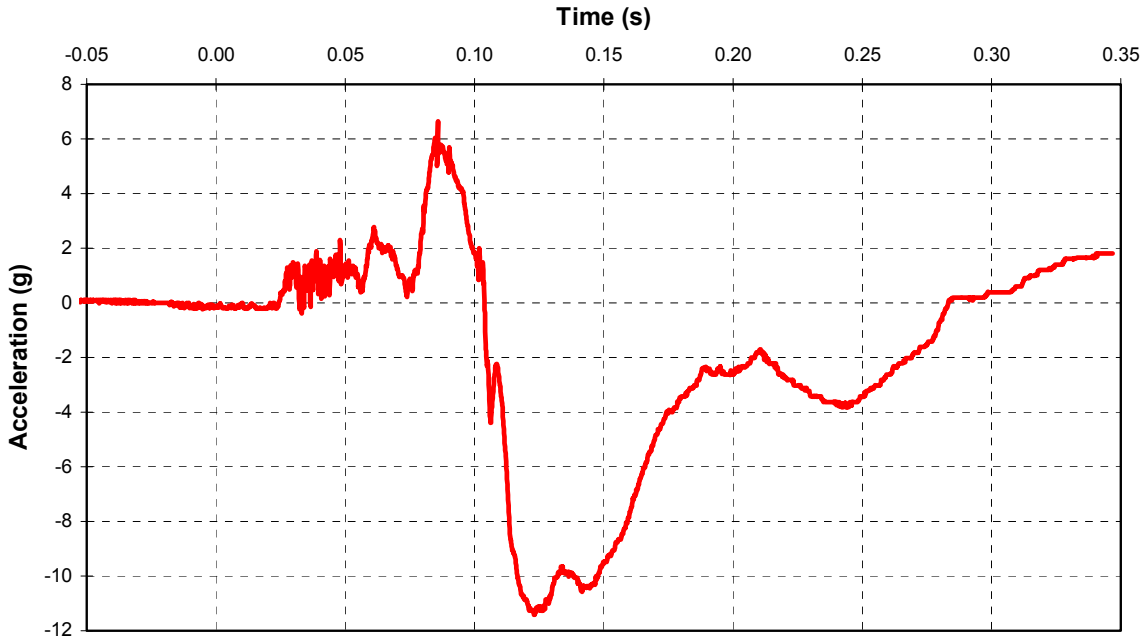
A-5 CF98009 1998 VW New Beetle Integration of Vehicle Longitudinal Acceleration



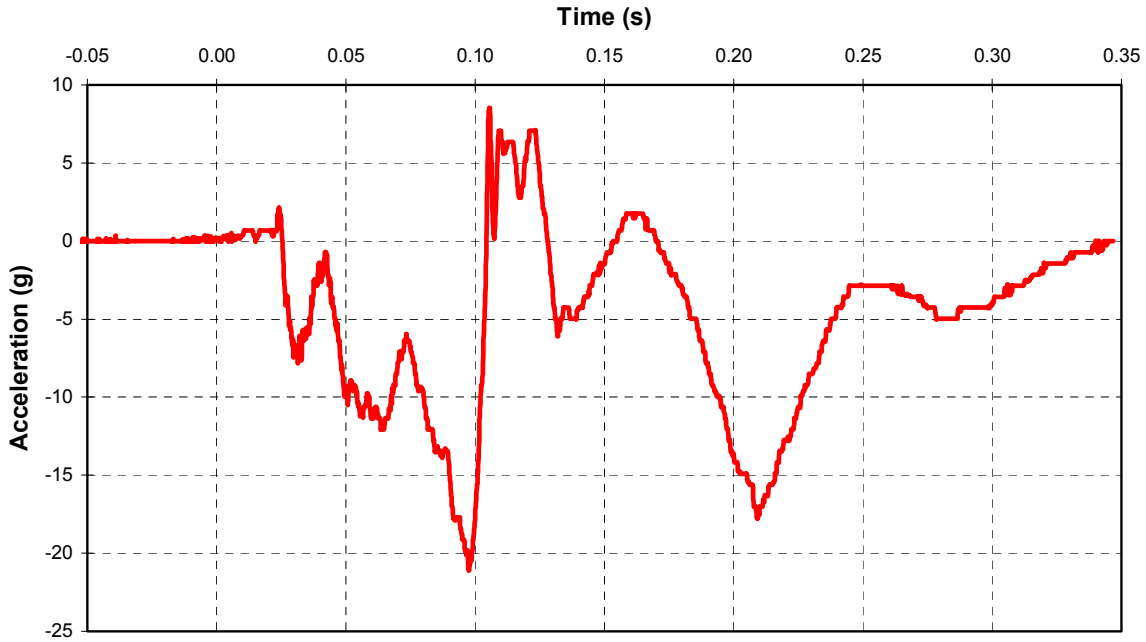
A-6 CF98009 1998 VW New Beetle Head A-P Acceleration



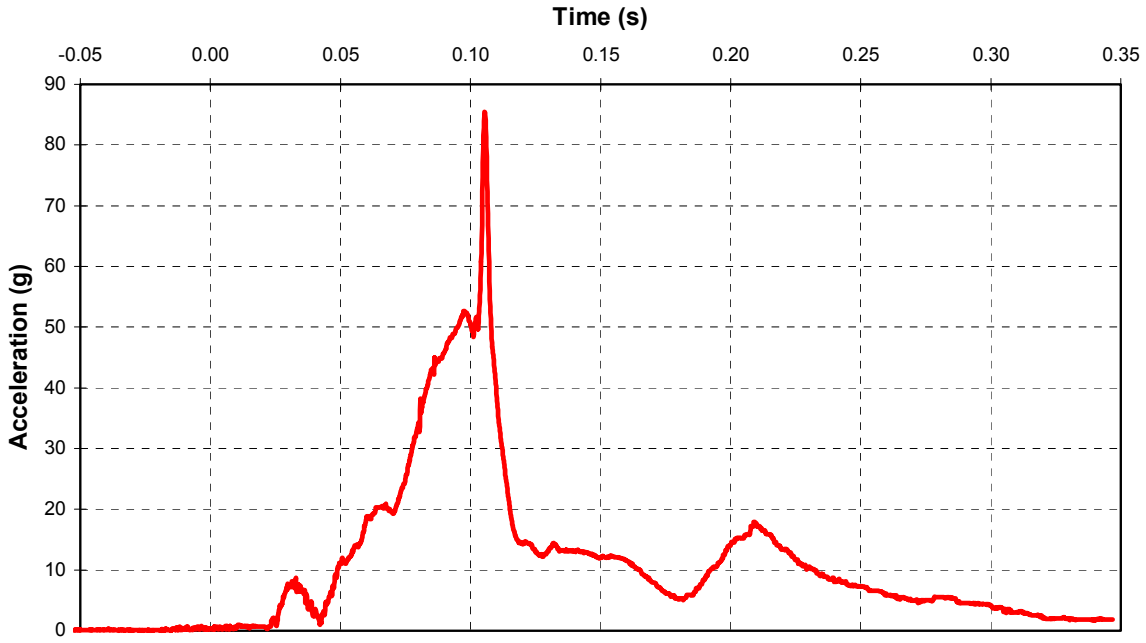
A-7 CF98009 1998 VW New Beetle Head L-M Acceleration



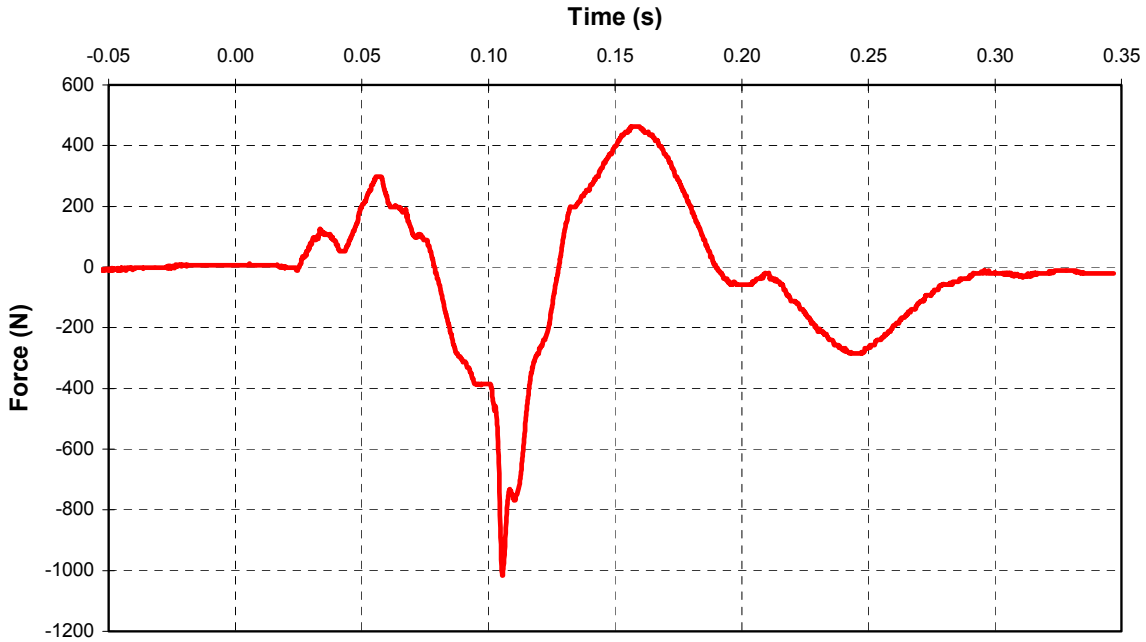
A-8 CF98009 1998 VW New Beetle Head I-S Acceleration



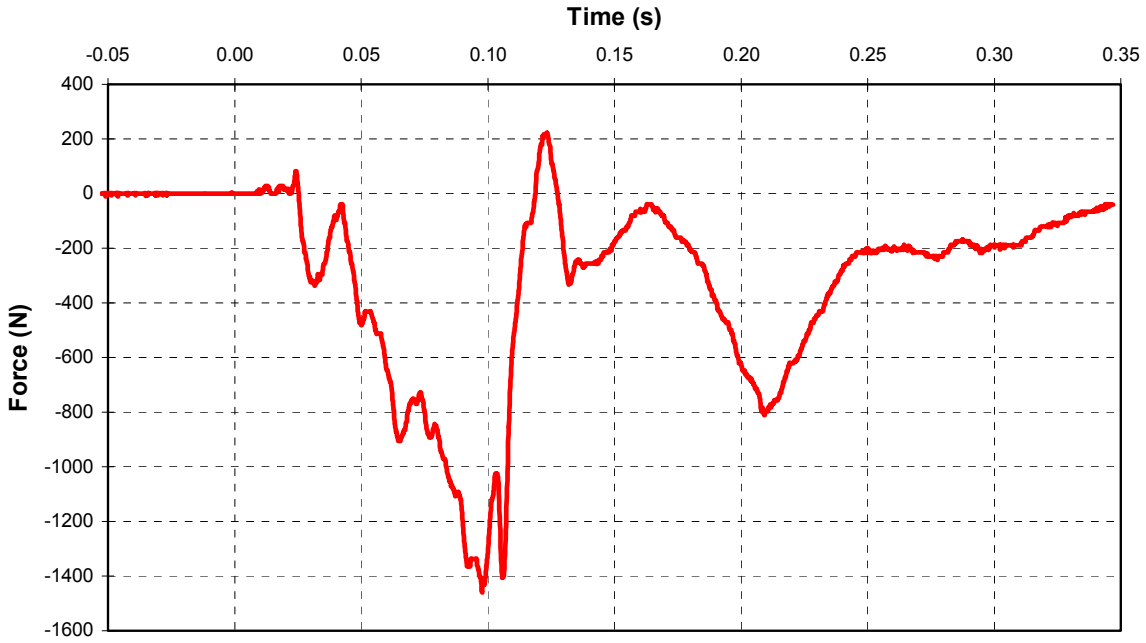
A-9 CF98009 1998 VW New Beetle Head Vector Resultant Acceleration



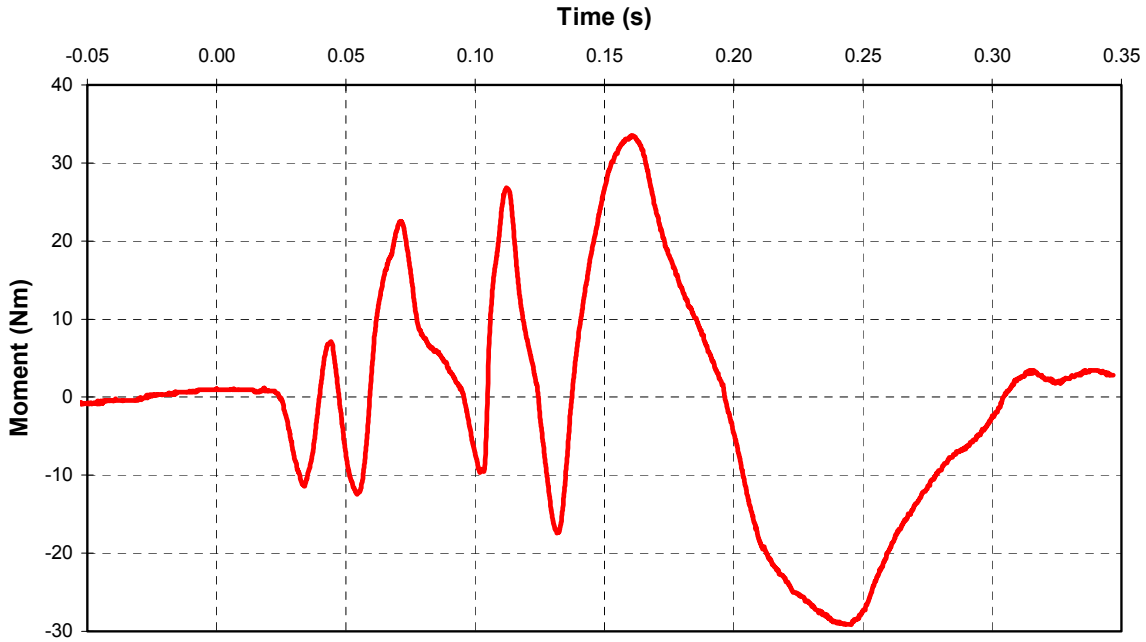
A-10 CF98009 1998 VW New Beetle Neck A-P Shear Force



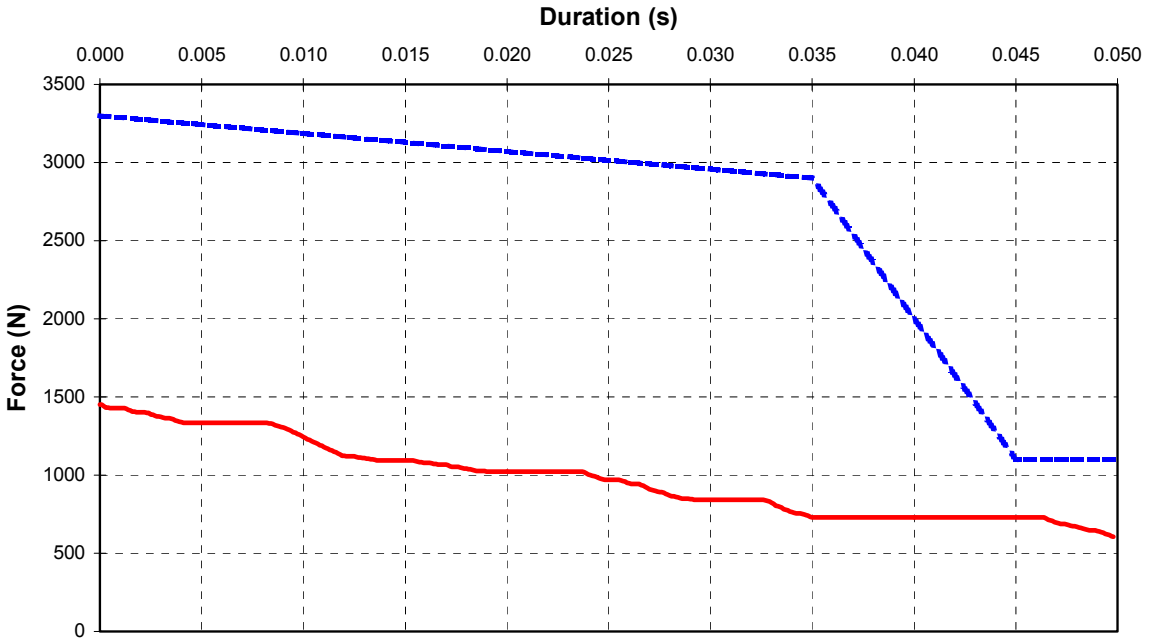
A-11 CF98009 1998 VW New Beetle Neck Axial Force



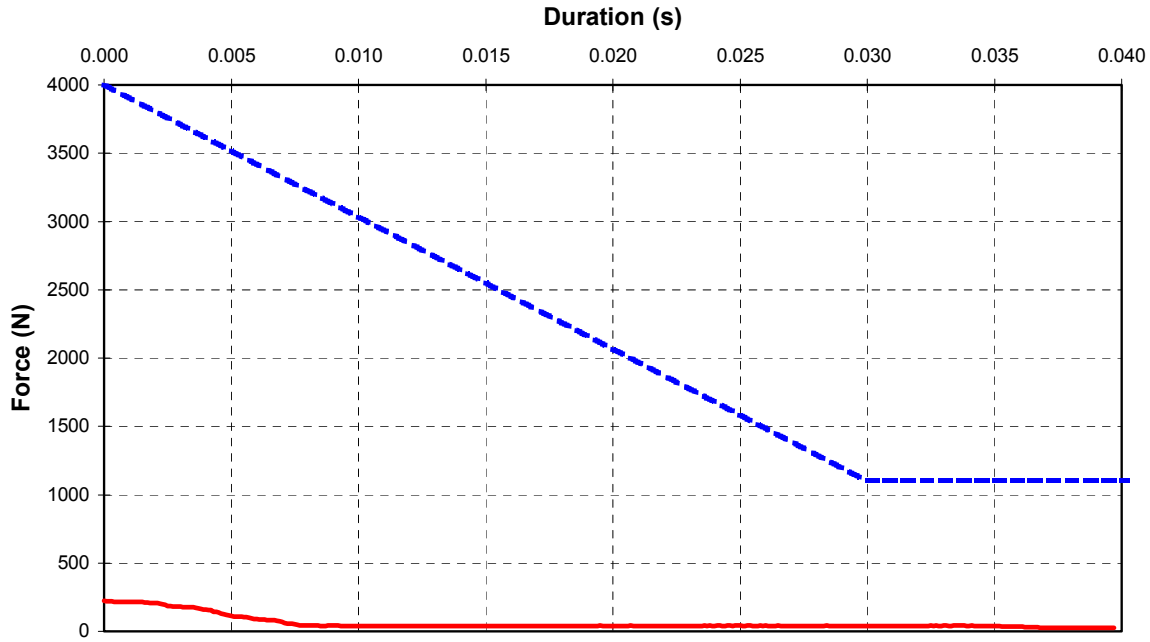
A-12 CF98009 1998 VW New Beetle Neck Occipital A-P Moment



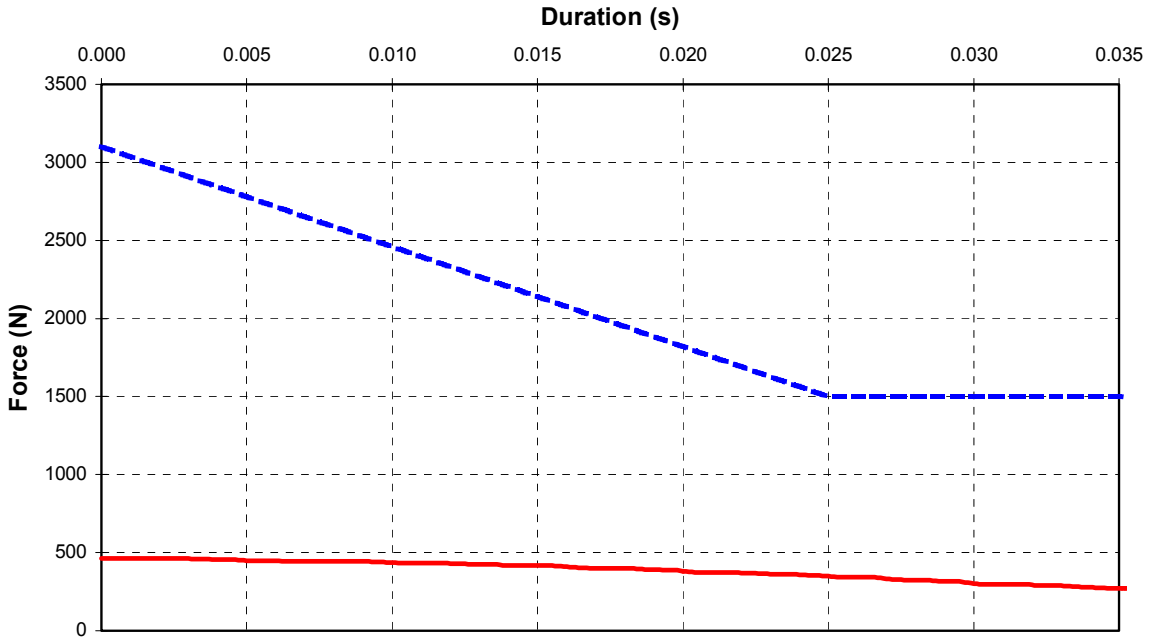
A-13 CF98009 1998 VW New Beetle Neck Tension Analysis



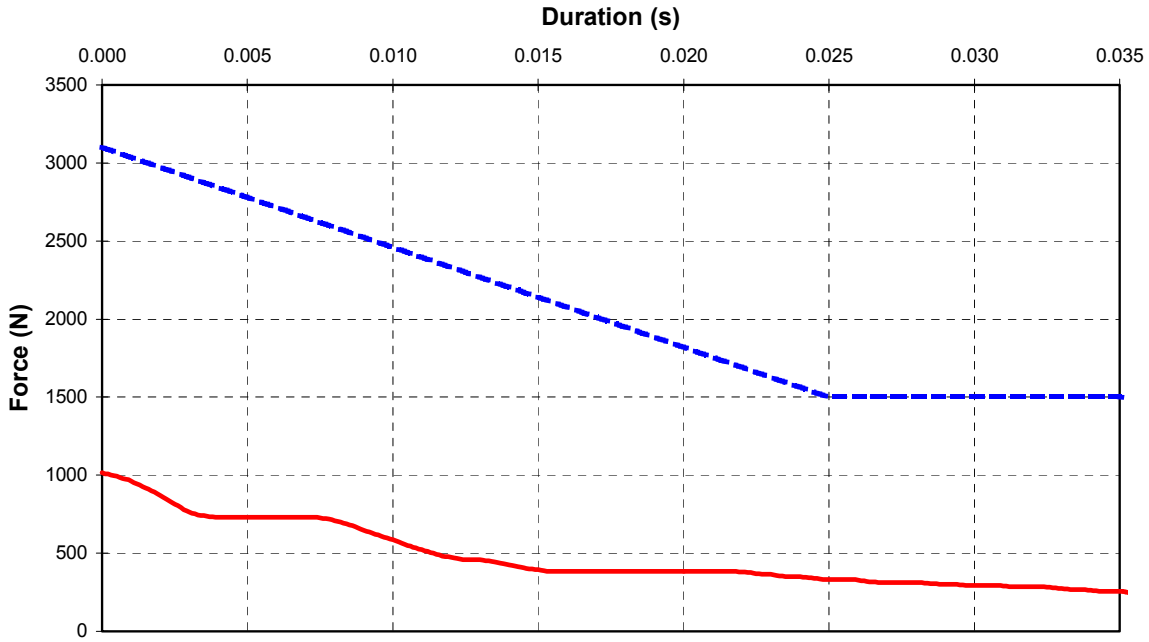
A-14 CF98009 1998 VW New Beetle Neck Compression Analysis



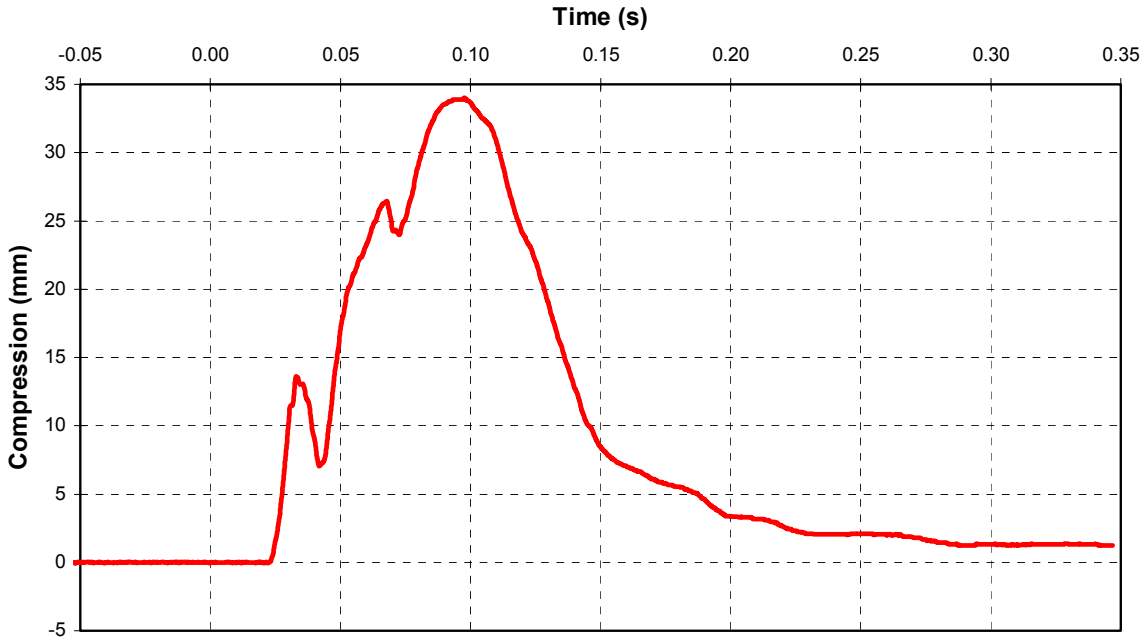
A-15 CF98009 1998 VW New Beetle Neck A-P Shear (Positive) Analysis



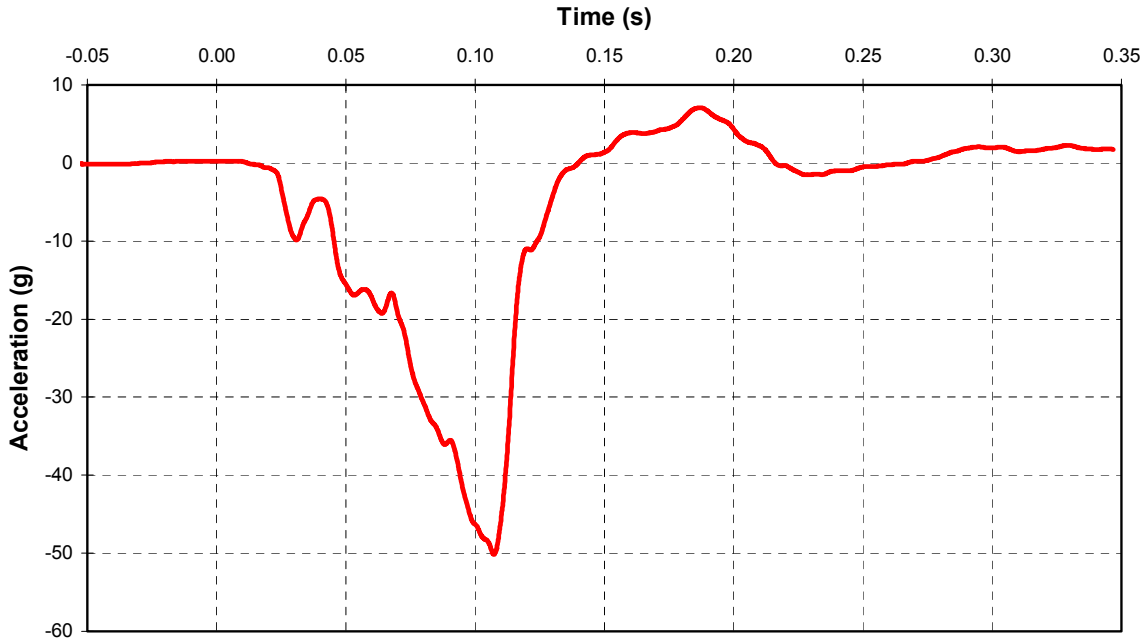
A-16 CF98009 1998 VW New Beetle Neck A-P Shear (Negative) Analysis



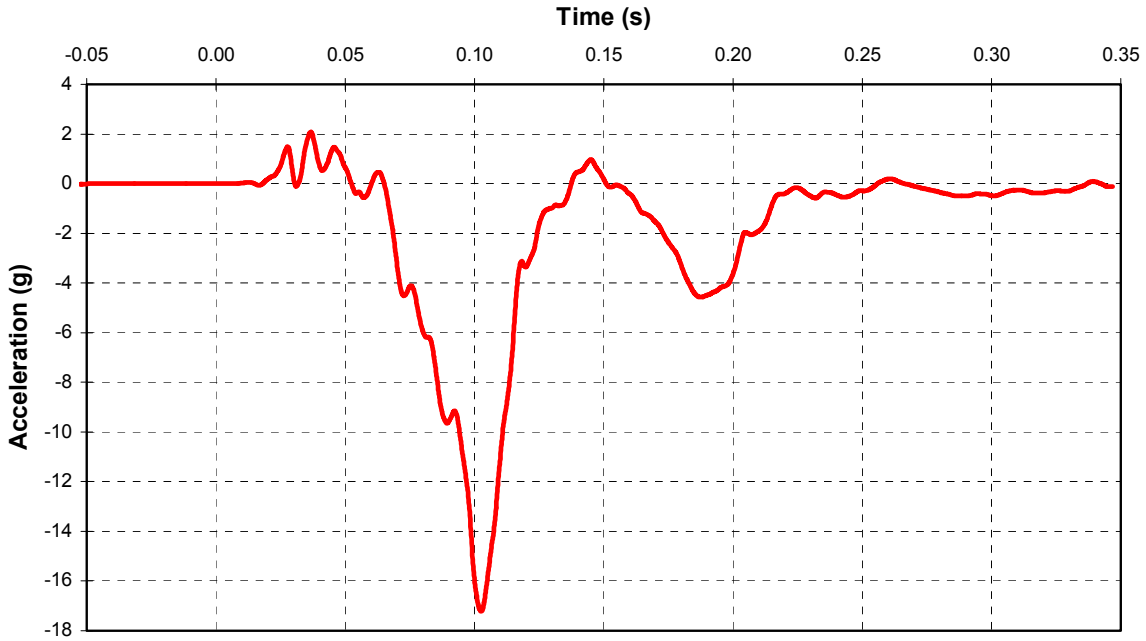
A-17 CF98009 1998 VW New Beetle Chest Compression



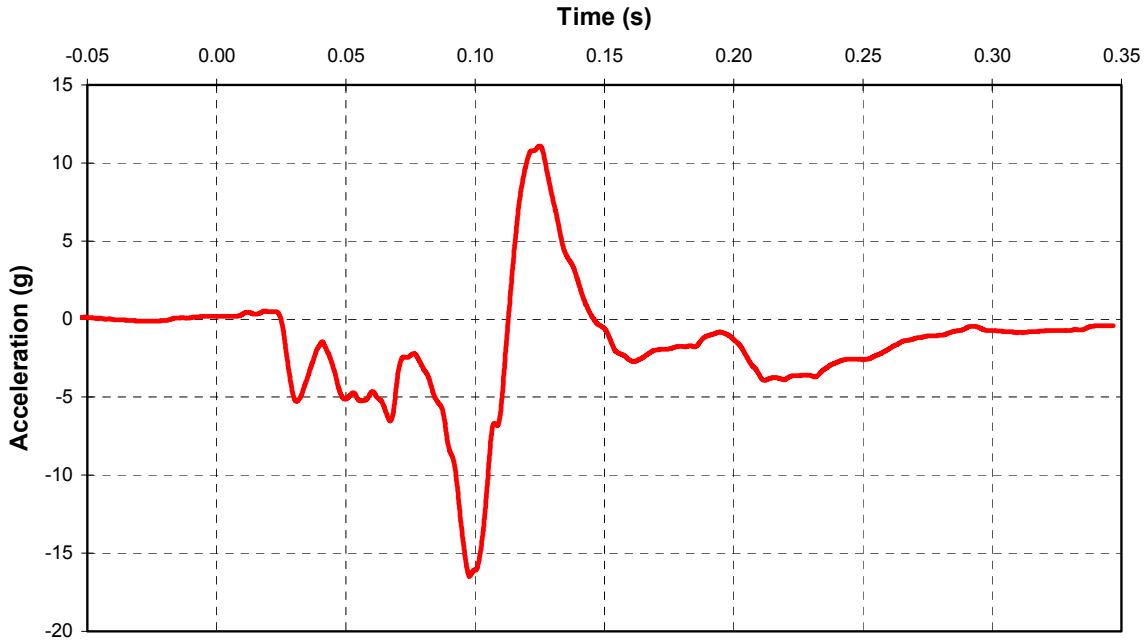
A-18 CF98009 1998 VW New Beetle Chest A-P Acceleration



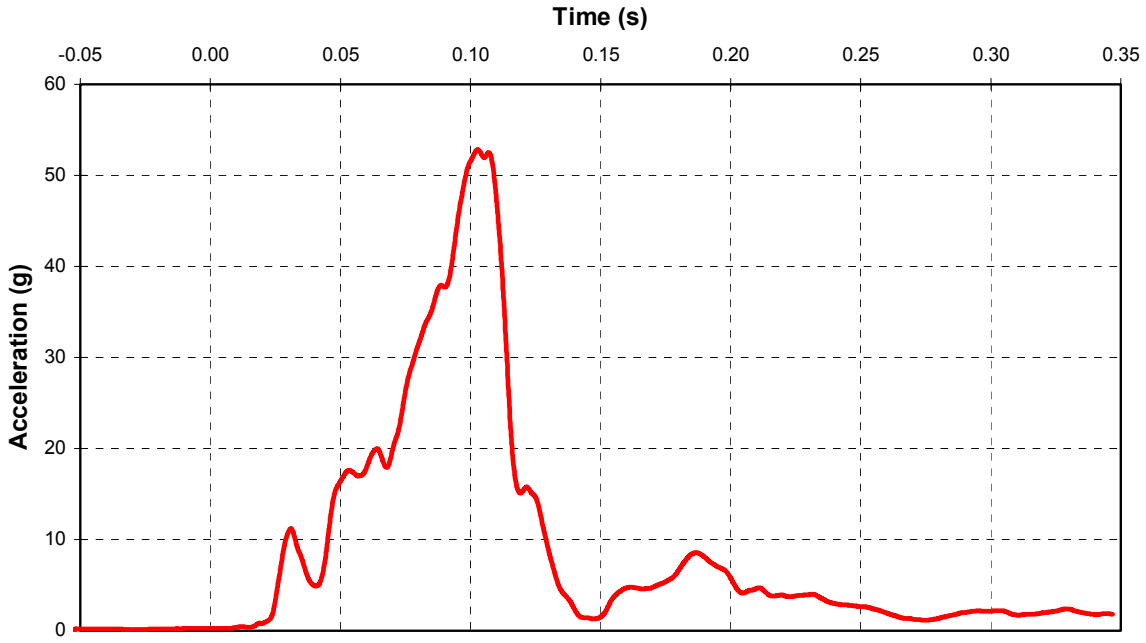
A-19 CF98009 1998 VW New Beetle Chest L-M Acceleration



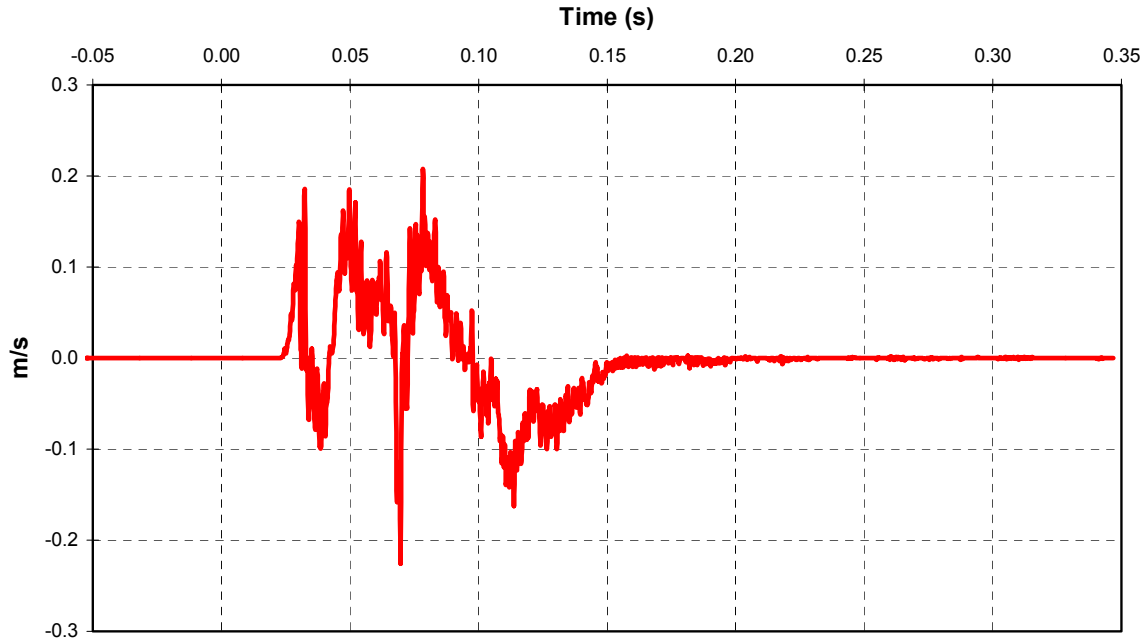
A-20 CF98009 1998 VW New Beetle Chest I-S Acceleration



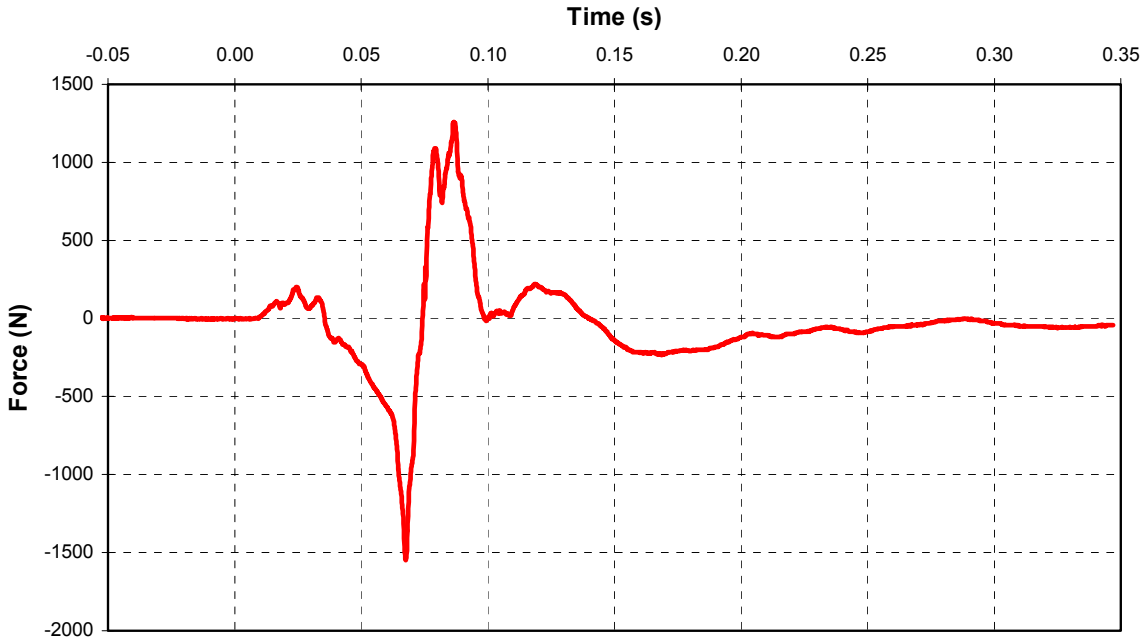
A-21 CF98009 1998 VW New Beetle Chest Vector Resultant Acceleration



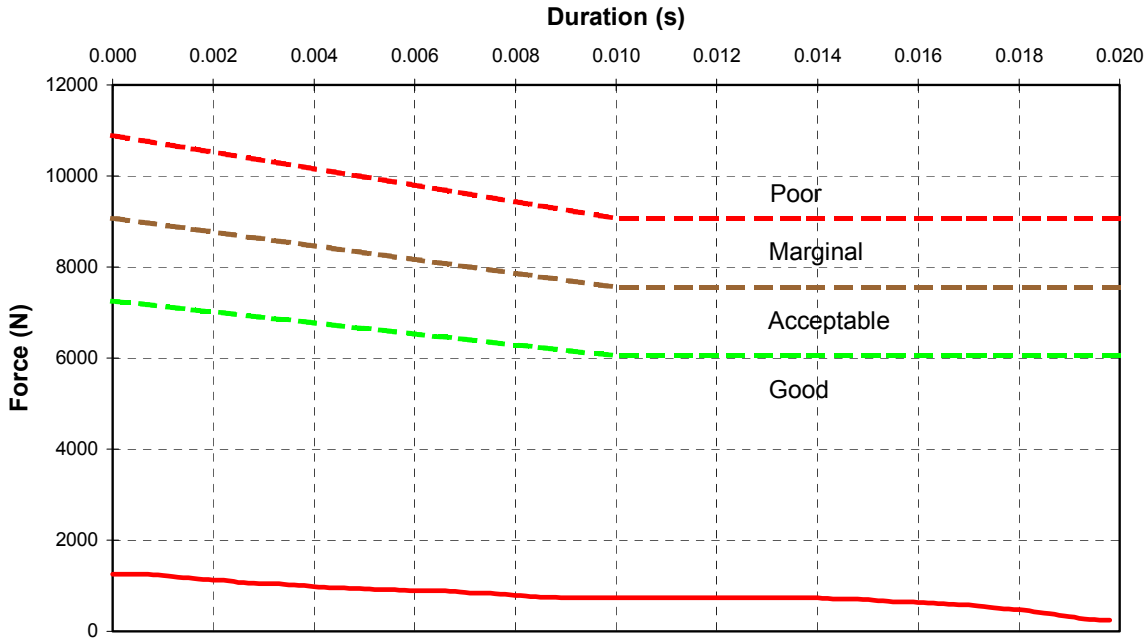
A-22 CF98009 1998 VW New Beetle Viscous Criterion



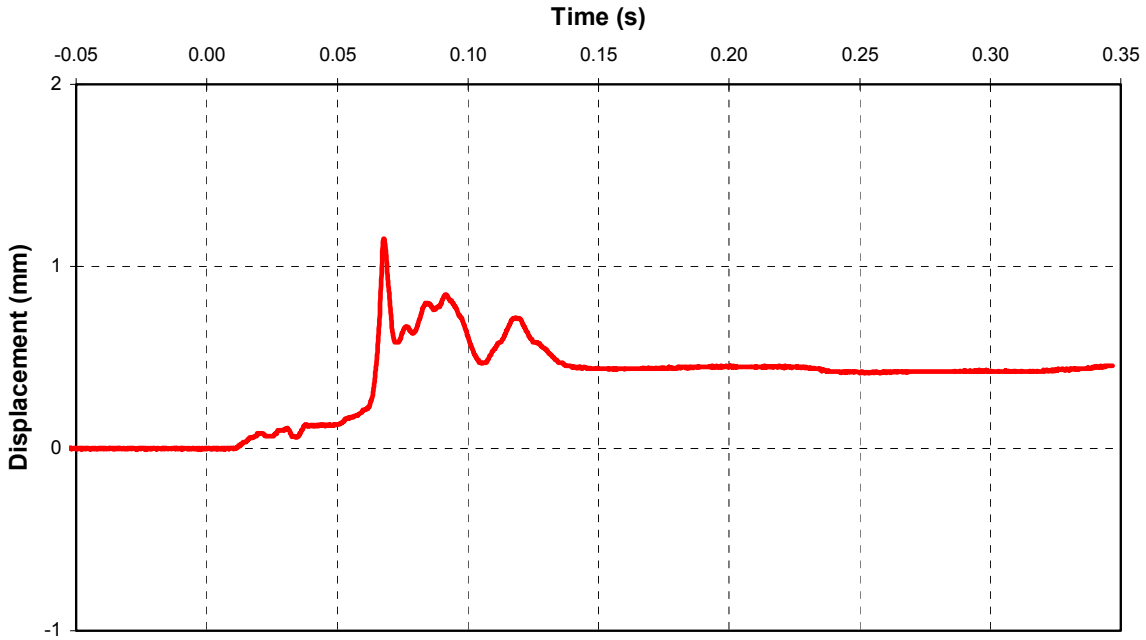
A-23 CF98009 1998 VW New Beetle Left Femur Axial Force



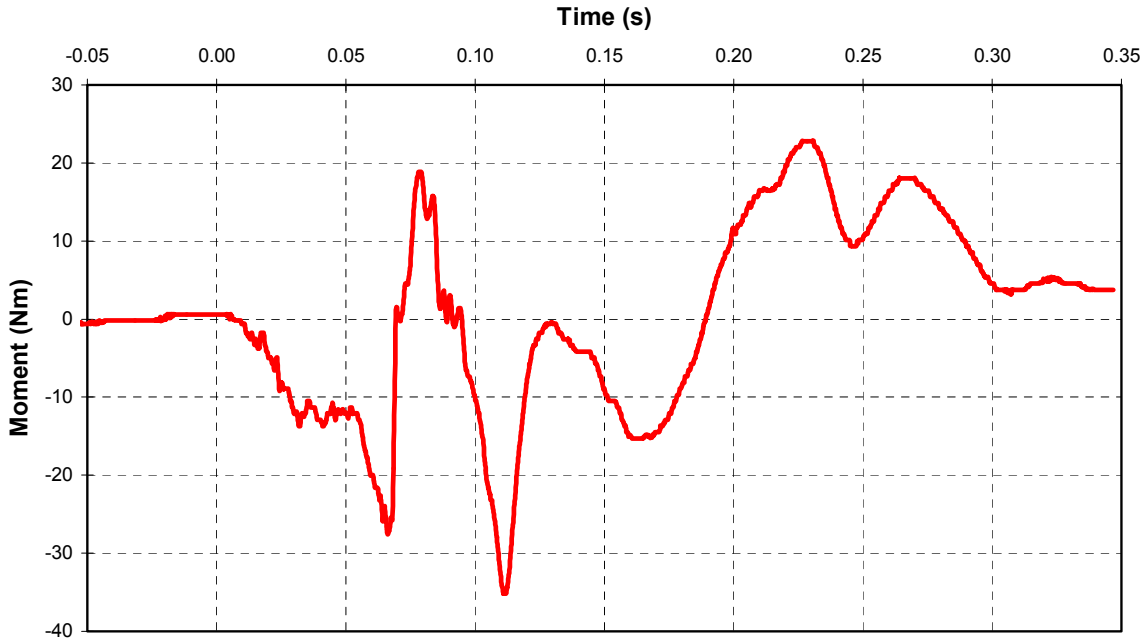
A-24 CF98009 1998 VW New Beetle Left Femur Axial Force Analysis



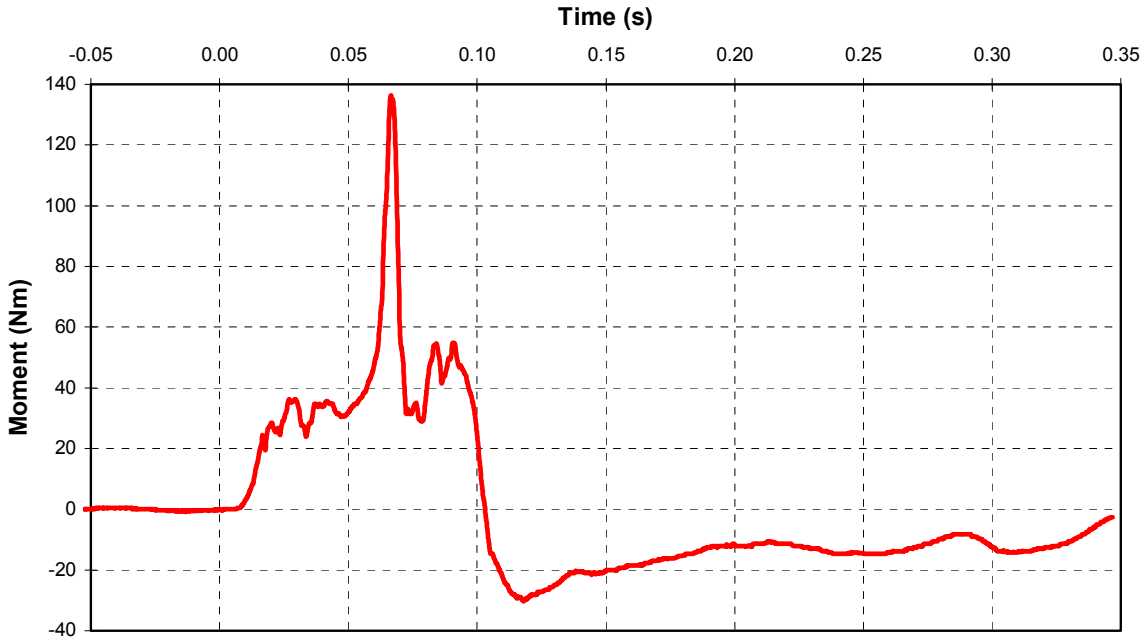
A-25 CF98009 1998 VW New Beetle Left Tibia-Femur Displacement



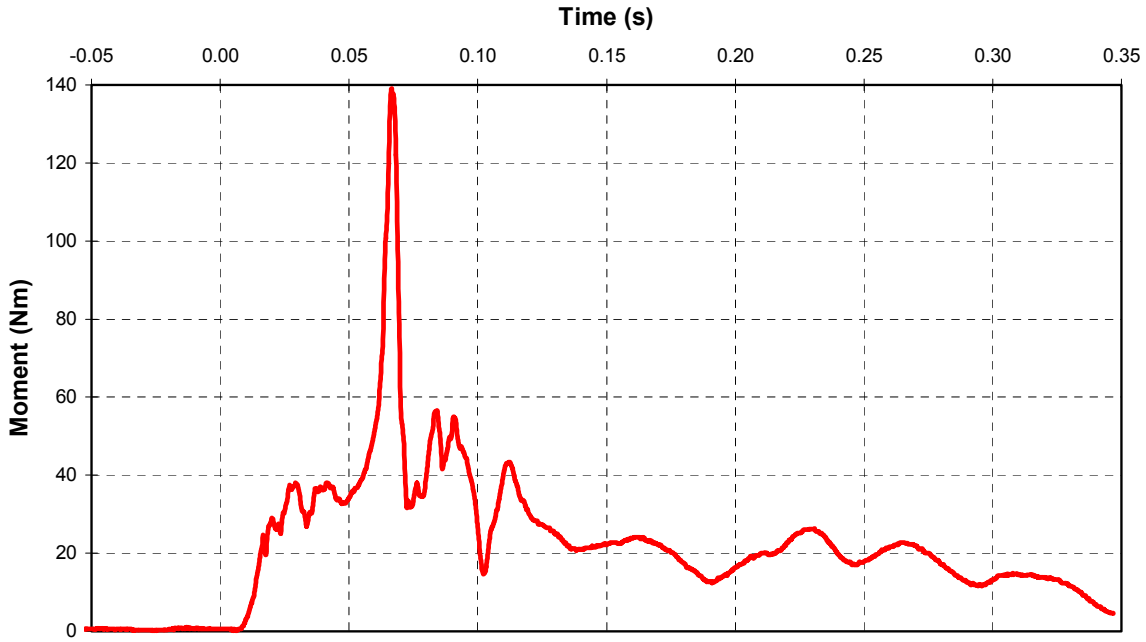
A-26 CF98009 1998 VW New Beetle Left Upper Tibia L-M Moment



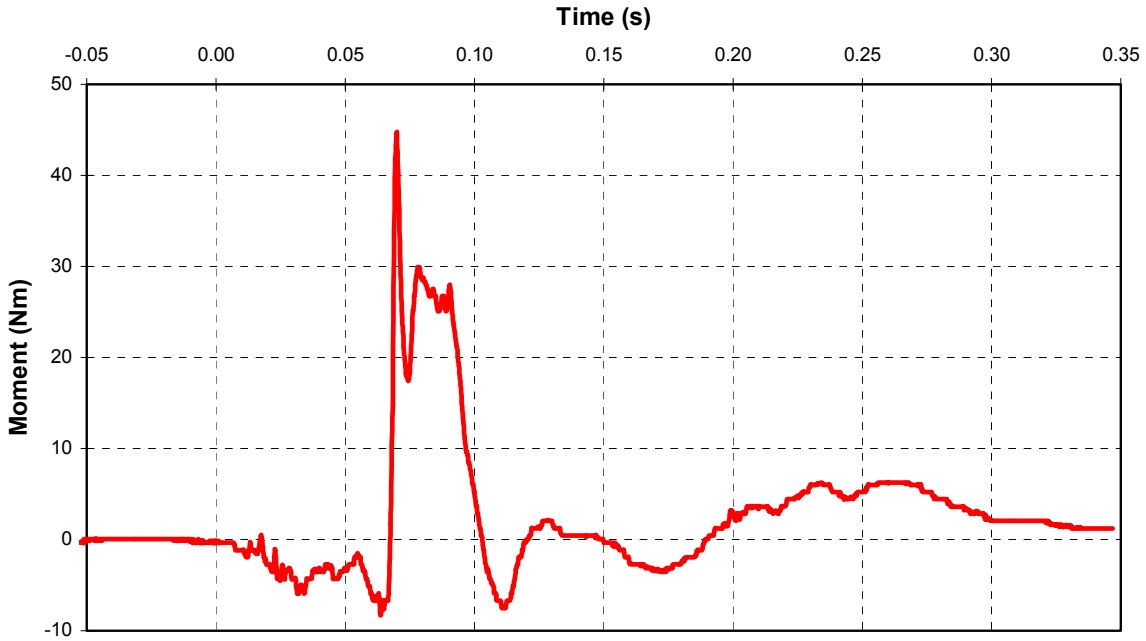
A-27 CF98009 1998 VW New Beetle Left Upper Tibia A-P Moment



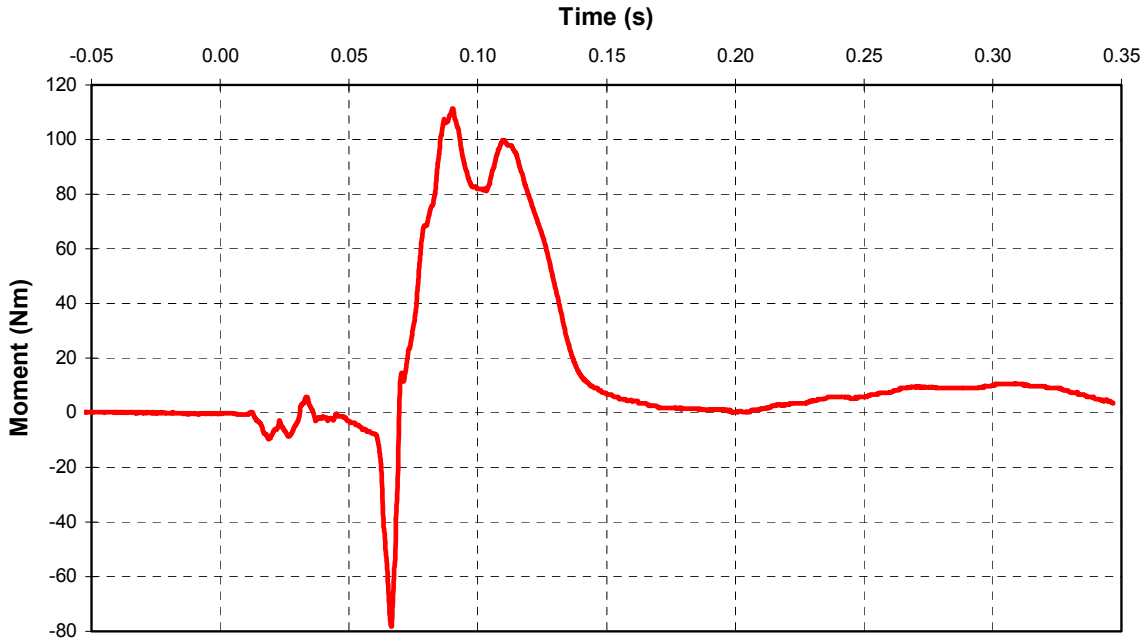
A-28 CF98009 1998 VW New Beetle Left Upper Tibia Vector Resultant Moment



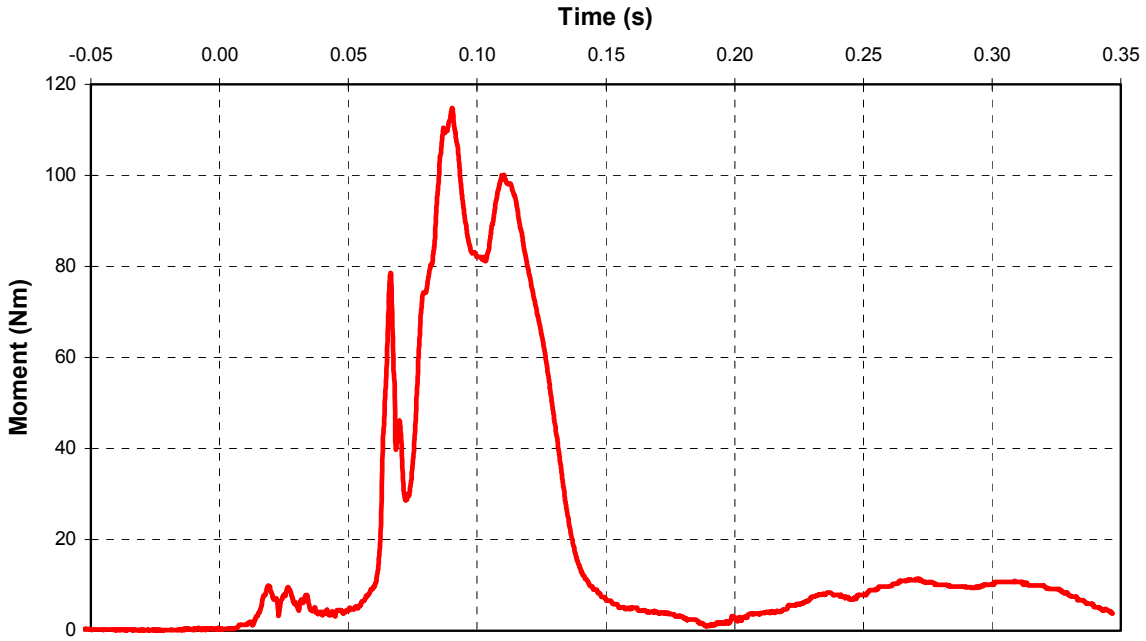
A-29 CF98009 1998 VW New Beetle Left Lower Tibia L-M Moment



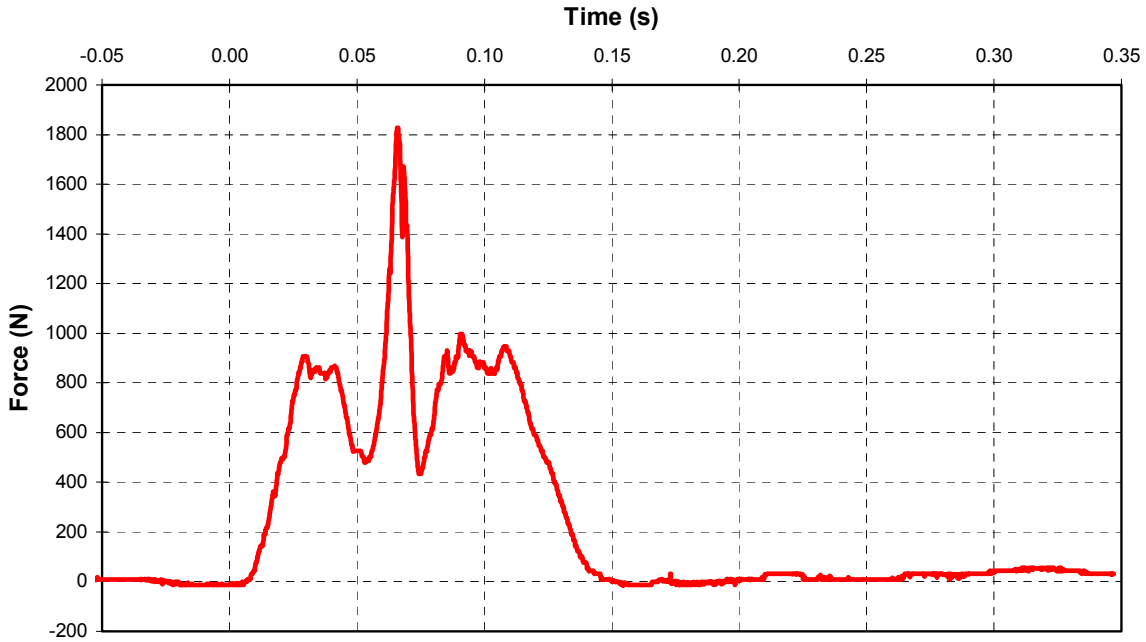
A-30 CF98009 1998 VW New Beetle Left Lower Tibia A-P Moment



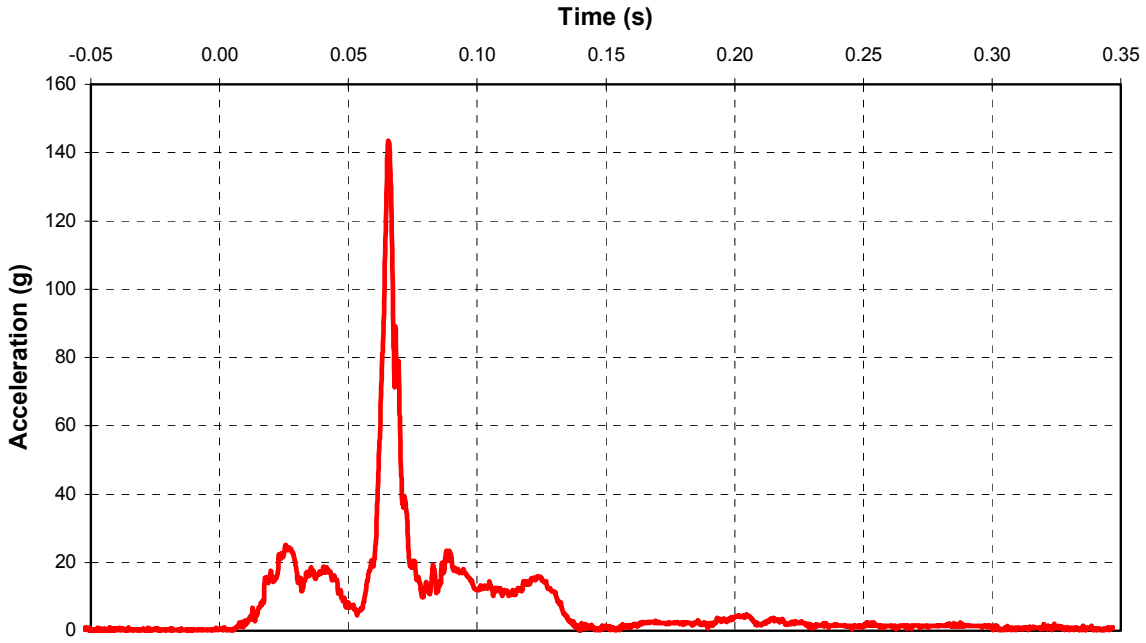
A-31 CF98009 1998 VW New Beetle Left Lower Tibia Vector Resultant Moment



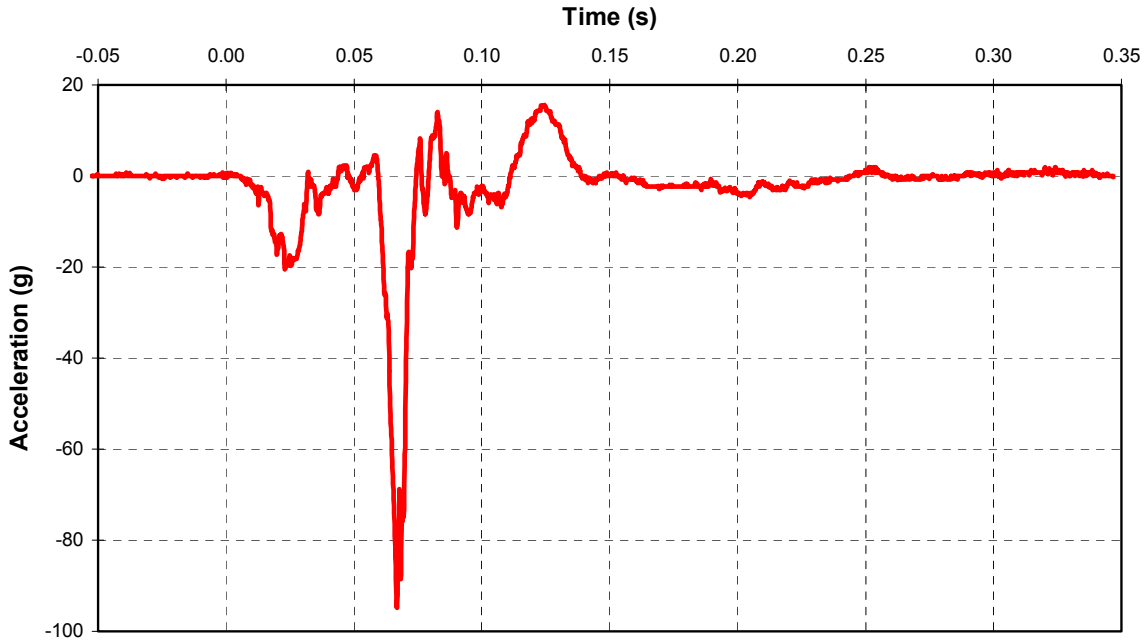
A-32 CF98009 1998 VW New Beetle Left Lower Tibia Axial Force



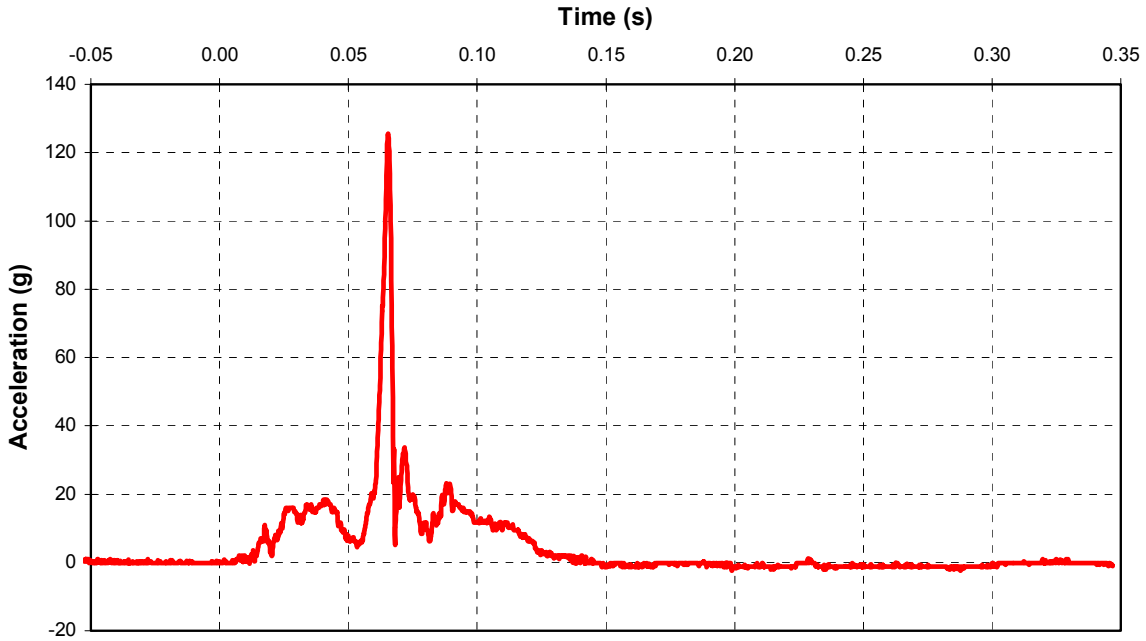
A-33 CF98009 1998 VW New Beetle Left Foot Vector Resultant Acceleration



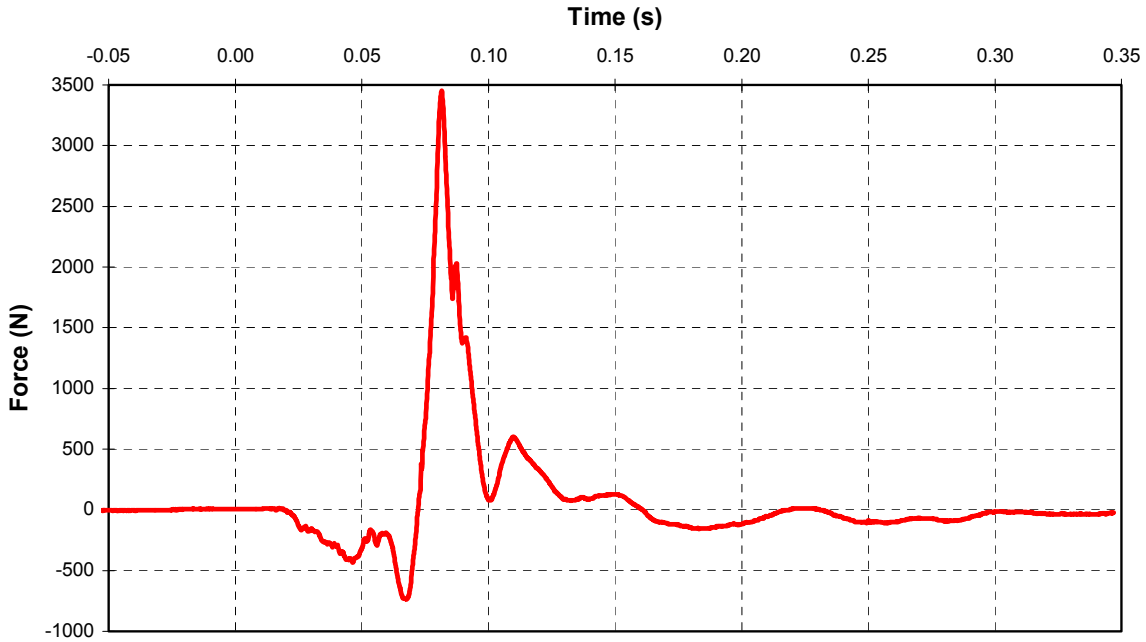
A-34 CF98009 1998 VW New Beetle Left Foot A-P Acceleration



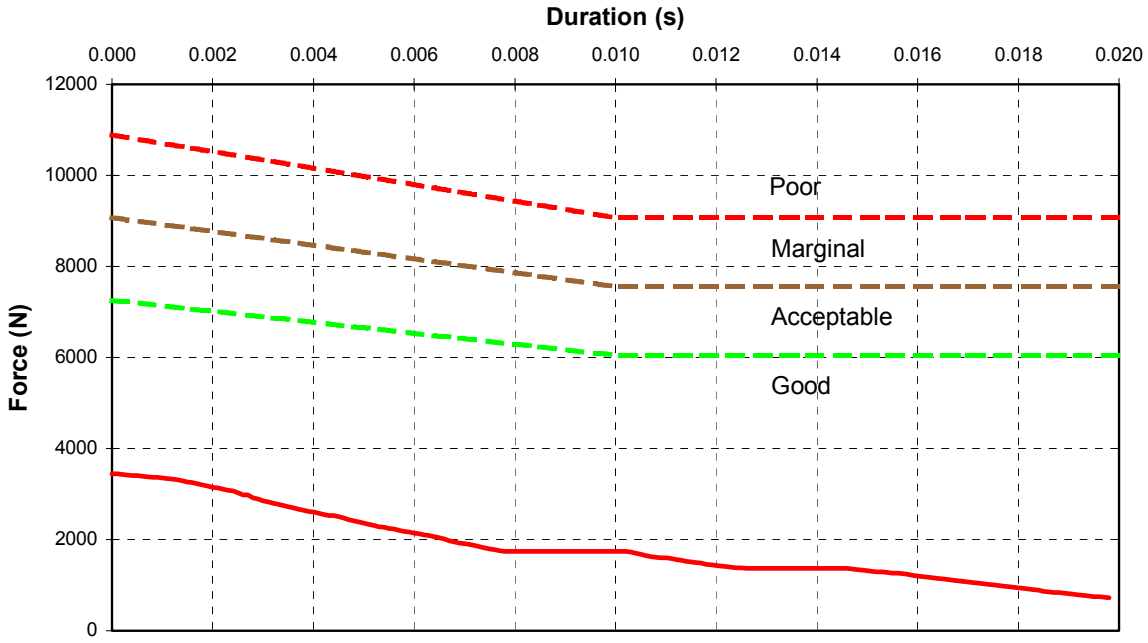
A-35 CF98009 1998 VW New Beetle Left Foot I-S Acceleration



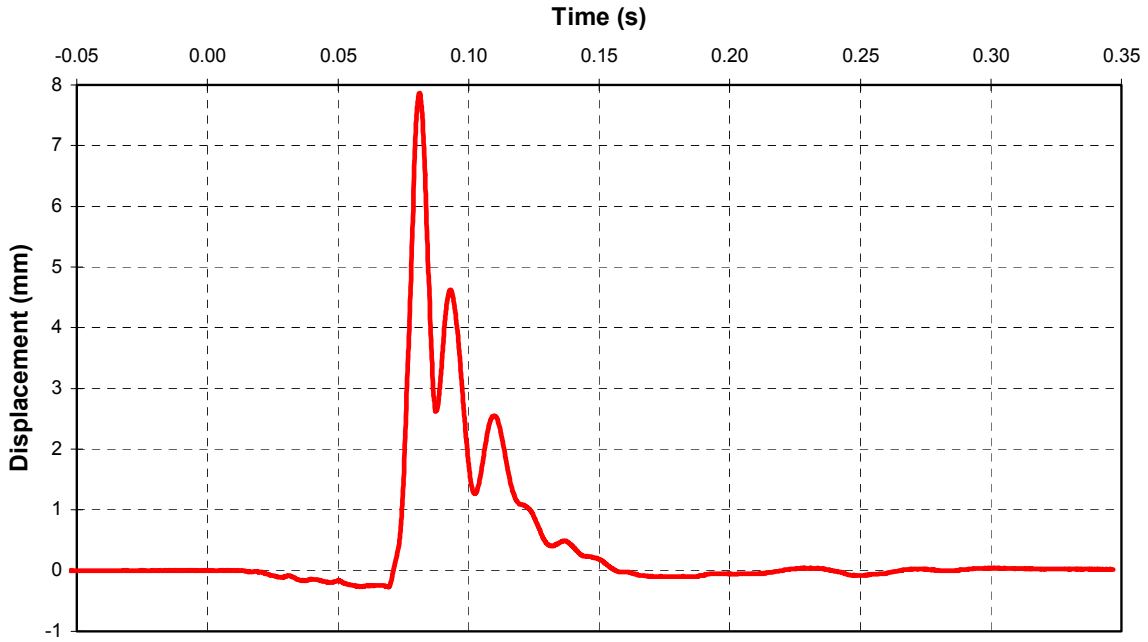
A-36 CF98009 1998 VW New Beetle Right Femur Axial Force



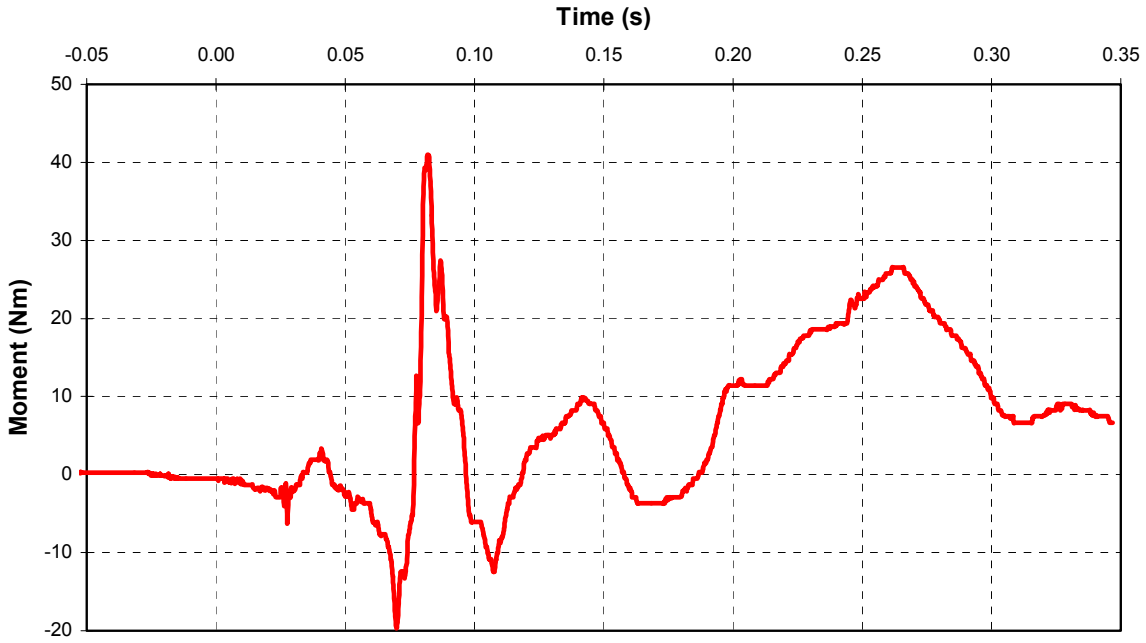
A-37 CF98009 1998 VW New Beetle Right Femur Axial Force Analysis



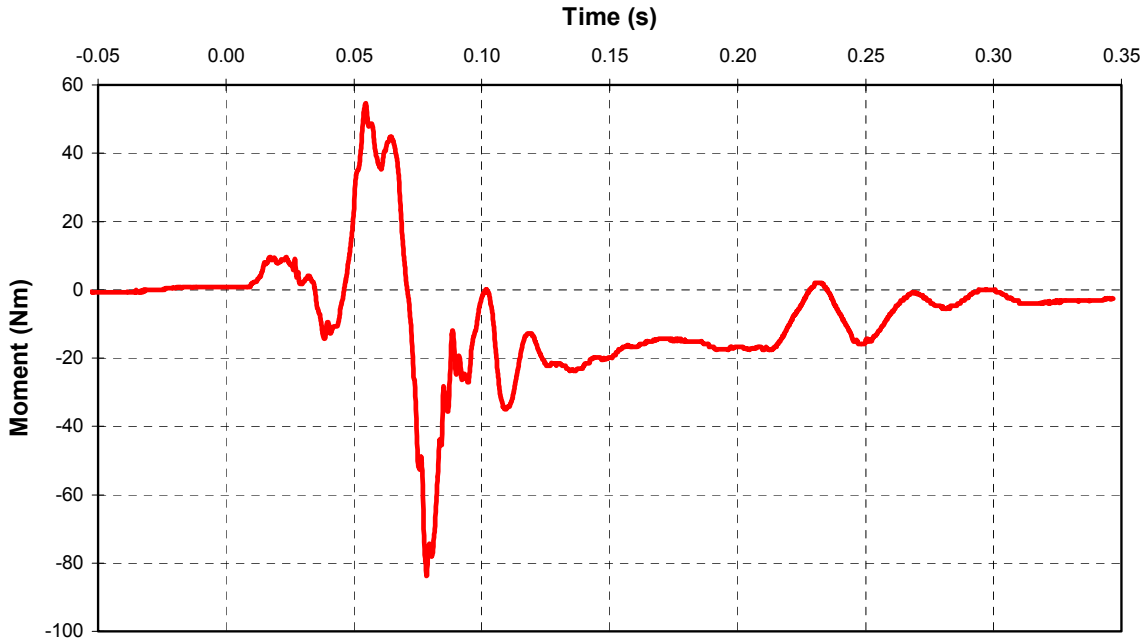
A-38 CF98009 1998 VW New Beetle Right Tibia-Femur Displacement



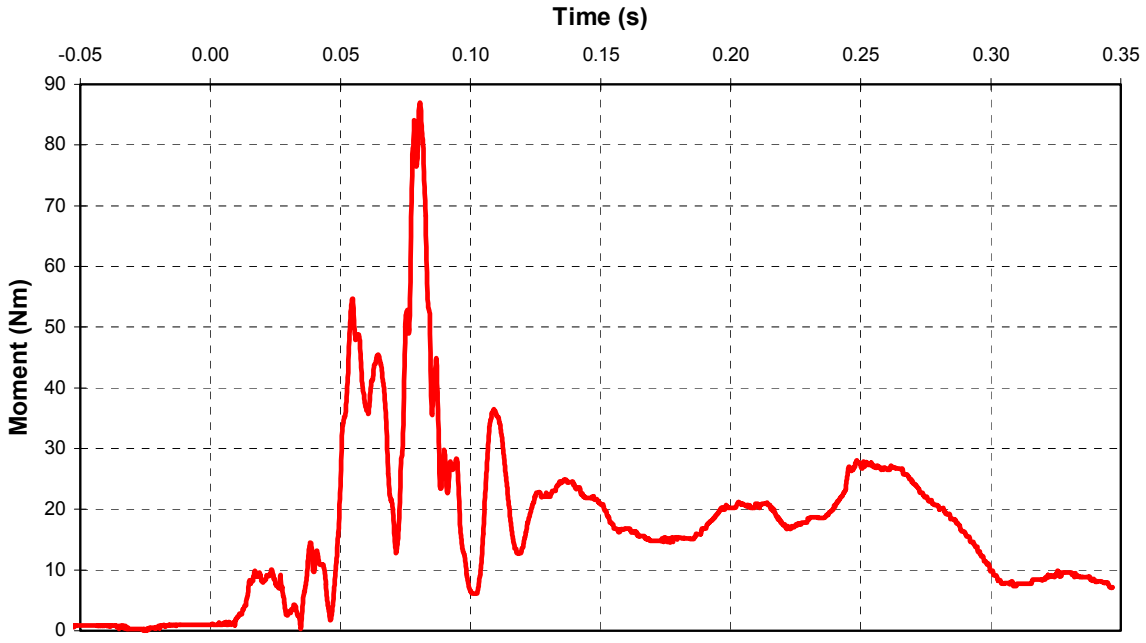
A-39 CF98009 1998 VW New Beetle Right Upper Tibia L-M Moment



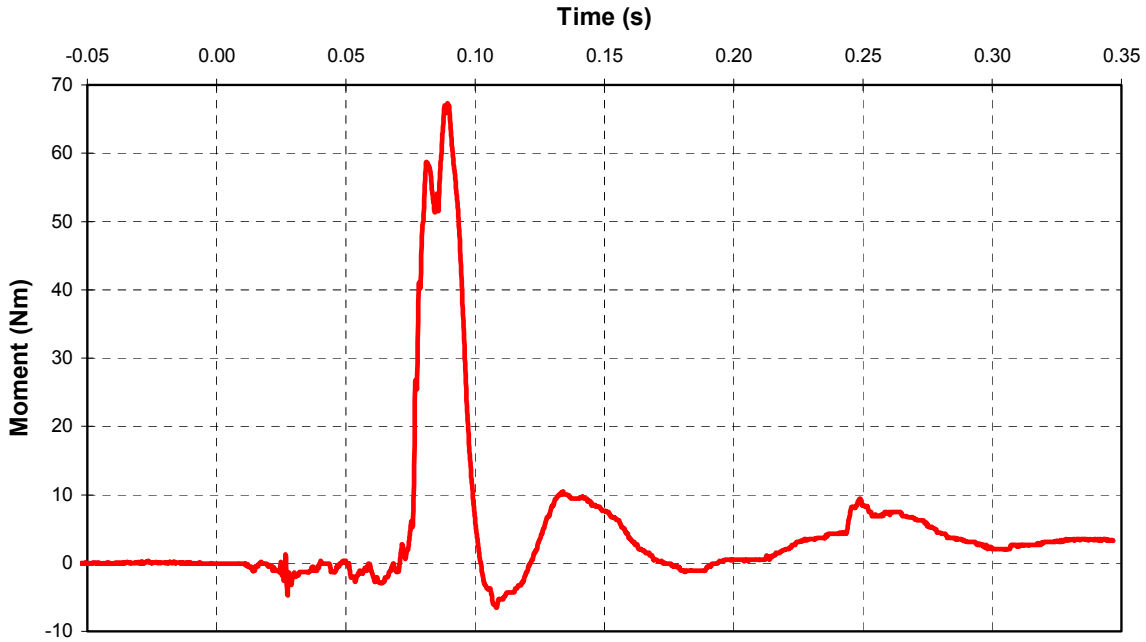
A-40 CF98009 1998 VW New Beetle Right Upper Tibia A-P Moment



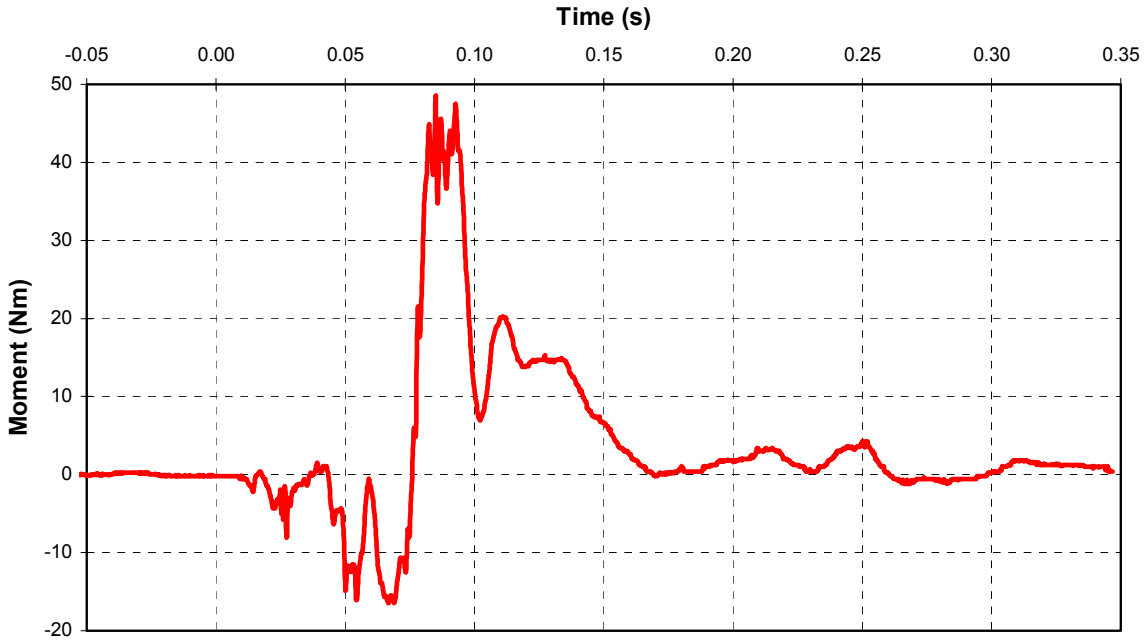
A-41 CF98009 1998 VW New Beetle Right Upper Tibia Vector Resultant Moment



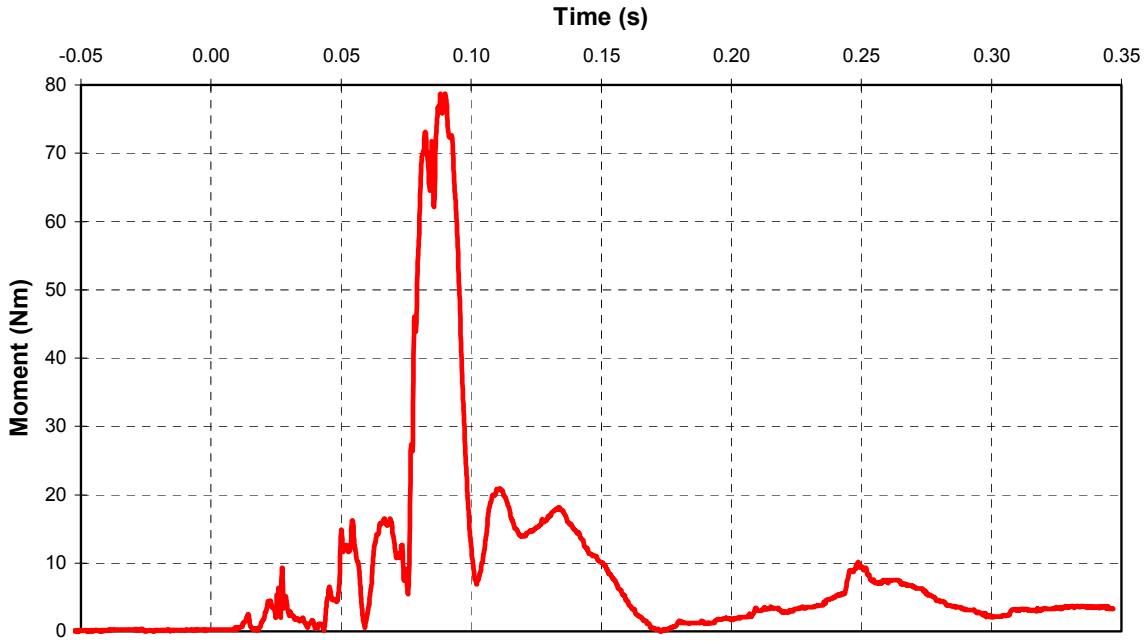
A-42 CF98009 1998 VW New Beetle Right Lower Tibia L-M Moment



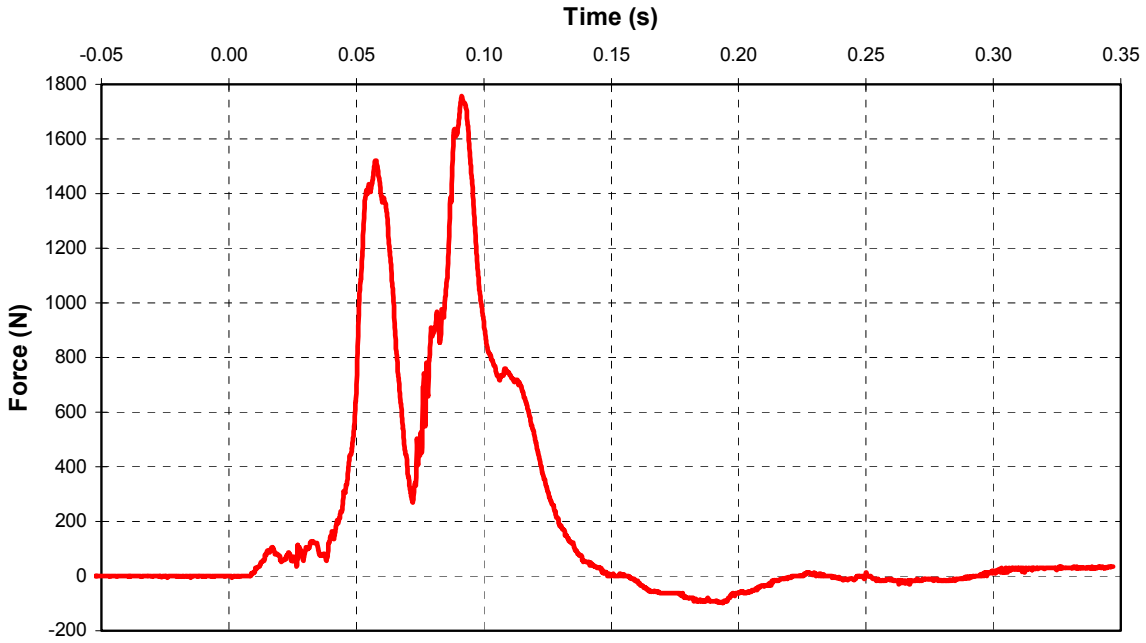
A-43 CF98009 1998 VW New Beetle Right Lower Tibia A-P Moment



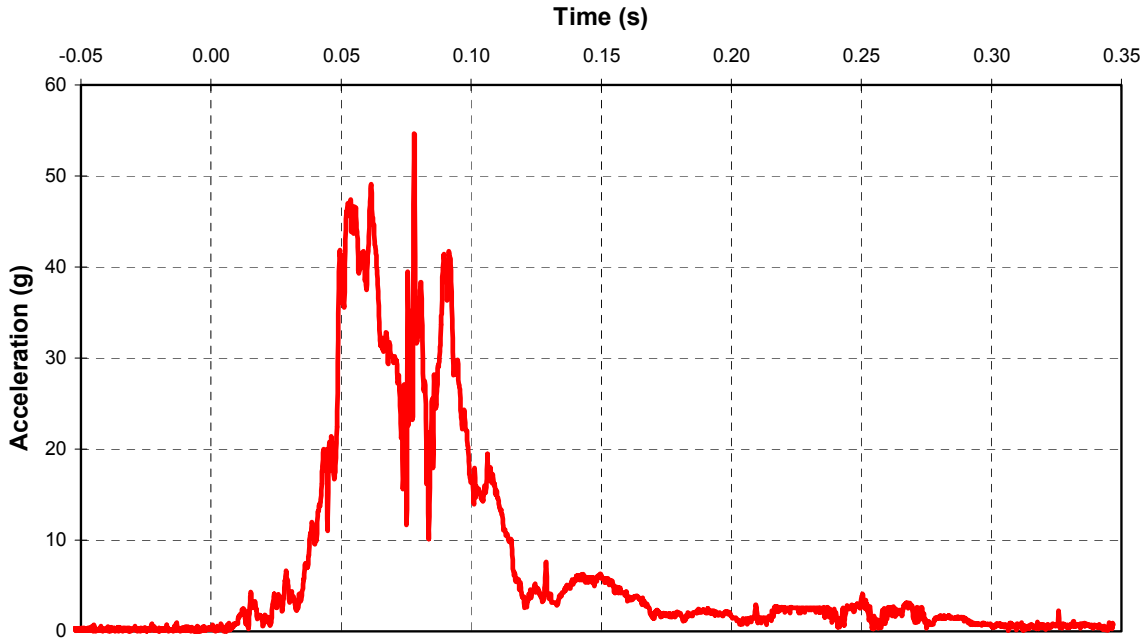
A-44 CF98009 1998 VW New Beetle Right Lower Tibia Vector Resultant Moment



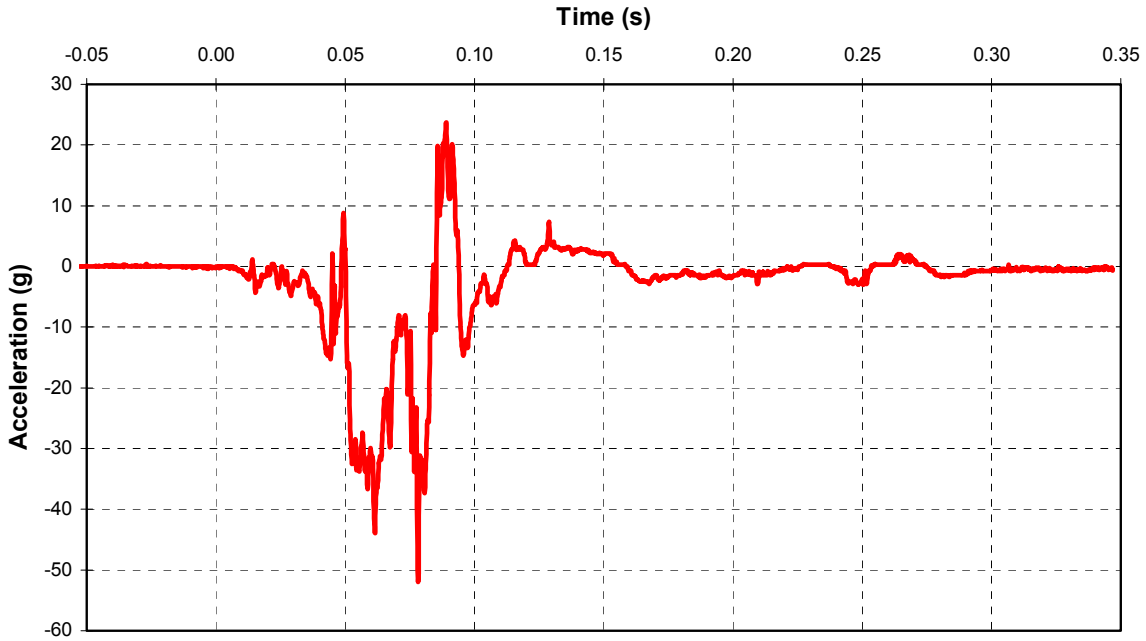
A-45 CF98009 1998 VW New Beetle Right Lower Tibia Axial Force



A-46 CF98009 1998 VW New Beetle Right Foot Vector Resultant Acceleration



A-47 CF98009 1998 VW New Beetle Right Foot A-P Acceleration



A-48 CF98009 1998 VW New Beetle Right Foot I-S Acceleration